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"LET KNOWLEDGE GROW FROM MORE TO MORE
AND THUS BE HUMAN LIFE ENRICHED."

ENCYCLOPÆDIA BRITANNICA

A New Survey of Universal Knowledge

Volume 18

PLANTS to RAYMUND OF TRIPOLI

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Volume 18

PLANTS to RAYMUND OF TRIPOLI

PLANTS AND PLANT SCIENCE. In the most generally used sense a plant is a member of the vegetable class of living things, plants and animals being the two classes into which living things (organisms) are roughly divided. With the higher forms the difference is very definite and leaps to the eye. In the case of lower forms of life the distinction is often very difficult, and indeed it is an artificial one, since plants and animals probably had common ancestors in evolution. The early use of the word "plant" was for a twig, shoot, cutting or sapling, which is the meaning of the Latin *planta*. Other meanings of the word are derived from the verb "to plant," *i.e.*, to fix in position or place. It is thus used of the fixtures, machinery or apparatus necessary for carrying on an industry or business; in colloquial or slang use it is applied to a swindle, a carefully arranged plot or trap laid to deceive. (*Cf.* also PLANTATION.)

In the following sections the botanical sense of the term is followed. An outline of the classification of plants is given under BOTANY and the chief groups, Algae, Fungi, Gymnosperms, etc., are dealt with in separate articles.

CLASSIFICATION OF PLANTS

In the article BOTANY reference has been made to the earlier systems of classification and the evolution of the idea of a natural system in which families are grouped according to their affinities. Details of classification *within* the large groups are given in the special articles on these groups. An outline of the generally accepted system of classification of the groups is given below.

Plants are sometimes divided into CRYPTOGAMS, in which there are no flowers producing seeds, the sexual reproductive organs being inconspicuous, and PHANEROGAMS, in which the plants bear flowers or flowerlike structures from which seeds arise. The term SPERMATOPHYTA is sometimes used for Phanerogams. To the more complex cryptogams, which show vascular strands (*see* below, *Anatomy*) the term vascular cryptogams is often applied.

Cryptogams.—The lower groups of cryptogams are classified as THALLOPHYTA, i.e., plants possessing a thallus or plant body which shows no differentiation into roots, stem and leaves. The large groups of the Thallophyta are the ALGAE, a group mostly of aquatic plants, showing various coloured pigments (green, red, brown, etc.) and the FUNGI (including the Bacteria), which are colourless parasitic or saprophytic plants derived by reduction from algalike ancestors or, more probably, descended from certain colourless flagellates. The lichens are a peculiar group of composite plants, consisting of an alga and a fungus living in association. (*See* ALGAE; FUNGI; LICHENS.)

The BRYOPHYTA (*q.v.*), which include the Hepaticae or liverworts and the Musci or true mosses, are distinguished from the Thallophyta by the fact that the sex organs are multicellular; the female reproductive organs are structures known as archegonia and the male organs are called antheridia.

The group PTERIDOPHYTA (*q.v.*), or fernlike plants, includes all the cryptogams higher than the Bryophyta. The plants show a marked differentiation into roots, stems and leaves (or fronds), some of the latter being of very great size and much divided. Furthermore, they show well-marked vascular strands, and their female reproductive organs are archegonia. This large group includes the Filicineae (true ferns), the Equisetineae (horsetails, etc.); and the Lycopodineae (club mosses, etc.).

Phanerogams.—To this group, which is sometimes termed SPERMATOPHYTA, all the higher plants belong. It includes the GYMNOSPERMS, in which the seed is not enclosed in an ovary and the male and female reproductive organs are not found contained in a single structure or cone, and the ANGIOSPERMS, in which the seed is not naked but enclosed in an ovary, and the male and female reproductive organs (stamens and carpels) are usually associated in a single flower.

Classification of Angiosperms.—This very large group of plants falls into two classes, MONOCOTYLEDONS and DICOTYLEDONS. The first class is characterized by an embryo with one cotyledon (seed leaf), a stem which usually shows no secondary thickening, and flowers with parts in threes. The second shows an embryo with two cotyledons, a stem with secondary thickening, and flowers with parts in fours or fives. The classification of angiosperms now in general use is that of A. Engler, the monocotyledons and dicotyledons being divided into classes termed orders (or cohorts or series), the name of each order usually ending in *-ales*. Each order includes a number of families (formerly termed "natural orders"), many of which are dealt with in special articles; the name of the family usually terminates in *-aceae*.

An outline of Engler's classification is given below, the orders (series) being printed in black-faced type and the families in italics. For the 11 orders of monocotyledons a synopsis of the chief characteristics is given. A selection of the more important families is made in the case of the orders which include a large number of families.

MONOCOTYLEDONS

Order 1. **Pandanales**—(Marsh herbs or shrubs or trees with large narrow leaves and compound heads or spikes of flowers. Seeds rich in endosperm.) *Typhaceae, Pandanaceae, Sparganiaceae.*

Order 2. **Najadales**—(Water or marsh plants with cyclic or hemicyclic flowers, often enclosed in a spathe. Embryo large with little or no endosperm.) *Potamogetonaceae, Najadaceae, Alismaceae, Butomaceae.*

Order 3. **Triuridales.**—(Saprophytes with scaly leaves and small long-stalked flowers.) *Triuridaceae.*

Order 4. **Graminales**—(Usually annual or perennial herbs with naked flowers covered by bracts. Ovary unilocular with one ovule.) *Gramineae, Cyperaceae.*

Order 5. **Palmales**—(Plants, usually trees, leaves of large size often fanlike or featherlike, male and female flowers usually in spikes enclosed in a spathe, ovary superior and fruit a berry or drupe with rich endosperm.) *Palmaceae.*

Order 6. **Cyclanthales**—(Often palmlike or climbers or large herbs with male and female flowers arranged alternately over the surface of a spike.) *Cyclanthaceae.*

Order 7. **Arales**—(Herbaceous or woody plants, sometimes climbing, flowers on a simple spike [spadix] more or less enclosed in a bract.) *Araceae, Lemnaceae.*

Order 8. **Xridales**—(Herbaceous or sometimes grasslike in habit, flowers cyclic, hermaphrodite or unisexual, androecium often reduced, ovary usually orthotropous, endosperm mealy.) *Bromeliaceae, Commelinaceae, Pontederiaceae.*

Order 9. **Liliales**—(Usually herbs, often with bulb, corm or rhizome, perianth petaloid or glumelike; ovary trilocular superior or inferior; fruit a capsule or berry; ovule anatropous; endosperm fleshy or oily.) *Juncaceae, Liliaceae, Amaryllidaceae, Dioscoreaceae, Iridaceae.*

Order 10. **Scitaminales**—(Tropical, large, perennial herbs, often with sheathing leaves; flowers hermaphrodite and irregular, androecium often reduced; ovary inferior, usually trilocular; fruit a berry or capsule with numerous seeds with much perisperm, little or no endosperm.) *Musaceae, Zingiberaceae, Cannaceae.*

Order 11. **Orchidales**—(Flowers of a pentacyclic trimerous type but often with great reduction in the stamens; ovary inferior; fruit a capsule with numerous minute seeds containing a very small undifferentiated embryo.) *Orchidaceae, Burmanniaceae.*

DICOTYLEDONS

Archichlamydeae.—(Flowers often without a perianth, usually polypetalous; wind pollination in the lower orders, insect pollination in the higher orders.)

Order 1. **Casuarinales**—*Casuarinaceae.*
Order 2. **Piperales**—*Piperaceae, Chloranthaceae.*
Order 3. **Salicales**—*Salicaceae.*
Order 4. **Garryales**—*Garryaceae.*
Order 5. **Myricales**—*Myricaceae.*
Order 6. **Balanopsidales**—*Balanopsidaceae.*
Order 7. **Leitneriales**—*Leitneriaceae.*
Order 8. **Juglandales**—*Juglandaceae.*
Order 9. **Batidales**—*Batidaceae.*
Order 10. **Julianiales**—*Julianiaceae.*
Order 11. **Fagales**—*Betulaceae, Fagaceae.*
Order 12. **Urticales**—*Ulmaceae, Moraceae, Urticaceae.*
Order 13. **Proteales**—*Proteaceae.*
Order 14. **Santalales**—*Santalaceae, Loranthaceae, Balanophoraceae.*
Order 15. **Aristolochiales**—*Aristolochiaceae, Rafflesiaceae, Hydnoraceae.*
Order 16. **Polygonales**—*Polygonaceae.*
Order 17. **Chenopodiales**—*Chenopodiaceae, Amaranthaceae, Phytolaccaceae, Caryophyllaceae.*
Order 18. **Ranales**—*Nymphaeaceae, Ranunculaceae, Berberidaceae, Magnoliaceae, Lauraceae.*
Order 19. **Rhoeadales**—*Papaveraceae, Cruciferae, Resedaceae.*
Order 20. **Sarraceniales**—*Sarraceniaceae, Nepenthaceae, Droseraceae.*
Order 21. **Rosales**—*Podostemaceae, Crassulaceae, Saxifragaceae, Hamamelidaceae, Platanaceae, Rosaceae, Leguminosae.*
Order 22. **Pandales**—*Pandaceae.*
Order 23. **Geraniales**—*Geraniaceae, Oxalidaceae, Tropaeolaceae, Linaceae, Rutaceae, Meliaceae, Polygalaceae, Euphorbiaceae, Callitrichaceae.*
Order 24. **Sapindales**—*Buxaceae, Empetraceae, Aceraceae, Sapindaceae, Balsaminaceae.*
Order 25. **Rhamnales**—*Rhamnaceae, Vitaceae.*
Order 26. **Malvales**—*Tiliaceae, Malvaceae, Sterculiaceae.*
Order 27. **Parietales**—*Dilleniaceae, Ochnaceae, Elatinaceae, Cistaceae, Bixaceae, Violaceae, Passifloraceae, Begoniaceae.*
Order 28. **Opuntiales**—*Cactaceae.*
Order 29. **Myrtales**—*Thymeleaceae, Elaeagnaceae, Lythraceae, Rhizophoraceae, Myrtaceae, Onagraceae, Hippuridaceae.*
Order 30. **Umbellales**—*Araliaceae, Umbelliferae, Cornaceae.*

Metachlamydeae (or Sympetalae)—(Flowers usually sympetalous, *i.e.*, with the parts of the corolla more or less united, often resulting in a tubular flower.)

Order 1. **Ericales**—*Pyrolaceae, Ericaceae, Epacridaceae.*
Order 2. **Primulales**—*Myrsinaceae, Primulaceae.*
Order 3. **Plumbaginales**—*Plumbaginaceae.*
Order 4. **Ebenales**—*Sapotaceae, Ebenaceae.*
Order 5. **Contortae**—*Oleaceae, Gentianaceae, Apocynaceae, Asclepiadaceae.*
Order 6. **Tubiflorae**—*Convolvulaceae, Polemoniaceae, Boraginaceae, Verbenaceae, Labiatae, Solanaceae, Scrophulariaceae, Bignoniaceae, Orobanchaceae, Acanthaceae.*
Order 7. **Plantaginales**—*Plantaginaceae.*
Order 8. **Rubiales**—*Rubiaceae, Caprifoliaceae, Adoxaceae, Valerianaceae, Dipsacaceae.*
Order 9. **Cucurbitales**—*Cucurbitaceae.*
Order 10. **Campanulales**—*Campanulaceae, Compositae.*

The classification described above is the time-honoured system, but one which modern research has found to be unnatural at many points. Recent investigations in the fields of palaeobotany, algology, mycology, and comparative morphology have led to the development of a new classification of the plant kingdom which seems to be more natural than the older scheme. An outline of this modern classification is given below, together with the older group names which are placed near the right-hand margin for convenience of comparison (from O. Tippo, "A Modern Classification of the Plant Kingdom," *Chronica Botanica*, vol. vii [Sept. 1942]).

Kingdom Plantae

Sub-kingdom Thallophyta	
Phylum Euglenophyta	
Euglena, etc.	
Phylum Cyanophyta—blue-green algae	
Oscillatoria, etc.	
Phylum Chlorophyta—green algae	
Ulothrix, Oedogonium, etc.	
Phylum Chrysophyta—yellow-green algae, golden-brown algae, and diatoms	"Algae"
Tribonema, Dinobryon, Navicula, etc.	
Phylum Phaeophyta—brown algae	
Fucus, Laminaria, Ectocarpus, etc.	
Phylum Rhodophyta—red algae	
Nemalion, Gelidium, etc.	
Phylum Pyrrophyta—cryptomonads and dinoflagellates	
Peridinium, etc.	
Phylum Schizomycophyta—bacteria	
Bacillus, etc.	
Phylum Myxomycophyta—slime moulds	
Fuligo, Stemonites, etc.	
Phylum Eumycophyta—true fungi	"Fungi"
Class Phycomycetes—algal fungi	
Class Ascomycetes—sac fungi	
Class Basidiomycetes—club fungi	
(Fungi Imperfecti)—imperfect fungi	
Sub-kingdom Embryophyta	
Phylum Bryophyta (Atracheata)—mosses and liverworts	"Bryophytes"
Class Hepaticae—liverworts	
Class Musci—mosses	

Phylum Tracheophyta (Tracheata)
- Sub-phylum Psilopsida
  - Class Psilophytinae
    - Order Psilophytales
      - *Rhynia, Asteroxylon, Psilophyton*, etc.
    - Order Psilotales
      - *Psilotum* and *Tmesipteris*
- Sub-phylum Lycopsida
  - Class Lycopodineae
    - Order Lycopodiales—club mosses
      - *Lycopodium* and *Phylloglossum*
    - Order Selaginellales—small club mosses
      - *Selaginella*
    - Order Lepidodendrales—giant club mosses
      - *Lepidodendron*, etc.
    - Order Pleuromeiales
      - *Pleuromeia*
    - Order Isoetales—quillworts
      - *Isoetes*

"Pteridophytes"

- Sub-phylum Sphenopsida
  - Class Equisetineae
    - Order Hyeniales
      - *Hyenia*
    - Order Sphenophyllales
      - *Sphenophyllum*, etc.
    - Order Equisetales—horsetails
      - *Equisetum, Calamites*, etc.
- Sub-phylum Pteropsida
  - Class Filicinae—ferns
    - Order Coenopteridales
      - *Botryopteris*, etc.
    - Order Ophioglossales—adder's tongue ferns
      - *Ophioglossum, Botrychium*, etc.
    - Order Marattiales—marattiaceous ferns
      - *Marattia*
    - Order Filicales—"true" ferns
      - *Polypodium, Pteris, Azolla*, etc.
  - Class Gymnospermae
    - Sub-class Cycadophytae
      - Order Cycadofilicales (Pteridospermae)—"seed ferns"
        - *Lyginodendron*, etc.
      - Order Bennettitales
        - *Benettites, Williamsonia*, etc.
      - Order Cycadales
        - *Zamia, Cycas*, etc.
    - Sub-class Coniferophytae
      - Order Cordaitales
        - *Cordaites*, etc.
      - Order Ginkgoales
        - *Ginkgo*
      - Order Coniferales
        - *Pinus, Taxus*, etc.
      - Order Gnetales
        - *Gnetum, Ephedra* and *Welwitschia*
  - Class Angiospermae
    - Sub-class Dicotyledoneae
      - Order Magnoliales { "Archichlamydeae" (Ranales) etc., etc. { ("Choripetalae")
      - Order Ericales { "Metachlamydeae" etc., etc. { ("Sympetalae")
    - Sub-class Monocotyledoneae.

"Spermatophytes"

BIBLIOGRAPHY.—One of the best surveys of the classification of plants is given by A. Engler and L. Diels, *Syllabus der Pflanzenfamilien* (Berlin, 1936); *see* also R. Wettstein, *Handbuch der Systematischen Botanik* (Leipzig, 1935); J. Hutchinson, *The Families of Flowering Plants* (vol. i, 1926, vol. ii, 1934, London); A. B. Rendle, *The Classification of Flowering Plants* (vol. i, 1930, vol. ii, 1938, Cambridge); and J. C. Willis, *A Dictionary of the Flowering Plants and Ferns* (Cambridge, 1931), which not only includes an outline of classification but gives in alphabetical order a brief account of the families and genera of all gymnosperms and angiosperms and also of the ferns. The fullest account of the classification of the plant kingdom is given by A. Engler, *Die natürlichen Pflanzenfamilien* (Berlin, 1887–1915), a work in over 20 volumes, of which a new edition (1925–) is now in progress. Good introductions to the systematic botany of flowering plants are D. B. Swingle, *A Textbook of Systematic Botany* (1934); A. M. Johnson, *Taxonomy of the Flowering Plants* (1931); and R. J. Pool, *Flowers and Flowering Plants* (1941); these books explain the basis of taxonomy (classification) and the terms used, and give a review of some of the important works in systematic botany. Newer systems of classification are treated in A. J. Eames, *Morphology of Vascular Plants* (1936), in G. M. Smith, *Cryptogamic Botany*, vol. i (1938); and in O. Tippo, "A Modern Classification of the Plant Kingdom," *Chronica Botanica*, vol. vii, p. 203 (1942).

(O. T.)

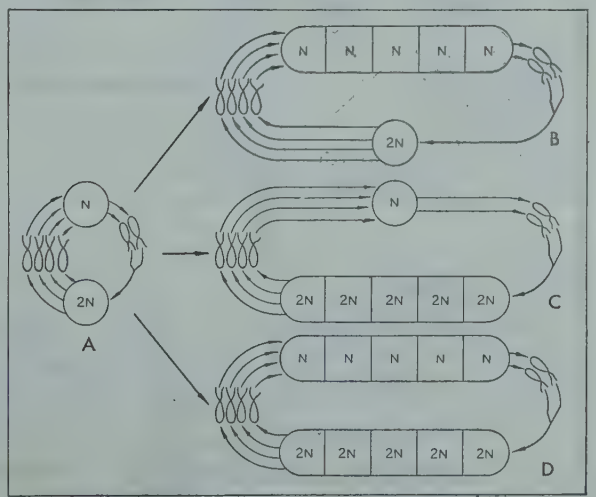
MORPHOLOGY OF PLANTS

Plant morphology is concerned with the form and structure of plants and of their parts, and with the relation of parts to one another and to the whole. Morphology is thus fundamentally descriptive. A morphological study may be merely the determination of the facts of the history of an organism through all stages of development and reproduction; that is, it may be a purely descriptive life-history study. As commonly understood today, however, morphology has a broader basis: its object is to trace the underlying similarities in form between various plant groups; it is comparative in its nature, and its comparisons are considered in the light of evolutionary modification and development. Morphology thus conceived aids in the establishment of a natural classification of plants and in the reconstruction of their evolutionary history (phylogeny).

The methods used in morphological studies are: (1) comparison of adult forms of living plants; (2) comparison of living plants with the ancient extinct forms as the latter are determined in the studies of fossils (palaeobotany); (3) observations on development of the individual (ontogeny). Morphology is generally subdivided into *external morphology* which deals with the external form, and *anatomy*—the study of the external and internal structure of plants. *Cytology*, study of the cell, arose as a subdivision of morphology concerned with internal structure, but it has become an independent branch of biological science. A morphological study may assume a somewhat specialized aspect. Thus it may deal with the early development of an individual (embryogeny); with the causes that determine form and structure (morphogenesis); or with plant parts considered as organs carrying out certain distinct functions (organography).

Alternation of Generations.—The phenomenon of alternation of generations is so prominent and important a feature of the morphology of plants that for many years it has been one of the main objects of morphological studies. The term alternation of generations is used to designate the occurrence of two distinct phases in the life history of the plant, each of which produces the other. One is the sexual phase, the *gametophyte*, that bears male and female organs (gametangia) and gametes (sperms and eggs) and in which fertilization (syngamy) is effected. The fertilized egg (zygote) develops into a non-sexual phase, the *sporophyte*, which produces a large number of single-celled spores. The latter develop directly into new gametophytes. The two phases of the life cycle are commonly referred to as "generations," though actually they are two phases of one generation if the latter concept is used in the same sense as in zoology.

At fertilization the number of chromosomes is doubled through the union of two gametes. At some other point of the life cycle this number is again halved through *reduction divisions* (meiosis). The phase of the life cycle in which all cells have a double complement of chromosomes (diploid) and which begins with the fertilization and ends with the reduction divisions is the sporophyte. The phase characterized by a single complement of chromosomes (haploid), from reduction division to fertilization, is the gametophyte. The character and relative extent of these two phases differ considerably in different groups and show great variability in the lower plants. In many of the thallophytes (Algae and Fungi) almost the entire life cycle is gametophyte, since the first divisions of the zygote are meiotic; in others it is almost all sporophyte. Still others show varying



AFTER G. M. SMITH, "CRYPTOGAMIC BOTANY," MCGRAW-HILL BOOK CO.

FIG. 1.—DIAGRAM SHOWING THE VARIOUS TYPES OF LIFE CYCLE AMONG THE CHLOROPHYCEAE (GREEN ALGAE). A, CHLAMYDOMONAD. B, HAPLONTIC. C, DIPLONTIC. D, DIPLOHAPLONTIC

degrees of relative development of these two phases, and often both are vegetative plants entirely similar in everything except the method of reproduction.

The diagrams give examples of different types of life cycles. The simplest possible life cycle (chlamydomonad) occurs in the unicellular Chlorophyceae (green algae). It consists of an alternation of a one-celled haploid phase with a one-celled diploid phase (fig. 1, A). In the somewhat higher Chlorophyceae vegetative cell divisions occur in one or the other or in both phases. In the *haplont* type a multicellular haploid phase alternates with a unicellular diploid one (fig. 1, B). In the *diplonts* the life cycle consists of an alternation of a diploid coenocyte (the morphological equivalent of a multicellular diploid generation) with a unicellular haploid phase (fig. 1, C). Certain Chlorophyceae are diplohaplonts and have an alternation of a many-celled haploid generation with a many-celled diploid generation (fig. 1, D).

The gametophyte is the dominant phase or "the plant" of the mosses (Bryophyta), whereas the sporophyte is merely a spore-bearing structure that develops from the zygote and remains attached to the gametophyte (fig. 2). In contrast, the vascular plants (Tracheophyta) have a large and conspicuous sporophyte with roots, stems and leaves and predominates in the life history. The fern sporophyte bears the spores on the backs of its leaves. Each spore may develop into a small but independent generation, the gametophyte or prothallus, on which the sex organs are borne (fig. 3). In the gymnosperms and angiosperms the gametophyte generation is extremely reduced. The spore (megaspore) producing the female gametophyte (megagametophyte) remains attached to the sporophyte after germination. Other spores (microspores) germinate to form the male gametophytes (pollen grains), which are liberated and carried to or near the ovule containing the female gametophyte. One of the two male gametes (sperms) produced by the male gametophyte fertilizes the egg. The zygote grows at once into the embryo (fig. 4).

Two theories have long existed concerning the nature and origin of the sporophyte of vascular plants: the *antithetic theory* and the *homologous theory*. The first assumes that the two phases are essentially distinct, that the sporophyte is a new phase introduced into the life cycle of vascular plants in relation to life in air. It is supposed to have evolved from the zygote of an ancestral algal form through a stage in which it was merely a spore-bearing structure wholly dependent upon the gametophyte.

According to the homologous theory (which is supported by modern morphological and palaeobotanical studies), the sporophyte and gametophyte are fundamentally alike in nature; they are correlative phases in the life cycle of plants that have arisen by modification of an original single sexual phase. In recent interpretations the homologous theory places the differentiation of the gametophyte and sporophyte in ancient algal stocks and assumes the origin of land-living independent sporophytes directly from independent aquatic sporophytes.

Plant Body.—In the simplest plants the body consists of a single cell within which all life activities are carried on. According to the evolutionary concept, the simple cells united into colonies forming at first a loose, later a more intimate, union, until a *multicellular plant* arose. With the advent of "division of labour" between the different parts of the multicellular body, a morphologic differentiation of these subdivisions occurred, so that a very complex plant body now appears in the higher plant groups. While in the lowest plants any part may perform all functions, in the highest the various functions have organs devoted to their performance, and in these the cells are grouped

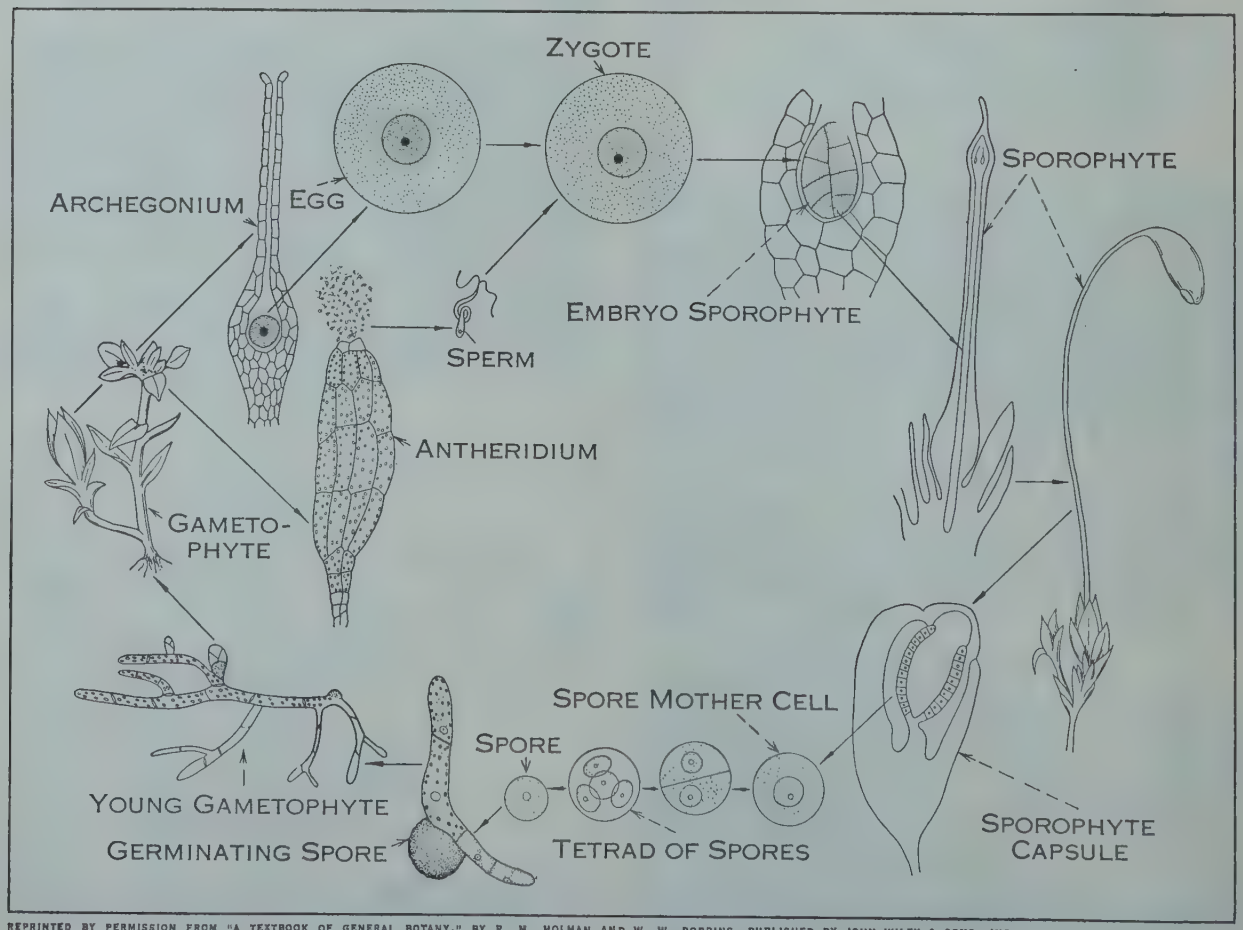


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FIG. 2.—DIAGRAM SHOWING THE LIFE CYCLE OF A TYPICAL MOSS (FUNARIA)

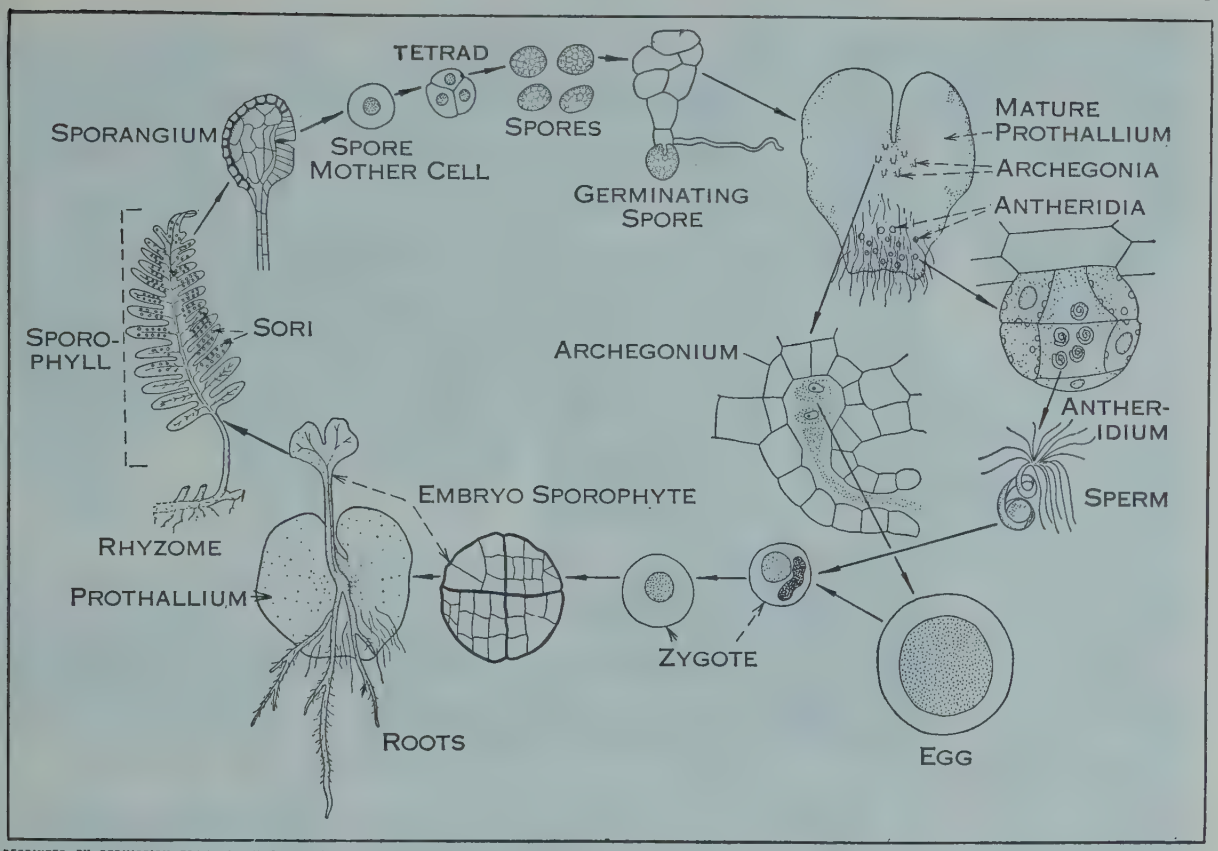

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FIG. 3.—DIAGRAM SHOWING THE LIFE CYCLE OF A TRUE FERN (POLYPODIUM)

in definite and very specialized tissues. The lower plants (Thallophyta) show various degrees of complexity of form and structure. Certain groups of red and brown algae somewhat resemble the higher plants in the formation and arrangement of the members of their bodies. The progressive differentiation of the thallus of the liverworts and mosses (Bryophyta) presents an even closer parallel to the organization of the higher plants. Some of these have stemlike and leaflike body parts resembling organs of the most highly organized plants. True roots, stems and leaves, however, do not occur in either thallophytes or bryophytes. These are characteristic organs of the vascular plants (Tracheophyta). According to a modern concept, these organs evolved with the invasion of the dry land by plants that formerly inhabited only the sea.

The nature of the plant body and its parts in vascular plants has long been a basic morphological problem. As was shown in the preceding section, it is the body of the sporophyte that is so complex in the higher plants. The gametophyte is extremely simple. In early days of morphological study the sporophyte body was looked upon as constituted of organs that were of different fundamental nature. The number of these organs was at first large; for example, stem, root, leaf, ovule, sporangium, sporangiophore, emergence, hair. With the development of the concept of homologies, the interrelation of parts of a plant body began to be recognized. Comparative and developmental studies suggested that differently appearing parts may bear the same relation to the whole plant body, that, in other words, they may be *homologous*. For example, the flower appeared homologous with the shoot, the floral members with leaves. In contrast, if parts differ in their relation to the whole, but are similar in function and structure, they are *analogous*. Thus the flattened green stems of many plants of dry habitats are analogous with leaves. With increase in comprehension of the relationship between parts the units of structure became reduced to three: stem, leaf and root.

The recent discoveries of early land plants and studies in development have indicated that even these three categories of parts are not absolute, but are results of evolutionary development and cannot be clearly separated morphologically. The general nature of the plant body seems to be that of an axis. Under this interpretation there are no fundamental parts. Roots and leaves, as elaborated organs, are secondary structures that differentiated on an originally primitive axis. The leaf may have arisen in two ways: (1) as a lateral emergence of the axis, and (2) as a branch system that became flattened and expanded, with a webbing of tissue uniting the branches into one. The view upon the relation of the angiospermous flower to the other plant parts is also in a state of flux. The concept of the flower as a modified shoot, and particularly that of the homology between the leaf and the carpel, is being contested. The complex problem of the nature of the plant organs is still awaiting its final clarification. A judicial use of data on ontogeny, vascular anatomy, palaeobotany and comparative morphology should eventually bring about such clarification.

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ANATOMY OF PLANTS

Anatomy deals with structure, gross and minute, external and internal. A special field of anatomy is *histology*, which is concerned with the minute structure of organisms. If an anatomical study deals with the structure of cells, particularly with the protoplast, it enters the field of *cytology*. Thus anatomy merges

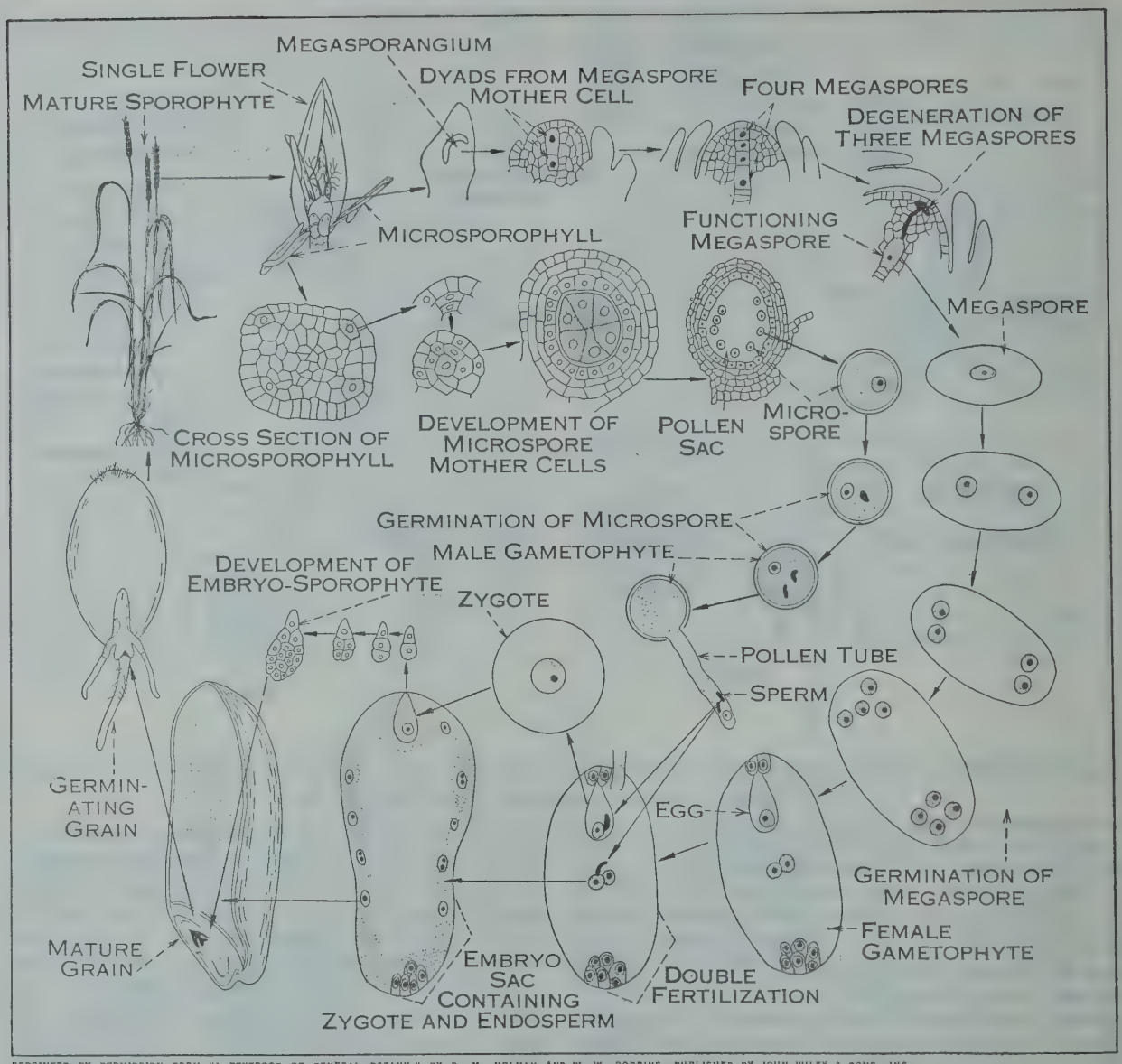

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FIG. 4.—DIAGRAM SHOWING THE LIFE CYCLE OF WHEAT (TRITICUM)

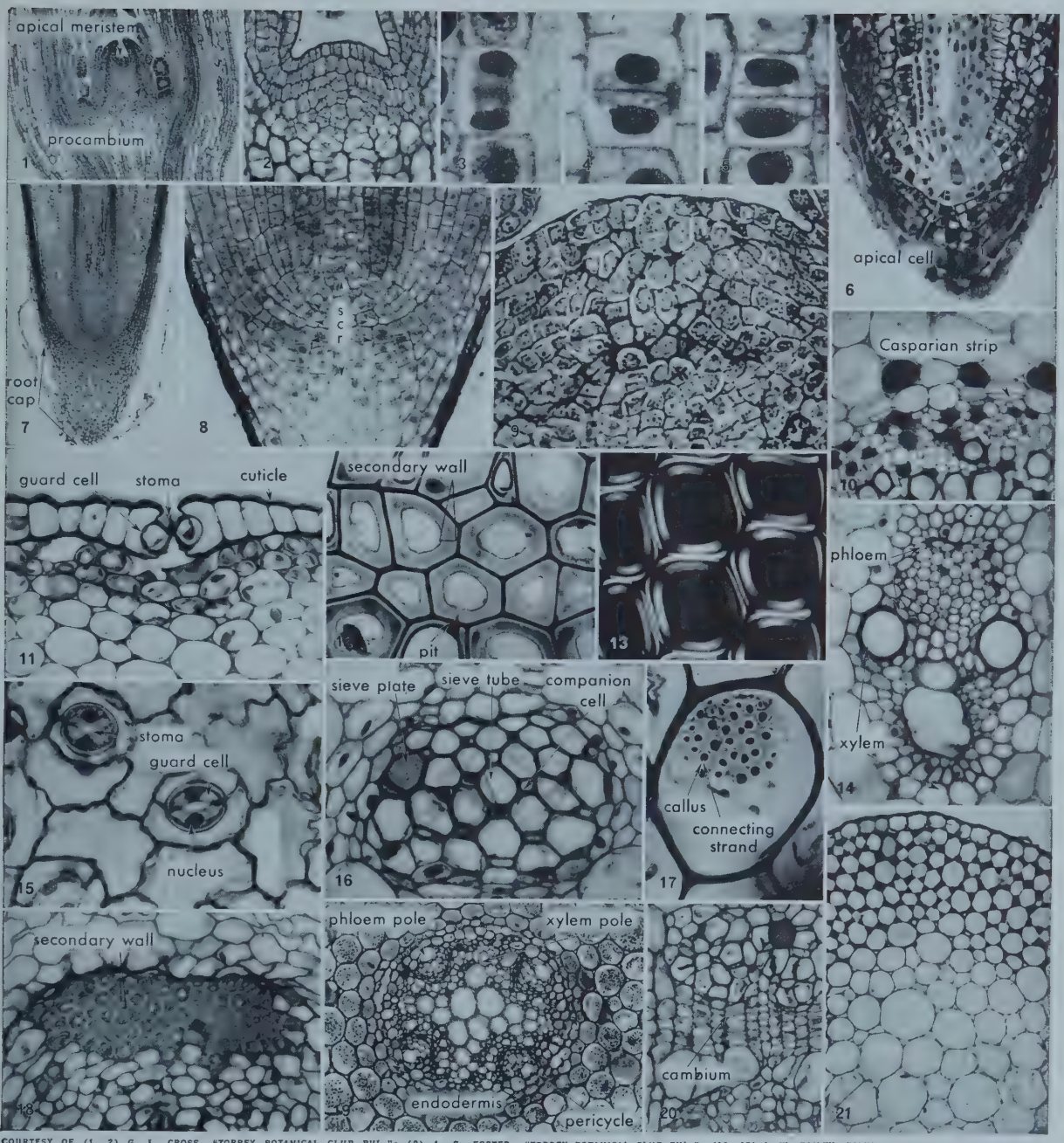
with cytology and only an arbitrary limit may be set up between the two.

The Cell.—An account of the anatomy of plants naturally begins with the cell, which is the proximate unit of organic structure. The cell is essentially an individualized mass of protoplasm, of small dimensions and containing many specialized structures, chief among which is the *nucleus*. Other protoplasmic bodies, known as plastids, and inanimate matter, are present. The different living bodies and nonliving inclusions are dispersed within the more or less fluid living substance called *cytoplasm*. Among the nonliving inclusions are starch grains, crystals of various shapes and compositions, oil globules, tannins and food masses of different sorts. Much of the inanimate matter occurs in a watery solution forming the cell sap. All cells that are permanent tissue elements of the plant body possess a more or less rigid limiting membrane or *cell wall*, consisting primarily of cellulose or some allied substance excreted by the living cell body. The presence of plastids in the protoplasm and the existence of the cell wall are the two main characteristics that differentiate plant cells from those of animals.

The walls of adjacent cells are cemented together so that the cells are united into more or less coherent masses or tissues. Upon the characters of constitution, thickness and sculpture of the cell walls, the qualities of a plant tissue largely depend. The life of all the cells in a plant body may be prolonged, or a number of the cells may die and their protoplasm be removed. Thus a tissue may consist of living cells combined with an inanimate framework of cell walls, enclosing in their cavities solely liquids and gases. In such cases the characters of the adult tissue largely depend on the proportion and distribution, the size, form and contents of the living and dead units, and on the nature of their walls.

In all but the simplest forms the plant body is composed of cells associated in more or less definite ways. In the higher or more complicated plants the cells differ greatly among themselves so that the adult body is composed of definite systems of units, the *tissue systems*. Each system has its own characteristic structure, depending partly on the characters of the component cells and partly on the method of association.

The structure and development of the plant cell with regard to

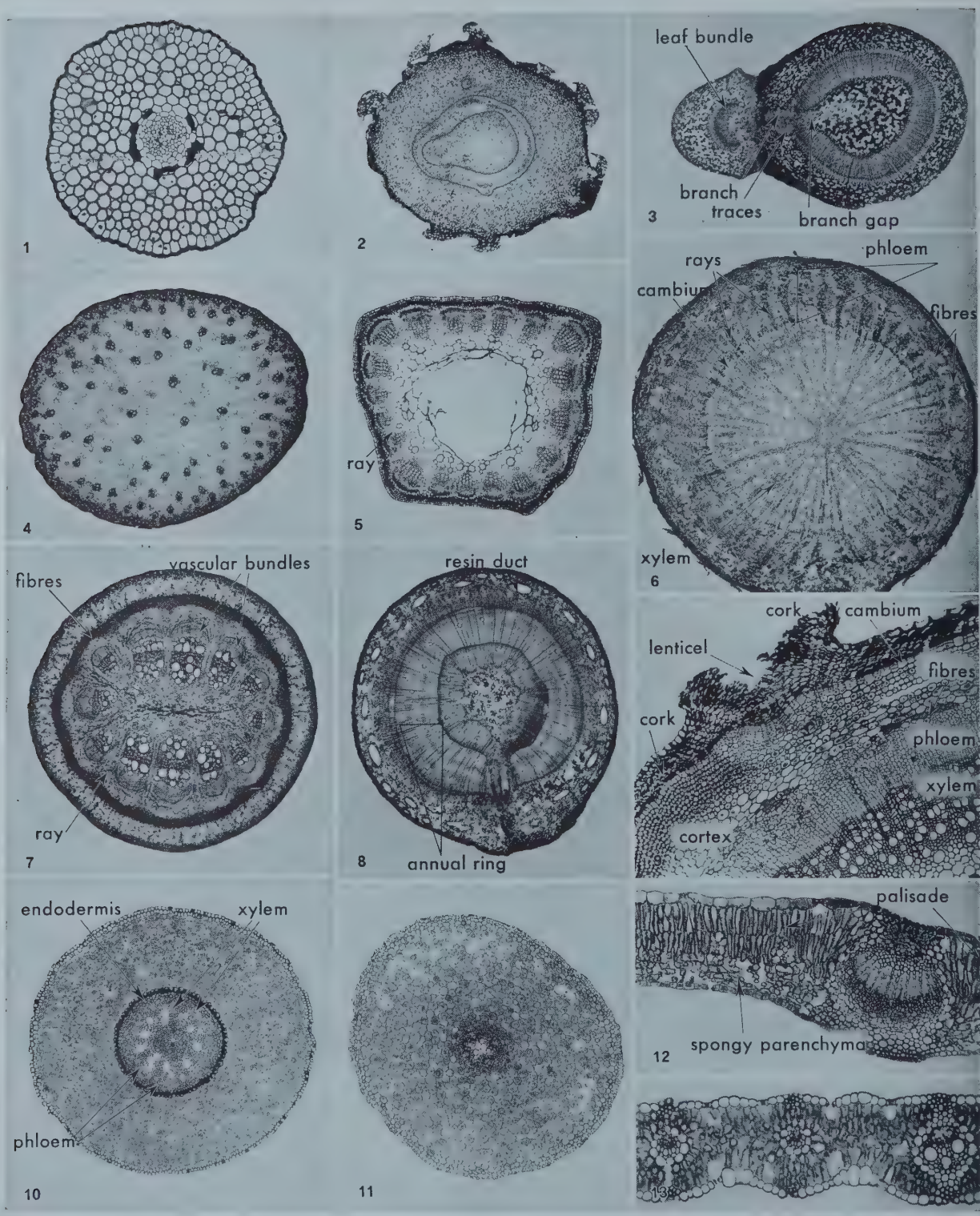


COURTESY OF (1, 2) G. L. CROSS, "TORREY BOTANICAL CLUB BUL."; (9) A. S. FOSTER, "TORREY BOTANICAL CLUB BUL."; (12, 13) I. W. BAILEY, "JOUR. OF THE ARNOLD ARBORETUM" AND "AMERICAN JOURNAL OF BOTANY" (17) A. S. CRAFTS, "AMERICAN JOURNAL OF BOTANY" (19) G. H. CONANT; (7, 14, 16) FROM KATHERINE ESAU, "HILGARDIA"; (3, 4, 5, 6, 8, 10, 11, 15, 18, 20, 21) ORIGINALS BY KATHERINE ESAU

EXAMPLES OF PLANT TISSUES

1. Shoot apex of *Vinca* with two leaf primordia on the flanks of the apical meristem. **2.** Apical meristem of *Vinca* shoot with two layers of tunica covering the corpus. **3, 4** and **5.** Stages of cell-plate formation in cells from onion root tip. **6.** Root tip of a fern (*Adiantum*). **7.** Root tip of a pear tree. **8.** Root tip of tobacco showing the initial regions of the stele, or vascular cylinder (*s*), of the cortex (*c*), and of the root cap (*r*). **9.** Apical meristem of *Ginkgo* shoot. **10.** Transverse section of portion of *Myriophyllum* rhizome showing endodermis with *Casparian strips* between cortex and vascular tissues. **11.** Transverse section of part of *Asparagus* stem showing epidermis and cortex. **12.** Transverse section of the xylem of *Trochodendron;* the dark material between the secondary walls consists of primary walls and intercellular substance. **13.** Transverse section of the xylem of *Taxodium* photographed in polarized light between crossed Nicols; it illustrates double refraction of layers of secondary walls. **14.** Vascular bundle from transverse section of *Zea* (corn) stem. **15.** Surface view of epidermis of a *Convolvulus* leaf. **16.** Transverse section of phloem from a vascular bundle of *Zea*. **17.** Transverse section of sieve tube of *Cucurbita* (pumpkin) showing, above, part of sieve plate. **18.** Transverse section of root tip of *Pisum* (pea) showing, in the centre, a bundle of fibres. **19.** Transverse section of *Ranunculus* root showing the vascular cylinder and some cortical parenchyma. **20.** Transverse section of vascular tissues of *Sambucus* stem showing cambium in the middle, some phloem and xylem above and below, respectively. **21.** Transverse section of beet petiole showing, from top to bottom, epidermis, collenchyma and parenchyma

PLANTS AND PLANT SCIENCE



COURTESY OF (2) R. H. WETMORE, (3) I. W. BAILEY, (4, 7, 8, 9, 10, 11, 12) G. H. CONANT, (6) FROM KATHERINE ESAU, "HILGARDIA"; (1, 5, 13) ORIGINALS BY KATHERINE ESAU

EXAMPLES OF STRUCTURE OF DIFFERENT PLANT ORGANS

Transverse sections of: 1. *Tmesipteris* (a primitive vascular plant) stem; 2. *Adiantum* (fern) stem; 3. *Illicium* (a dicotyledon) stem; 4. *Zea* (a monocotyledon) stem; 5. *Medicago* (a dicotyledon) stem; 6. *Pyrus* (pear) root with secondary growth; 7. *Aristolochia* (vine) stem; 8. *Pinus* (a gymnosperm) stem; 9. Portion of *Sambucus* (elderberry) stem; 10. *Smilax* (a monocotyledon) root in primary state; 11. *Ranunculus* (a dicotyledon) root in primary state; 12. *Syringa* (a dicotyledon) leaf; 13. *Triticum* (wheat, a grass) leaf

the protoplasm and the nucleus are considered in detail in the article CYTOLOGY.

Plastids.—The plastids are portions of the protoplasm that have become specialized for the performance of certain functions. They are readily distinguished in the adult cell by their size and definite form, and they are often conspicuously coloured. Leucoplasts are colourless and occur in the cells of the deeper lying tissues where light cannot penetrate—if exposed to light they often become green. They are frequently concerned with the formation of starch grains. Chromoplasts are colour-carrying bodies giving red and yellow colours to the petals of flowers, ripe fruits, etc.; they contain yellow and red pigments such as xanthophyll and carotin. The most important of all the plastids, however, are the green chloroplasts. These contain chlorophyll and are of universal occurrence throughout the plant kingdom with the exception of the important groups of Fungi and Bacteria. By means of this pigment the plastids are enabled in the presence of light to form carbohydrates from water and carbon dioxide. The chloroplasts are extremely variable in shape, particularly in the Algae. In the higher plants the chloroplast is discoid and, according to the prevalent view, consists of a mass of somewhat dense colourless cytoplasm, the *stroma,* and of granules containing chlorophyll. Chloroplasts frequently include starch grains.

The differentiated plastids seen in mature tissues may be traced back to plastid primordia, or *proplastids,* in the youngest tissues (*meristems*) or embryo. The proplastids appear in the cytoplasm of the young cells as minute bodies grading off to the limit of visibility. At all stages of development from proplastids, and at maturity, the plastids may divide by simple constriction. These divisions are sufficiently numerous to account for the large numbers of plastids in mature cells. It has not been disproved, however, that plastids arise also anew (*de novo*) in the cytoplasm. The problem of individuality of the plastid is mainly one of determining whether they are continuous or not through the critical stages in the life cycle, the gametes and spores. They have been shown to be present in the gametes and spores of some plants and are, in these instances, apparently passed on from one generation to another.

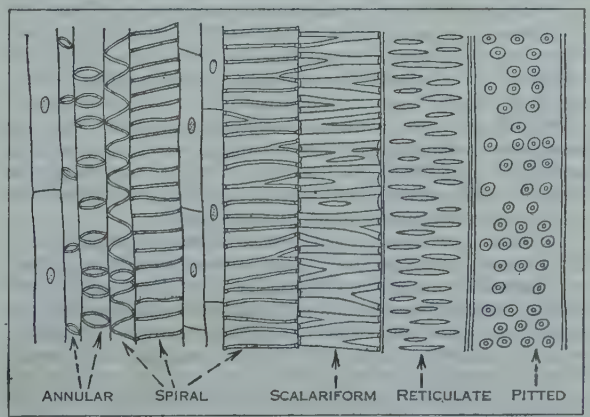
Mitochondria.—In addition to the plastids there are other bodies in the cytoplasm which are very minute and appear as tiny granules, rods or threads and whose nature and function are not well understood. They are called *chondriosomes* or *mitochondria.* According to one opinion, mitochondria are the bodies from which plastids develop; according to another, the proplastids and mitochondria are distinct structures. Mitochondria are also thought to be concerned with respiration or to be merely food substances.

The Cell Sap.—All living cells in plants contain variable amounts of nonliving materials that are collectively designated as *inclusions* or *ergastic substances.* They include storage products, waste material, or by-products of protoplasmic activity. One of the most common examples of ergastic substances is the cell sap, which occurs, in mature cells, within the central cavity of the cell, or the *vacuole.* On all sides the vacuole is surrounded by cytoplasm and does not come in contact with cell walls. One or more vacuoles may be present in a cell, their number and shape varying from time to time in the same cell. The vacuolar system of a cell or other protoplasmic mass, whether this system consists of one or more vacuoles, is called the *vacuome.* The cell sap is water in which are dissolved substances of various kinds, some being food materials, others products of the metabolism of the protoplasm. Its composition is constantly changing, but among the substances of constant occurrence are inorganic salts, carbohydrates such as the sugars, and soluble nitrogenous compounds.

Vacuoles appear to be universally present in living plant cells. In the youngest, or meristematic cells, which by division form the tissues and organs of the plant body, the vacuoles are rather numerous, small spherical, or drawn out into other shapes by the streaming cytoplasm in which they are dispersed. As the meristematic cells multiply, the vacuoles are distributed, with or without division, to the daughter cells. During the enlargement and maturation of the cell the vacuoles increase in size and eventually coalesce to form one large central vacuole in the cytoplasm, which thus becomes restricted to a comparatively thin layer closely applied to the cell wall.

The Cell Wall.—The cell wall in meristematic cells is thin and extremely delicate but, with the completion of the growth in size of the cell, it is increased in thickness and may in certain cases undergo considerable modification. It is commonly regarded as a secretion of the protoplasm and is, in living cells, in intimate relation with the protoplasm which may interpenetrate the particles of its substance. This close relation can be readily appreciated when the process by which the wall is first laid down is considered. From the beginning of the plant's existence as a single cell, all new cell formation consists in the division of a pre-existing cell into two halves by the formation of a dividing wall. In this process the cytoplasmic spindle, which functioned in the preceding nuclear division (*see* CYTOLOGY), plays an important part. The new wall begins with the appearance of a *cell plate* dividing the spindle in two halves (Pl. I, fig. 3). If the spindle does not reach to the side walls of the dividing cell, new fibres arise on its periphery and extend the cell plate to the side walls (Pl. I, figs. 4, 5). The cell plate is a fluid layer appearing first as minute droplets that unite to form a continuous layer. Some interpret these small units as swellings of the spindle fibres. The fluid cell plate apparently soon solidifies and becomes part of the wall. The two daughter protoplasts that resulted from the division of the original cell secrete additional wall substances. These are deposited among the existing particles (intussusception) and also over the inner surface of the new wall (apposition). Thus the wall becomes thicker. The amount of wall material deposited varies in different kinds of cells. One extreme is cells with walls that are little thicker than those of the meristematic cells from which they arose; the other, cells whose lumina are almost filled with wall material.

Commonly the wall does not appear homogeneous, but shows layering. The layers may differ in origin, appearance, when viewed in polarized light, and chemical and physical structure. Three main categories of wall layers exist: (1) The *intercellular substance,* which is composed of pectic substances and is isotropic (*i.e.,* dark or non-refringent when viewed under polarized light). This substance acts as a cementing material binding the walls of adjacent cells together. Some regard it as being derived from the cell plate formed during cell division. (2) The *primary wall,* which consists largely of cellulose and pectic substances and is anisotropic (*i.e.,* bright or refringent when viewed under polarized light). It occurs next to the intercellular substance. Many thin-walled tissues contain only primary walls (Pl. I, fig. 11). These walls, however, may also be comparatively thick. They are formed while the cell is still enlarging during differentiation from a meristematic cell. (3) The *secondary wall,* which



AFTER E. W. SINNOTT, "BOTANY PRINCIPLES AND PROBLEMS," MCGRAW-HILL BOOK CO.

FIG. 5.—CELL WALL TYPES IN PRIMARY XYLEM SHOWN IN A LONGITUDINAL SECTION OF VASCULAR BUNDLE IN A STEM

is extremely complex, physically and chemically, and strongly anisotropic (Pl. I, fig. 12). Cellulose is its basic component and it is formed after the cell attains its final size and shape. The secondary wall of plant cells is rarely continuous over the entire surface of the underlying primary wall. It may develop as discrete rings, spirals, bars, or as complex network or mesh; or it may cover most of the primary wall except for small interruptions or cavities which are termed *pits* (fig. 5). All three wall layers may become modified by impregnation with a variety of inorganic and organic substances, notably lignin, which renders the walls firm and hard.

The anisotropy of the primary and secondary walls (Pl. I, fig. 13) indicates that they are crystalline in nature. The crystalline properties are imparted to the wall by cellulose, a carbohydrate with the general formula $(C_6H_{10}O_5)n$. The units $C_6H_{10}O_5$ (anhydrous glucose residues) are combined into long chains—the cellulose molecules. These chain-molecules tend to occur in aggregations within which the molecules are arranged parallel to one another with characteristic spacings between the chains. The molecules and their aggregations are too small to be seen through a microscope and are studied by their effect upon X-rays and polarized light. The aggregations of chain-molecules appear to overlap each other and form a coherent system perforated by a continuous system of spaces. Within these spaces substances other than cellulose (*e.g.*, lignin, fatty substances, water) are deposited. As seen through the microscope after special treatments the cellulose wall also appears as a continuous system of microfibrils interpenetrated by a system of microporosities. How the submicroscopic system formed by the aggregations of chain-molecules and the microscopic system of microfibrils are related to each other is not yet clear.

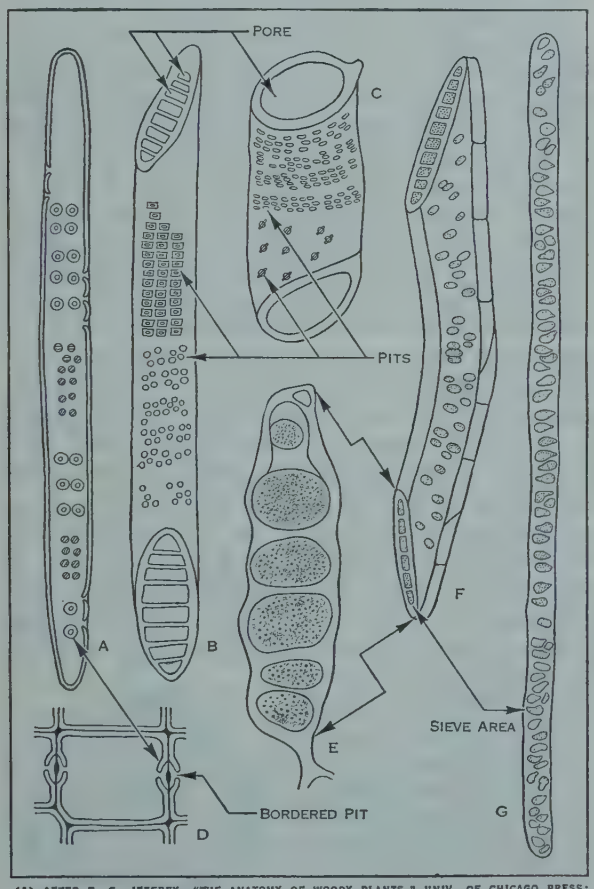
Many conspicuous differences in the optical and mechanical properties of cell walls are correlated with variations in the orientation of the microfibrils. If the latter are oriented parallel to the long axis of the cell, the wall or layer in which they occur does not contract longitudinally in drying. The opposite is true if the walls have transversally oriented microfibrils. Various intermediate conditions occur in walls whose microfibrils are oriented helically in relation to the long axis of the cell. Microfibrils may be differently oriented in the different wall layers of the same cell.

Plasmodesmata.—The living cell in a complex multicellular plant body is a unit, but not an independent one, and its functions are conditioned by, and related to, the activities of the organism as a whole. This must involve a close connection between the living protoplasm of neighbouring cells, and this is effected by delicate connecting strands, the plasmodesmata, which traverse the walls. The connecting strands may be scattered singly throughout a wall or may be aggregated in thinner places of the wall, the pit areas. Plasmodesmata may represent the persistence of the original continuity of the protoplasm of two sister cells, but also are established when growth is completed. These delicate connections seem to occur universally in the higher plants. They play a part in the correlation of the functions of the cells, and they may also provide the means by which stimuli can be conveyed through long tracts of tissue.

Cell Types and Tissues.—As previously stated, the cells have come to differ greatly among themselves since the plants increased in complexity. Plant cells may vary in size, shape, contents and wall structure, and may be highly specialized with relation to the performance of definite functions.

The chief types of plant cells are as follows: *Parenchyma* cells (Pl. I, fig. 21) are commonly more or less isodiametric in form, have thin walls and active protoplasts. A certain degree of variation in characteristics occurs with relation to the functions performed by parenchyma. Thus the parenchyma cells of the photosynthetic tissue of a leaf are rich in chloroplasts and may be considerably elongated or lobed (Pl. II, fig. 12); the parenchyma cell of a potato tuber contains leucoplasts that store starch; the parenchyma cells within the water-conducting tissue (xylem) may have thick secondary walls. The retention at maturity of living protoplasts is one of the most important characteristics of parenchyma cells. These cells are regarded as the least differentiated, the least specialized, and they make up the entire plant bodies of most of the Thallophyta (Algae and Fungi). *Collenchyma* cells (Pl. I, fig. 21) occur in layers or strands in the subsurface region of many stems, petioles and ribs of leaves where they serve as a supporting tissue. Like the parenchyma, this tissue retains living protoplasts at maturity. The shape of the cell varies from nearly isodiametric to very much elongated (prosenchymatous). The principal characteristic is the thick cellulose wall, the thickening being irregular and massive. The thickenings occur in strips along most walls, or the tangential walls or only in the corners. The walls are very strong but plastic, and do not hinder the elongation of the growing organs in which collenchyma is the chief supporting tissue. *Sclereids* show similar variations in shape as the parenchyma cells but have very thick lignified walls with tubular pits. The protoplasts are usually lacking at maturity. One of the best-known examples of a sclereid is the stone cell that is a common component of the flesh of the pear fruit. The hard shell of the walnut is made up largely of sclereids. *Fibres* are elongated cells, sometimes very much so, with thick pitted secondary walls (Pl. I, fig. 18) which may be of cellulose or lignified cellulose. The protoplasts usually die when the cells mature. Stone cells and fibres are often treated as elements of one type of tissue called sclerenchyma (mechanical or supporting tissue), because both have thick walls, lack protoplasts and serve for support. The two main groups of fibres are those that occur in the wood tissue, the *xylem fibres*, and those located in various parts of the plant outside the xylem, the *bast fibres*. The xylem fibres are usually lignified and are chiefly responsible for the rigidity and hardness of the wood. Some bast fibres are lignified, others have unmodified cellulose walls. The latter kinds of fibres are valued commercially and occur in such well-known fibre plants as flax, hemp and ramie. *Tracheary elements* are water-conducting elements located in the xylem or wood. The vascular plants are called Tracheophyta because they contain tracheary elements. Two principal types of tracheary elements occur in plants: *tracheids* (fig. 6, A) and *vessel elements* (fig. 6, B, C). Both of these are commonly prosenchymatous with oblique or transverse end walls. They have secondary walls of lignified cellulose that are deposited as rings, spiral bands, bars, a network, or as pitted layers upon the thin primary wall. At maturity the protoplasts are lacking. The principal distinction between the two types of tracheary elements is that the tracheid is an imperforate cell with a continuous primary wall, whereas a vessel element has openings or perforations usually located in the end walls of the cell. The vessel elements are combined into longitudinal pipelike units, the *vessels*, in which water passes freely through perforations from element to element. Water moving through tracheids passes from one cell into the other through places where the secondary wall is discontinuous but the primary wall is present. Often these places are very restricted and are then called pits. The water passes through the exposed part of the primary wall of the pit, the *pit-closing membrane*. In the wood of the gymnosperms (firs and their allies) the pits show very elaborate structure. The pit-closing membrane has small but numerous perforations and is reinforced by a primary thickening, the *torus*, in the middle. The secondary wall overhangs the pit cavity as a border (hence bordered pit), leaving a small opening (pit mouth) at the entrance into the pit cavity (fig. 6, D). The pit-closing membrane is flexible and can bulge one way or the other within the cavity formed by two communicating bordered pits of the adjacent cells. The torus may become appressed to the mouth of one or the other pit, obstructing the entry into the pit cavity. Thus, apparently by changes in the position of the closing membranes of bordered pits, some control is exercised over the passage of fluids in the xylem. *Sieve cells* (fig. 6, G) and *sieve-tube elements* (fig. 6, F) are the characteristic components of the tissue concerned with the conduction of the manufactured food (chiefly sugars and protein), the *phloem*. The sieve-tube elements occur in the angiosperms (plants having their seeds enclosed in an ovary), whereas sieve cells are typical of gymnosperms and ferns. The sieve-tube

elements have specially modified walls or portions of walls called *sieve plates* (fig. 6, E). The essential feature of a sieve plate is the presence of perforations (sieve-plate pores) in the wall through which the protoplasts of two adjacent or superposed elements are continuous. These connecting strands are comparable with plasmodesmata but tend to be thicker than ordinary plasmodesmata. In the sieve plate a special kind of carbohydrate, *callose,* surrounds each strand (Pl. I, fig. 17). In other words, each strand is enclosed in a tube or cylinder of callose, the *callus cylinder.* The whole mass of callose on a sieve plate is usually called *callus.* As the sieve tube ages, the callus becomes more massive. Since each callus cylinder thickens, the strands are constricted and, furthermore, callus bulges and spreads over the surface of the plate until the latter appears completely buried within the callus. The bulging callus masses on both sides of the sieve plate are referred to as *callus plugs,* but it is not known whether they actually plug the sieve plate. Nevertheless, the appearance of the callus plugs indicates that the sieve-tube element has ceased to function. Therefore, the final callus masses developed at the end of the active period of the conducting element are also called *definitive callus.* As it matures the protoplast of the sieve-tube element loses its nucleus, but the cytoplasm is retained until the cell ceases to function. Some studies indicate that this cytoplasm is peculiar: it appears to be wholly permeable. The contents of the vacuole are often slimy and readily coagulate when the tissue is killed. The so-called *slime plugs* often seen on sieve plates result from such coagulation. The sieve-tube elements of the angiosperms tend to have their sieve plates on the end walls. The sieve plate may cover the wall uniformly or may be broken up into more or less clearly defined sieve areas. The lateral walls show similar sieve areas, but with thinner strands (fig. 6, F). Series of sieve-tube elements are combined into longitudinal series, the *sieve tubes.* Each sieve-tube element is closely associated with one or more slender parenchyma cells called *companion cells* (fig. 6, F; Pl. I, fig. 16). These arise by division from the same mother cell as the sieve-tube element. The sieve cell of the gymnosperms and ferns shows no differences between end and lateral walls. All bear sieve areas of similar nature with rather thin connecting strands. Furthermore, sieve cells are not arranged in vertical superposed series and have no companion cells. Otherwise the sieve cell resembles the sieve-tube element in having callus associated with the connecting strands of the sieve areas and containing no nucleus in the mature protoplast.



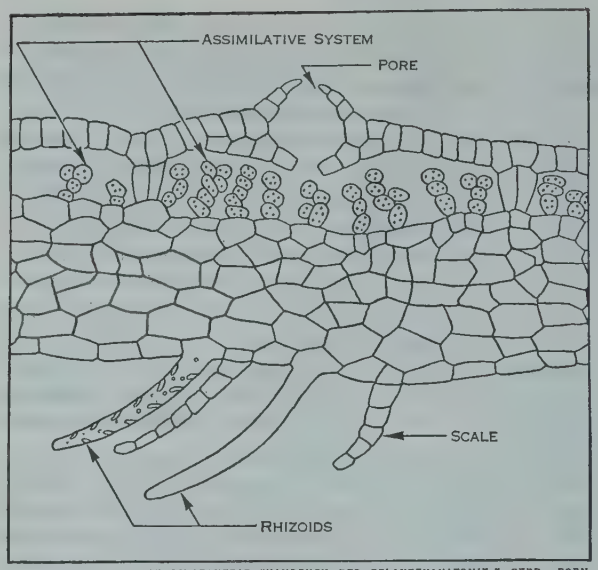
(A) AFTER E. C. JEFFREY, "THE ANATOMY OF WOODY PLANTS," UNIV. OF CHICAGO PRESS; (B, C, F, G) AFTER A. J. EAMES AND L. H. MACDANIELS, "AN INTRODUCTION TO PLANT ANATOMY," MCGRAW-HILL BOOK CO.; (E) FROM K. ESAU, "HILGARDIA"

FIG. 6.—TYPES OF CONDUCTING ELEMENTS IN XYLEM AND PHLOEM. A, TRACHEID OF A GYMNOSPERM. B AND C, VESSEL ELEMENTS. D, TRANSVERSE SECTION OF TRACHEID SHOWING TWO BORDERED PITS. E, SIEVE PLATE, FROM A SIEVE-TUBE ELEMENT LIKE THAT SHOWN IN F. THE LIGHT SPOTS IN EACH SIEVE AREA IN E ARE CALLUS RINGS WITH THE CYTOPLASMIC CONNECTING STRAND IN THE CENTRE OF EACH. THE SMALL CELLS ATTACHED TO THE SIEVE-TUBE ELEMENT IN F ARE COMPANION CELLS. G, SIEVE CELL OF A GYMNOSPERM

The different types of cells characteristic of the plant body are combined into tissues in various manners. For example, only one kind of cell may form a tissue, as in parenchyma or collenchyma tissues (Pl. I, fig. 21). The fibres also may be aggregated into a simple mechanical or supporting tissue (Pl. II, fig. 7). These are *simple tissues.* In other instances many different kinds of cells are combined to make a *complex tissue.* The best examples of complex tissues are the xylem and phloem, which together constitute the *vascular* or *conducting tissues* (Pl. II, fig. 9). The xylem is concerned principally with the conduction of water and inorganic solutes and contains vessels and tracheids (or only tracheids), xylem fibres of different kinds, xylem parenchyma, and ray parenchyma in different proportions and combinations. The phloem translocates various organic solutes and contains sieve tubes and companion cells (or sieve cells), phloem parenchyma, ray parenchyma and bast fibres. The vascular tissues, notably the xylem, function also as supporting tissues because of presence of fibres. The parenchyma that occurs in these tissues commonly serves for storage of different ergastic substances, particularly starch. The vascular tissues together form an elaborate system, the *vascular system.* Parenchyma is the principal tissue that surrounds and interpenetrates the vascular system. It may be spoken of as *ground tissue.*

Organization of the Plant Body.—The reader is referred to special articles on the anatomy of the lower plants (Thallophyta: ALGAE and FUNGI; and BRYOPHYTA: mosses and liverworts) in which the tissues are rather undifferentiated. Suffice it here to mention that both Algae and Fungi range from the simplest unicellular forms with no external differentiation of the body to forms of larger size and greater complexity of organization. The progress in complexity is closely associated with division of physiological labour among the component cells and with the adaptation of the multicellular organism to its environment. But whatever are the various states attained by individual genera, the majority of the cells of the adult bodies of both Algae and Fungi remain alive and the tissues are essentially parenchymatous.

In accordance with the greater complexity in the conditions of life on land for self-supporting plants, considerably more advanced tissue differentiation is exhibited by the Bryophyta, which are mainly terrestrial plants. In a general way this greater complexity consists (1) in the restriction of regular absorption of water to those parts of the plant body which are in close contact with the soil, and (2) in the more regular evaporation of water from the parts exposed to the air. In the higher vascular plants these two principles find their full expression, whereas in the bryophytes water is still absorbed (as, for example, from rain or dew) by the general plant surface. The lowest liverworts have an extremely simple vegetative structure comparable to that of many of the simpler Algae. Since their bodies are small and normally live in damp air, the demands of terrestrial life on them are at a minimum. Their bodies consist of true parenchyma, and the vast majority of the component cells remain alive. Rooting and absorbing threadlike cells (rhizoids) universally occur on



AFTER TH. HERZOG, IN LINSBAUER'S "HANDBUCH DER PFLANZENANATOMIE," GEBR. BORNTRAEGER

FIG. 7.—SECTION OF THALLUS OF A LIVERWORT (MARCHANTIA)

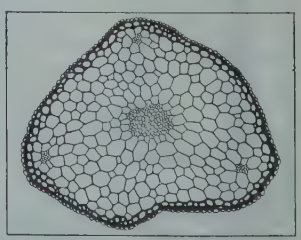
their lower surfaces in contact with the soil, and considerable tissue differentiation may occur within the body. Thus some possess a distinct assimilative system consisting of branched chains of thin-walled cells packed with chloroplasts and arising from the bases of large cavities directed toward their upper illuminated surfaces (fig. 7). These cavities are completely roofed by a layer of surface cells pierced by pores through which aeration and evaporation are freely maintained. In certain forms in which the body consists of thick midribs and delicate lateral leaflike appendages, strands or bundles of long thick-walled fibrelike prosenchymatous cells with pointed ends are arranged longitudinally within the midribs, which are devoid of special assimilative tissue. The walls of these cells are strongly lignified and are irregularly thick and thin so as to be closely studded by simple pits. The latter are usually arranged in spirals and are often elongated in the direction of the spiral. There is much variety of detail in the differentiation of the tissues of the liverworts, but the general plan of construction resembles that characteristic of the leaves of higher plants.

In the mosses the plant body is generally more elaborate. There is a radially organized supporting and conducting axis (stem) bearing laterally through most of its length thin, flat assimilating and transpiring appendages (leaves). Branched rhizoids are attached to the base of the stem or to parts in contact with the soil. In some instances the stem possesses a special surface or epidermal layer of cells, but usually all the outer layers of the stem (the outer cortex) are composed of brown, thick-walled, lignified, prosenchymatous, fibrelike cells forming a peripheral sclerenchyma (fig. 8). This passes gradually into the thinner-walled parenchyma of the *inner cortex*. The entire cortex is generally alive, and its cells often contain reserve foods in the form of starch. The centre of the stem, in the forms which live on soil, is composed of a strand of narrow, elongated, thin-walled, unlignified, dead cells, which are commonly interpreted as water-conducting elements (*hydroids*). This hydrom strand has in most cases no connection with the leaves, but forms a straight column in the stem and branches locally below the reproductive organs. In the aquatic and semiaquatic forms, and in those mosses which live under conditions of extreme drought, the entire plant surface absorbs water. In all such forms the hydrom strand is either slightly developed or altogether absent. The leaves of most mosses are flat plates, each consisting of a single layer of square or oblong assimilating cells containing chloroplasts. The marginal cells of the plates are frequently produced as teeth, and their walls are thick. The centre of the leaf is often occupied by a midrib consisting of several layers of parenchymatous cells elongated in the direction of the long axis of the leaf and poor in chloroplasts. This midrib is usually considered a primitive conductive foliar strand or *leaf bundle*. Hydroids, like those of the central strand of the stem, are frequently associated with this conducting parenchyma, and in some instances are continued into the cortex of the stem as a *leaf-trace bundle* (the anatomically demonstrable *trace* of the leaf in the stem) (fig. 8). In several forms the leaf trace extends vertically downward for some distance in the outer cortex and ends blindly in a fan-shaped expansion; in others it joins the central hydrom strand so that a connected system is established between stem and leaf.

Further differentiation of tissues characterizes the highest family of mosses, the Polytrichaceae. In these, elongated, living, nucleated cells with a thin lining of protoplasm surround the dead central strand and form the phloemlike tissue, commonly called *leptom*. Between the hydrom and leptom is a cylinder of cell layers that may serve for the temporary storage and distribution of carbohydrates, since they sometimes contain an abundance of starch. The underground portion of the stem (rhizome) bears rhizoids and simple scales. The aerial parts bear leaves, each with a simple midrib several cells thick with a strong band of sclerenchyma above, and below a bundle of leptom, hydrom and starch cells, all of which join the central cylinder of the stem. Each midrib bears two wings, one cell thick, while above the midrib is a series of closely set, vertical, longitudinally arranged plates of green assimilative cells.

Vascular Plants.—The greatest anatomical complexity occurs in the vascular plants, which comprise the pteridophyta and the spermatophyta (*qq.v.*). The vascular plants are not exactly comparable with the bryophytes for while the body of the latter bears the sexual organs and is called a *gametophyte*, the vascular plant is a sporophyte. Nevertheless the gametophytic bryophyte and the sporophytic vascular plant have similar physiological needs and are both fixed to the soil. The chief new feature in external conformation of the body of a vascular plant compared with that of a bryophyte is the presence of "true" roots, the first formed of which is the downward prolongation of the primary axis of the plant. From this and from various parts of the shoot system, other roots originate. The roots of ferns are structurally simple and uniform compared with those of seed plants, but all manifest a primary plan of construction in direct relation to their normally subterranean life and fixative and absorptive functions; they differ from aerial stems in the characters of their surface tissues, in the absence of the green assimilative pigment chlorophyll, in the arrangement of their vascular systems, and in their mode of apical growth. Great variety in stem and leaf form and structure is shown by the vascular plants.

In spite of the many differences of detail between ferns and seed plants, we can trace, alike in root, stem and leaf, a threefold division of tissue systems, already indicated among the bryophytes, and expressive of the fundamental conditions of evolution of the bulky body of a land plant. Thus there is (1) a specialization of a surface layer of cells that regulates the immediate relations of the plant with its surroundings, while varying in expression in the subterranean and aerial parts. In the former the surface layer is preeminently absorptive whereas in the latter it is protective and is concerned with the gaseous interchange of oxygen and carbon dioxide involved in respiration, and in such vital functions as assimilation and transpiration. This surface layer is known as the *epidermis*. Then there is (2) an internal differentiation of conductive tissue, presaged in the bryophytes, and collectively known in the vascular plants as the vascular system. The vascular structures are imbedded in



AFTER W. LORCH, IN LINSBAUER'S "HANDBUCH DER PFLANZENANATOMIE," GEBR. BORNTRAEGER

FIG. 8.—TRANSVERSE SECTION OF STEM OF A MOSS (MNIUM). SCLERENCHYMA IN THE OUTER CORTEX. CENTRAL STRAND IN MEDIAN POSITION. BLIND LEAF TRACES IN THE CORNERS

(3) *fundamental* or *ground* tissue. The latter may show different distribution and may be combined with other types of tissue. Thus in the axis a *cortex* appears between the epidermis and the vascular tissues and, in the stem, a *pith* usually occurs enclosed by the vascular tissues. In the root the pith is usually absent. In leaves the vascular system is imbedded in parenchyma which is called *mesophyll.* The mesophyll is especially adapted for photosynthesis. Besides absorption, assimilation, conduction and protection, plant tissues serve for support and the storage of food. Thus locally in the cortex, mesophyll and vascular system, special supporting tissues (sclerenchyma) may be developed, and living cells of both the ground tissue and the vascular system may serve for temporary storage of foods and are specialized accordingly. The functions of aeration, assimilation and transpiration are maintained by an extensive system of *intercellular spaces* communicating with the external air.

Meristems.—The different types of cells characteristic of the body of higher plants are alike at the beginning of their existence. They arise together from meristems, and only through subsequent differentiation in development become unlike. A meristem is best defined as a specific region in the plant body where cells are engaged chiefly in division and enlargement. Meristems can be conveniently classified according to position as *apical* and *lateral* meristems. The apex or growing point of the root or shoot illustrates the former type, the *vascular* and *cork cambia* the second. The localization of the areas of cell formation in the plant body distinguishes the plants from the animals, whose parts grow through their whole extent. Also, unlike animals, the higher plants have a continuous formation of new tissues and organs throughout the life of the individual. A meristem is described as undifferentiated embryonic tissue exhibiting juvenile characteristics in contrast with the differentiated or mature tissues that arise from it. Meristems, however, differ morphologically and physiologically from each other and are not sharply separated from those differentiated tissues that retain protoplasts at maturity, particularly the parenchyma tissue. The living mature tissues are potentially meristematic, and resume meristematic activities when appropriately stimulated. Furthermore, cells of a given meristematic area may vary among themselves in many features.

Apical Meristems.—These meristems are usually composed of approximately isodiametric cells with prominent nuclei. The cytoplasm is often dense but may be also conspicuously vacuolated. The dense cells have many small vacuoles dispersed in the cytoplasm. The walls are commonly thin, and the cells are closely packed without intercellular spaces among them. The architecture of the apical meristems varies in different groups of plants. In most ferns, in the horsetails and in some other vascular plants, all tissues of the stem and root are derived from single *apical cells* located at the apices of these organs (Pl. I, fig. 6). The apical cell, which may be termed also *initial cell,* is usually tetrahedral in shape. Its base occupies the surface of the apical mound of tissue, and the apex points inward. By definite and regular divisions of such a cell, a mass of still undifferentiated cells is produced immediately below the apex that is continuously occupied by a residual apical cell. From these undifferentiated cells the different tissues sooner or later arise by further growth, divisions and differentiation. In the seed plants a few to many cells at the apex of shoot and root initiate the body tissues, and these cells function in different manners. In angiospermous shoots one or more superficial layers and a central core of the apical mound have independent initials (Pl. I, fig. 2). The peripheral layers (tunica) are characterized by surface growth, that is, anticlinal divisions predominate. The underlying core (corpus) shows divisions in all planes and thus grows in volume. The two zones are interdependent and their extent and behaviour fluctuate. They are not at all specific as to the tissues that originate from them. The peripheral zone may be concerned with the production of the epidermis only, or it may give rise to one or more of the underlying regions. Similarly, the central zone may produce pith only or also the vascular tissues and even the cortex. In the gymnosperms a peripheral and central zone may also be distinguished but here they appear to be more interdependent than in the angiosperms: a superficial group of initials divide anticlinally and periclinally and give rise to both the external and the internal cells of the apical mound (Pl. I, fig. 9).

The root and shoot apices differ from each other in several fundamental features. The shoot apex is concerned with the production of the lateral organs of the stem axis, that is, the leaves; the root apex produces no lateral organs: the lateral roots arise some distance from the apex and not superficially (like the leaves) but in the deeper layers of the axis. Thus the lateral roots have an *endogenous* origin in contrast to the leaves, whose origin is described as *exogenous.* The shoot apex is exposed to the outside and cuts off cells only toward the axis (Pl. I, figs. 1, 2). The root apex is covered with a protective tissue, the *root cap,* produced by cells that are cut off away from the axis of the root (Pl. I, figs. 7, 8). Thus, strictly speaking, the apical meristem of the root is *subterminal,* whereas that of the shoot is *terminal.* The initial cells of the root apex of angiosperms are commonly arranged in two or more tiers. One tier may form the root cap, epidermis and cortex, the other the central cylinder containing the vascular tissues. In other species the root cap arises from a separate initial layer (calyptrogen), the cortex and epidermis from another, the central cylinder from a third; or the epidermis and root cap have common origin (Pl. I, fig. 8). Sometimes all four root regions arise from separate sets of initials. In some roots the apical meristem appears generalized and shows no distinct tiers of initials. The study of a root having separate initials for the various regions of the root axis might give the impression that the regions are predetermined in the apical meristem. Such a view has been actually held and the supposedly independent meristematic regions, the *histogens,* have received special names: *dermatogen, periblem* and *plerome,* the precursors of the epidermis, cortex and central cylinder, respectively. Since in some roots, and apparently in all shoots, the regions of the axis cannot be traced back to separate sets of initials, the deterministic scheme of apical structure cannot be accepted.

The Primary Plant Body.—The apical meristem of shoot and root produce a complete plant body with all its vegetative and reproductive organs. This body is spoken of as the primary body, and the tissues composing it as *primary tissues* in distinction from the secondary body or *secondary tissues* that are later added to the primary body by the two lateral meristems, the vascular cambium and the cork cambium. The primary tissues result from progressive differentiation of the cell masses produced by the apical meristems, and the latter may be traced back to the embryo and the zygote. As previously stated, the various tissues or regions of the plant body do not appear to be predetermined in the initial regions of the apical meristems. The first certain evidence of tissue differentiation occurs in the subapical regions. Here some cell masses show speeded up vacuolation of their protoplasts, others remain dense somewhat longer, but divide largely by longitudinal walls and soon become longer than wide. The more highly vacuolated parts of the subapical meristem later differentiate into the cortex and pith (if the latter is present) and are termed the *ground meristem;* the meristem part composed of the dense elongated cells is the precursor of the primary vascular system called *procambium.* It forms the primary xylem and primary phloem. A young plant organ, or part of it, composed of these partly differentiated but still meristematic tissues, is covered on the outside by a discrete meristematic layer, the *protoderm,* which later matures into the epidermis. These three meristems, the ground meristem, the procambium, and the protoderm, as well as the apical meristems, are the *primary meristems* whereas the two cambia are *secondary meristems.*

Epidermis.—The epidermis of the aerial stems and leaves is primarily a covering layer which protects against harm from loss of water and against mechanical injury. It usually consists of a single layer of living cells devoid of chloroplasts, and with thickened and cuticularized outer walls (Pl. I, fig. 11). At intervals the epidermis is interrupted by small pores (stomata) leading from the outer air to the system of intercellular spaces in the underlying tissues, and serving for gaseous interchange between

these tissues and the outer air. Each stoma is surrounded by a pair of peculiarly modified epidermal cells called *guard cells* (Pl. I, figs. 11, 15), which possess chlorophyll and open and close the pore in accordance with the changes in turgidity. The stomata of leaves are generally much more numerous in the lower epidermis than in the upper, and may be absent in the latter. They are often situated at the bottom of pits in the leaf surface. Thus transpiration is checked by the creation of a still atmosphere in the pit above the pore. Such an arrangement of the stomata is found especially in plants adapted to growth in regions where the supply of available water is deficient. In some angiosperms the epidermis is doubled or trebled by tangential divisions in the original layer, resulting in a *multiple epidermis,* which functions as a water-storage tissue. In many vascular plants epidermal organs, known as *hydathodes,* are developed, especially on foliage leaves, and serve for excretion of water in liquid form.

Hairs and Scales.—The epidermis of many species of vascular plants bears hairs or scales of varied form and function. The simplest hairs consist of single elongated cells projecting above the general surface of the epidermis, while others consist of simple or branched cell-chains. The more complex scales are flat plates of cells commonly inserted on mounds or stalks, and may be placed parallel to the leaf surface or projecting directly from it. In other instances the hairs are glandular and excrete ethereal oils, or they may be stinging, as in the common stinging nettle, in which the top of the hair is brittle, and when touched penetrates the skin, breaks, and injects formic acid into the slight wound thus formed. In many plants both hairs and scales are shed before the stems and leaves are mature; in others they are retained throughout the life of the plant.

Epidermis of Root.—The epidermis of the root is fundamentally different from that of the stem or the leaf. In relation to its normal function of water absorption its cell walls are not cuticularized, and usually remain thin. The absorbing surface is increased because many of the cells expand their outer walls into tortuous, delicate, unicellular tubes (root hairs) which aid in anchoring the root, and readily absorb the surface films of water from the soil particles. A root hair thus corresponds in function with a rhizoid of a bryophyte. The hairs are normally definitely restricted to a more or less definite zone of the root a little removed from the growing root tip. At the lower limit of this zone hairs are constantly being formed as the root advances in the soil, while at the upper limit they have passed maturity, are dying and are being destroyed. Thus beyond the zone which at any moment bears living absorbing hairs the epidermis is extensively or completely destroyed, and its place is taken by the immediately subjacent cortical layer, which is not absorptive, but becomes protective like the epidermis of the stem or leaf.

The Cortex.—The cortex consists primarily of living parenchyma, but its differentiation may be extremely varied, and in the complex bodies of vascular plants its functions are varied and may be modified. The cortex of a young stem is usually green, as its cells possess chloroplasts, and a fine system of intercellular spaces communicates with the external air through stomata (Pl. I, fig. 11). With age the inner cortical layers may lose their chlorophyll and become storage tissue, and the outer layers may be extensively modified. In many ferns and lower vascular plants the mature outer cortical layers of the stem and root are hard *sclerenchyma* with thick brown walls, but in flowering plants, while the stems are still slender, the cells of the outer cortical layers elongate and become cylindrical or spindle-shaped and develop localized cellulose thickenings; that is, this part of the cortex differentiates as *collenchyma.* It provides peripheral support for the growing stem, and as its cells are alive, is open to later modifications with changing conditions in stems that undergo annual increase in girth. On the other hand sclerenchyma is commonly dead, and provides a more rigid but usually unmodifiable supporting tissue. Its adequacy will be evident for stems such as those of modern ferns, which do not increase annually in girth. Less commonly, scattered cells or cell groups which increase little in length may become stone cells, with irregularly but inordinately thickened hard walls. Various secretory cells may occur in the cortex, usually lining cavities or canals which arise through a breakdown of certain cells (oil cavities in a citrus stem or fruit) or through enlargement of intercellular spaces (resin canal in pine stem). The cortex of the stem shows more modifications than that of the root. In the dicotyledons the root cortex commonly remains entirely parenchymatous and is early shed in connection with secondary growth, whereas in the monocotyledons and in the ferns it is more or less sclerified at maturity.

Endodermis.—The innermost layer of the living cortex investing the centrally located vascular system of the axis may be early and peculiarly modified as a continuous cylinder called the endodermis. Throughout its extent the endodermal cells are in close contact, so that the system of intercellular spaces in the cortex is not continued into the central cylinder of conductive tissue. In the absorbing region of angiospermous roots the endodermis shows a very characteristic structure. A band of wall material impregnated with fatty substances and lignin extends completely about the inner surface of the lateral longitudinal and end walls of each cell. These bandlike thickenings of the wall are known as *Casparian strips* (Pl. I, fig. 10). This kind of endodermis is thought to play a role in the regulation of the transfer of solutes from the cortex into the vascular system: the presence of the fatty substances in the Casparian strip and the firm connection between the strip and the cytoplasm of the cell apparently force the soil solution to move through the cytoplasm and be subjected to the protoplasmic control of the endodermal cells. In older roots that cease to absorb the endodermis may develop thick lignified walls (Pl. II, fig. 10); or it is torn and shed because of secondary increase in thickness of the central cylinder. The stems of seed plants rarely show peculiar morphologic characteristics in the innermost layer of the cortex. In the youngest part of the stem this layer is commonly differentiated as a *starch sheath,* which may be regarded as an equivalent of the endodermis. It is rich in starch and forms a continuous layer around the vascular system. In the more mature regions of the stem starch is absent. In most ferns the endodermis appears as a morphologically distinct layer throughout the stem and the root. Casparian strips and more generally suberized endodermal cells have been observed in this group of plants.

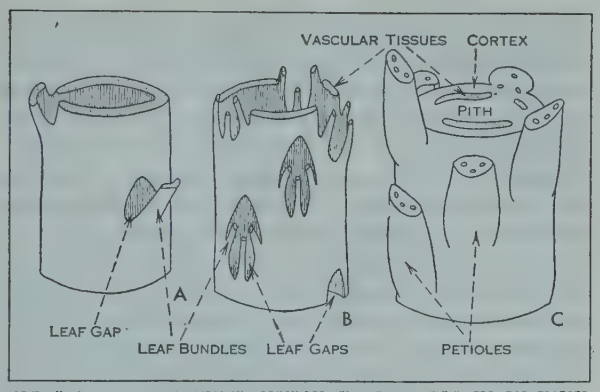
Mesophyll.—The mesophyll of the leaf is primarily concerned with the fundamental function of carbon assimilation, and to the active performance of this function the maximum exposure of living parenchymatous tissue containing chloroplasts is necessary. Thus the mesophyll is essentially a green expanse of thin-walled parenchyma and is penetrated by a large and elaborate system of intercellular spaces which serve at one and the same time for the promotion of transpiration and respiration. The pathways for the gases between the mesophyll and the outer air are the stomata which are in direct communication with the ample system of intercellular spaces in the mesophyll. The lower layers of the mesophyll are loosely arranged as spongy tissue with extensive intercellular spaces (Pl. II, fig. 12). This is the main transpiring tissue of the leaf, and in it chloroplasts may be comparatively few. It is protected from direct illumination and is at the same time liable to over-evaporation. The main assimilating tissue, on the other hand, is under the upper epidermis and it is well illuminated; its cells are densely packed with chloroplasts, and are commonly oblong, with their long axes perpendicular to the leaf surface. The intercellular spaces are here narrow, as between sticks in a bundle, and are in open communication with the intercellular spaces in the spongy tissue below. By reason of its resemblance to the boards in a fence, when viewed in a transverse section of the leaf, this portion of the mesophyll is called the *palisade tissue* (Pl. II, fig. 12). Leaves with blades held in a vertical position commonly possess palisade tissue on both sides or have little or no distinction in the form and arrangement of the cells of the mesophyll (Pl. II, fig. 13), since there is no difference in the illumination or other external conditions, while cylindrical or approximately cylindrical leaves may have palisade tissue all around. The leaves of shade plants have little or no differentiation of the palisade tissue. In fleshy leaves, which

contain a great bulk of tissue in relation to their chlorophyll content, the central mesophyll contains little or no chlorophyll and may consist of water-storage tissue, while locally a layer or mass of subepidermal cells may be thick-walled and fibrous.

The cortex of the leaf stalk or petiole is transitional in structure to that of the stem and leaf blade. The petiole is traversed by one or more vascular strands connected below to the central conductive system of the stem, and leading forward in the leaf blade to a complex system of minor strands which ramify the mesophyll in the plane of junction of the spongy and palisade tissue. The layer of mesophyll immediately investing each bundle usually has the form of a special parenchymatous sheath of elongated cells (Pl. II, fig. 13). In dicotyledons the sheath cells commonly have fewer chloroplasts than the rest of the mesophyll. The *bundle sheaths* are considered important in the conduction of carbohydrates from the assimilative cells to the conductive strands and in the supply of water from the latter for transpiration. Their function is thus considered in some measure comparable with that of the endodermis.

Vascular System.—Among the most striking characters of vascular plants is the possession of a double (xylem-phloem) conducting system, such as has been presaged in the higher mosses, but with more sharply defined and specialized features. This is the vascular system, and associated with it are other tissues consisting of parenchyma and sclerenchyma. The primary vascular system together with the associated tissues is known as the *stelar system* (from the way in which in its simpler forms it traverses the whole axis of the plant as a column). When it is remembered that the moss plant is a gametophyte while the vascular plant is a sporophyte, it will be realized that the vascular system of the latter is not the result of elaboration of the conductive system of the former, but that these vascular systems are most readily interpreted as somewhat similar products of differentiation in plants adapted to life on land.

Arrangement of the Vascular System.—In the vascular system the xylem and phloem are nearly always found in close association in strands or *bundles* (Pl. I, fig. 14), but as is to be expected the arrangement of such bundles is by no means stereotyped either in the given plant group or in the different parts or members of the plant body. A connected vascular system penetrates, however, the entire body. When the vascular system of the axis appears in the form of a solid rod, with a core of xylem ensheathed by phloem, it is termed *protostele* (Pl. II, fig. 1). Usually a discrete parenchymatous layer, the so-called *pericycle,* surrounds the phloem, then follows the endodermis. The evidence from comparative anatomy and palaeobotany indicates that protostele is the primitive type. It occurs in both the stem and root of many lower vascular plants, but is restricted to the root of seed plants (Pl. I, fig. 19). In the advanced ferns the vascular system of the juvenile stem is a solid protostele, but that of the more bulky portions of the adult plant shows a different arrangement. If the xylem core is not solid but contains parenchyma (pith or medulla), the stele becomes a medullated protostele or *siphonostele* (fig. 9, A, Pl. II, figs. 2, 3). In the protosteles the vascular system is not interrupted, at least not markedly so, where a vascular bundle, the leaf trace, diverges to a leaf. Siphonosteles usually show breaks in the continuity of the vascular tissues above the departure of a leaf trace, these breaks being called leaf gaps. The gaps are filled with parenchyma, which connects the pith with the cortex. In cross sections of internodes such a stele appears as a continuous circle but shows breaks in the nodal region. If the leaf gaps overlap in their longitudinal extent in a siphonostelic vascular system, the stele is a *dictyostele* which, in cross section of both nodes and internodes, appears composed of several portions (fig. 9, B). This kind of dictyostele may be found, for example, among ferns. In a dictyostele breaks other than leaf gaps—the parenchymatous *medullary rays* —may be present (Pl. II, fig. 5). A stele of this type should be visualized as a tubular network, the meshes representing the vertical leaf gaps and parenchymatous rays. The stems of seed plants typically have such steles. Thus the vascular system of the axis (root and stem) commonly has the shape of a solid rod or



AFTER Y. OGURA, IN LINSBAUER'S "HANDBUCH DER PFLANZENANATOMIE," GEBR. BORNTRAEGER

FIG. 9.—DIAGRAMS OF A SIPHONOSTELE, A, AND A DICTYOSTELE, B. TISSUES OTHER THAN THE VASCULAR ARE SHOWN IN C IN CONNECTION WITH A DICTYOSTELE

a tube with or without perforations. The leaves, if small as in the lower Tracheophyta (*e.g., Selaginella, Equisetum*) or the conifers (*e.g.,* firs), have a very simple system which typically consists of one unbranched vein. The large-leaved ferns have complex systems of bundles in the petioles and rachises, with branches given off into the pinnae. The angiosperms commonly have rather large leaves with complex vascular systems (*see* below, *Vascular System of Leaf*). The xylem and phloem show two types of disposition in siphonosteles. If the phloem appears only on the outside of the xylem the stele is *ectophloic,* if on both sides, *amphiphloic.* If the ectophloic stele is a much dissected dictyostele the individual strands making up such a stele are *collateral bundles,* having xylem on one side, phloem on the other. The component parts of an amphiphloic dictyostele are bicollateral bundles having phloem on both sides of the xylem.

The Vascular System in the Stem of Seed Plants.—In this group of plants distinct vascular bundles traverse the axis and anastomose with each other (very much dissected dictyostele). At certain intervals one or more bundles diverge into a leaf, and it appears that all bundles of the stem are directly or indirectly related to the leaf bundles. In other words, the vascular system may be regarded as made up of leaf traces and their fusions. The number of leaf traces to a given leaf varies. Common numbers are one, three and many. If the trace is single only one leaf gap or *lacuna* is associated with the given leaf and the condition is spoken of as *unilacunar.* If there is more than one trace the node may show a *trilacunar* (three gaps) or a *multilacunar* (more than three gaps) condition. The trilacunar node appears to be primitive in the angiosperms. The development of axillary buds further complicates the vascular anatomy of the node. The vascular bundles connecting the bud with the vascular system of the main axis are known as *branch traces,* which are usually two in number. *Branch gaps* or parenchymatous areas in the vascular system of the main axis occur above the divergence of the branch traces. In the gymnosperms and dicotyledons the vascular bundles are usually arranged in one circle, with parenchymatous rays separating the bundles from each other. The monocotyledons typically possess large leaves with broad sheathing bases containing numerous bundles. Therefore the number of bundles present at any given level of the stem is high. They are arranged in more than one circle or are scattered in a definite, though not superficially obvious, order throughout the cross-sectional area of the stem so that the delimitation of cortex and stele is difficult or impossible (Pl. II, fig. 4). The bundles are surrounded by large-celled ground tissue and around each bundle there is a fibrous investment or sheath (Pl. I, fig. 14).

Vascular System of Root.—The stele of the primary root of a gymnosperm or angiosperm is of radial structure (Pl. II, figs. 10, 11). There are usually two or more xylem strands radially alternating with as many phloem strands, and the first formed xylem groups (protoxylem) are peripheral (Pl. I, fig. 19). Depending on the number of the xylem strands, the root is called

diarch, triarch, tetrarch or *polyarch*. The centre of the stele is either solid xylem or is pithed, and sclerotic cells are in the ground tissue. Thus the vascular system of the root in seed plants is much simpler than in the stem. It forms a protostele, though not of the most primitive kind: the phloem does not completely ensheath the xylem but appears in strands alternating with the protoxylem points.

Vascular System of Leaf.—In the leaf of the average seed plant the vascular tissue appears as a number of branching or approximately parallel, and usually anastomosing, strands. Above and below the larger strands the leaf parenchyma is raised so as to produce the so-called *veins*. The vein system is typically very elaborate, and the bundle system is concentrated in the petiole as the tributaries of a river are massed in the main stream. The leaf bundles are usually collateral (the phloem being turned downward and the xylem upward), and the whole bundle may be protected above and below by fibrous cells (Pl. II, fig. 13). As the bundles are followed toward their blind endings in the mesophyll the fibres first disappear, the sieve tubes are replaced by narrow elongated parenchyma which also disappears before the end of the bundle is reached. The bundles usually end in short or long spiral or reticulate tracheids covered by the bundle sheath.

Ontogeny of the Vascular System.—The primary vascular system in the various organs of the plant is first delimited in the form of a meristem called *procambium*. The latter assumes similar aspect as the mature vascular system with its continuities and interruptions, gaps, traces, bundles and other details. But all parts of the procambial system are short. The elongation of these parts is one of the phases in the maturation of the procambium into the vascular system. In a given transverse section of the procambium the vascular elements differentiate not all at once, but gradually. The first primary xylem elements (protoxylem) may appear on the periphery of the xylem system, and the subsequent primary elements (metaxylem) toward the centre. Such order of differentiation is spoken of as *centripetal* and the xylem of this kind is *exarch;* or the protoxylem occupies the innermost position in the xylem system and the further xylem differentiates *centrifugally*. Such primary xylem is *endarch*. The first phloem is termed *protophloem;* then follows the *metaphloem*. The phloem located on the outside of the xylem differentiates centripetally. The internal phloem, as in an amphiphloic siphonostele, differentiates centrifugally. A good example of exarch xylem is found in the roots of seed plants. Here the starting points of xylem differentiation, the *protoxylem poles,* occur on the periphery of the stele and alternate with the *protophloem poles* (Pl. I, fig. 19). Both metaxylem and metaphloem differentiate toward the centre of the root, but the phloem remains essentially peripheral, whereas the metaxylem frequently reaches the centre. The xylem in the stems of seed plants is typically endarch. The protoxylem occurs on the periphery of the pith in each major subdivision of the dictyostele. Opposite each protoxylem strand on the periphery of the stele is the protophloem bundle. The metaxylem and metaphloem differentiate toward each other, that is, the xylem shows a centrifugal, the phloem a centripetal order of development. The leaf bundles commonly show the same order of differentiation as the stem bundles.

The longitudinal course of differentiation in the root is from the more mature toward the younger parts of the root, that is, the differentiation is acropetal. In the stem, however, xylem and phloem, as far as known, differ from each other in their initial course. The phloem differentiates acropetally from the lower regions of the axis toward the apex and into the leaf primordia, whereas the xylem is initiated at the base of the leaves or in the leaves and then differentiates toward the apex of the elongating leaf and downward (basipetally) into the axis toward the junction with the mature xylem below.

The primary xylem is simpler in structure than the secondary. The protoxylem contains only one or two kinds of tracheids or vessels (commonly with annular and spiral secondary thickenings) and some parenchyma. The metaxylem shows greater variety of elements and often contains fibres. The primary phloem also is simpler than the secondary. The protoxylem and protophloem mature before the organ in which they occur completes its elongation. Since the water-conducting elements are dead at maturity and the sieve tubes or sieve cells have enucleate protoplasts, these vascular elements cannot respond with growth to the continued division and elongation of the adjacent tissues. For a while the protoxylem and protophloem elements, which have no rigid walls, are passively stretched, then they are torn and more or less completely obliterated while new conducting elements differentiate to take the place of the old ones. Consequently in mature plant organs the protophloem and protoxylem may appear much modified as compared with their original state. This is particularly true of the protophloem in which fibres (bast fibres) or collenchyma-like cells often differentiate after the obliteration of the conducting elements. The fibrous or collenchymatous protophloem appears like a region very distinct from the rest of the phloem and has often been called the pericycle. The metaxylem and metaphloem remain longer intact, though they too become functionless when secondary vascular tissues are formed. In plants having no secondary growth, the metaxylem and metaphloem are the main conducting tissues of the mature plant.

Laticiferous Tissue.—In certain families of Angiosperms there are peculiar tissues that do not occur in the ferns and their more primitive relatives. Such, for example, is the laticiferous tissue found in Compositae and Euphorbiaceae, which appears in the form of long, usually branched tubes penetrating the other tissues of the plant in a general longitudinal direction. The tubes possess a delicate layer of protoplasm with numerous nuclei lining the walls, whereas the interior of the tube (corresponding with the cell vacuole or cavity) contains a fluid called *latex*, consisting of an emulsion of fine granules and drops of various substances, suspended in a watery medium, in which other substances (salts, sugars, rubber-producers, tannins, alkaloids and various enzymes) are dissolved. Of the suspended substances, grains of caoutchouc, drops of resin and oil, proteid crystals and starch grains may be mentioned. Of this varied mixture of substances some are undoubtedly *plastic* (*i.e.*, of use in constructing new plant tissue), while others are apparently end-products of metabolism, secreted within the plant body. The latex may be milky in appearance or nearly colourless. The use of certain plants as rubber producers (notably *Hevea brasiliensis*, the Para rubber tree), depends on the property of coagulation of the latex. The trees are regularly tapped and the coagulated latex which exudes is collected and worked up into rubber. Opium is obtained from the latex of the opium poppy (*Papaver somniferum*), which contains the alkaloid morphine.

Laticiferous tissue is of two kinds: (1) laticiferous cells, which branch but do not anastomose, and the apices of which keep pace in their growth with the other tissues of the plant (Apocynaceae and most Euphorbiaceae); (2) laticiferous vessels, which are formed from rows of actively dividing (meristematic) cells. The end walls of these cells break down so that a network of laticiferous tubes arises (Papaveraceae, *Hevea*). In some plants, as in *Allium* and in the Convolvulaceae, rows of cells with latexlike contents occur, but the walls separating the individual cells do not break down.

Cambium and Secondary Growth.—Most of the modern ferns, horsetails and herbaceous monocotyledons, and many of the annual dicotyledons, are composed of primary tissues only. The gymnosperms and many dicotyledons, particularly the arborescent, have, in roots and stems, large amounts of secondary vascular tissues added to the primary so that the axis becomes many times thicker than it was in the primary state. These tissues are formed by the *vascular* cambium (Pl. I, fig. 20). In the stems this meristem arises partly from the procambial cells that remain in meristematic state after the primary xylem and phloem of the bundles mature, and partly from the ray and gap parenchyma cells located between the bundles. Because of this double origin it is customary to speak of *fascicular* cambium, if it arises within the bundle, and *interfascicular*, if it is formed between the bundles. The two, however, form one continuous meristem, circular in cross section. In the roots, the cambium arises first on the inside of the phloem strands. Then these strips of cambium be-

come connected with each other by cambial cells that arise within the parts of pericycle located outside the protoxylem poles. Thus in both the stem and root a continuous cambial cylinder is formed, which produces secondary xylem toward the centre of the axis, secondary phloem toward the periphery.

It is difficult to indicate precisely when procambium becomes cambium. Generally, one might say that the procambium exists and produces the primary vascular tissues as long as the primary organ is still elongating by continued cell division and cell enlargement in the differentiating primary tissues. After this growth ceases, the remaining vascular meristem assumes the characteristics of the cambium. The latter thus functions in the part of the body that attained its final length. Therefore, if the elements produced by the cambium elongate, they do so not in harmony with the adjacent tissues but by a kind of sliding growth in which the elongating cell intrudes among other cells. In a wide range of dicotyledons and gymnosperms the vascular cambium shows certain common characteristics. It is composed of two kinds of initials: (1) the elongated, prosenchymatous, sometimes spindle-shaped, *fusiform* initials, and (2) the prismatic parenchymatous *ray* initials. Both kinds of initials are highly vacuolate. The fusiform initials form such elements as tracheids, vessels, fibres, wood parenchyma and sieve tubes, that is, vascular elements that are disposed vertically in the axis of the plant. The ray initials are points of origin and propagation of the radially disposed xylem and phloem rays. There is only one layer of initials around the circumference of the axis but the immediate products of this layer cannot be distinguished anatomically from the initials. The initials and their nearest products (the xylem and phloem mother cells) together form a few-layered cylinder of thin-walled vacuolate cells between the xylem and the phloem.

Through secondary growth the primary xylem is buried in the centre of the stem or root, while the primary phloem is pushed outward. The cambial cylinder itself moves outward because of the accumulation of secondary xylem inside of it. As it does so, it also increases in circumference. The divisions that add to the xylem and phloem are tangential, but those that cause the increase in girth of the cambial cylinder are either radial longitudinal (anticlinal) or oblique radial divisions, followed by such elongation of the daughter cells that they appear to slip past each other and eventually lie side by side, at least part of their length.

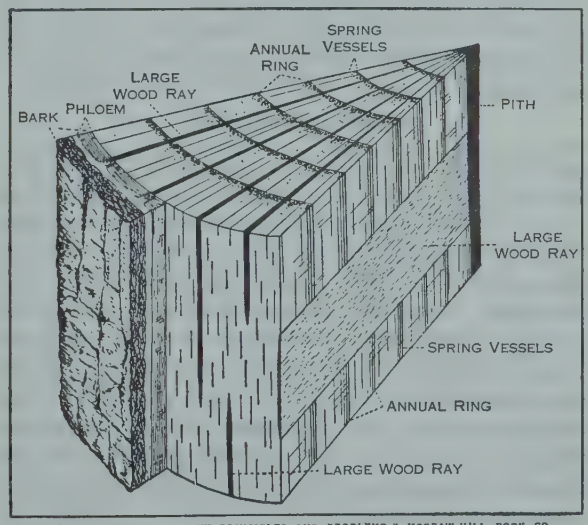
Secondary Vascular Tissues.—The secondary xylem and phloem are highly complex tissues composed of many kinds of cells. As in the cambium, two systems of cells may be distinguished in the secondary tissues, the radial or transverse formed by rays, and the vertical or longitudinal made up of various cells having their long axes parallel with the axis of the organ (fig. 10). The xylem and phloem rays are usually parenchymatous, but may contain ray tracheids in the xylem of gymnosperms. The longitudinal system of the phloem contains sieve cells, phloem parenchyma and fibres in the gymnosperms; sieve tubes with companion cells, phloem parenchyma and fibres in the dicotyledons. The vertical system of the xylem in gymnosperms may contain only tracheids or also fibres and xylem parenchyma. The dicotyledons have a more complex longitudinal system, the complexity varying in different groups. Vessels, tracheids, several kinds of fibres, and xylem parenchyma are common components. The patterns of distribution of the different elements of the secondary phloem and xylem vary greatly and serve as useful criteria in the recognition of relationships among plants.

The secondary vascular tissues in roots and stems are fundamentally similar, but often the root contains a higher proportion of storage parenchyma. The fascicular and interfascicular cambium portions of stems may produce essentially the same kinds of tissues, as in most trees (Pl. II, fig. 8); or the interfascicular cambium forms only ray parenchyma, as in woody vines (Pl. II, fig. 7). In the former case the secondary xylem and phloem form continuous cylinders; in the second the vascular system is broken up into blocks or large strands, each associated with a primary xylem strand next to the pith. Similarly in the roots, the cambium arising in the pericycle may form parenchyma only; or the cambium produces a continuous vascular cylinder (Pl. II, fig. 6).

Annual Rings.—In those plants whose annual activity is interrupted by a regular winter or dry season the limit of each year's increment of secondary wood is marked by a more or less distinct line which is produced by the sharp contrast between the elements formed in the late summer of one year and those produced in the spring of the next (Pl. II, fig. 8). Frequently large vessels are produced by the cambium in the spring, while as summer advances the vessels formed are narrower, and then fibres with greatly reduced cavities arise. In gymnosperms containing no vessels the tracheids formed in the spring have much thinner walls and wider lumina than those produced during the summer. Thus in a single season of cambial activity a rough outward progression may be traced in the secondary wood of that season from wide vessels or tracheids to narrow fibres, beyond which the transition to the wide vessels or tracheids of the succeeding spring is sudden. Each zone thus recognized in a cross section of the stem is called an annual ring, and the lines of separation of successive rings mark the temporary halting places of the cambium at the end of successive seasons.

Sapwood and Heartwood.—The older wood of large trees, forming a cylinder in the centre of the trunk, frequently undergoes marked changes in character. The wood parenchyma and medullary rays die, and the walls of all the cells often become greatly hardened, owing to the deposit in them of special substances. Wood thus altered is called heartwood or duramen, as distinguished from the younger sapwood or alburnum, which is nearer the cambium, carries on the active function of conduction, and retains its parenchymatous cells in life. The heartwood ceases to be of any use to the tree except as a support, and because of its dryness and hardness is much used for industrial purposes.

Phellogen and Periderm.—The secondary increase of xylem and phloem involves an outward movement of the primary phloem and of all the elements which surround the latter. The cortex, and particularly the epidermis, must accommodate for this movement, either yielding passively to a limit and being injured or



AFTER E. W. SINNOTT, "BOTANY PRINCIPLES AND PROBLEMS," MCGRAW-HILL BOOK CO.

FIG. 10.—A SEGMENT OF AN OAK LOG. AT THE RIGHT, THE BLOCK HAS BEEN CUT RADIALLY; AND ABOVE TRANSVERSELY. AT THE LEFT (THE SURFACE OF THE LOG), A PORTION OF THE PHLOEM AND BARK HAS BEEN REMOVED, SHOWING A TANGENTIAL VIEW OF THE WOOD UNDERNEATH

destroyed by the outward pressure, or being to some extent modified so as to persist. Mostly the epidermis is unable to maintain the active radial division of its cells necessary for such expansion, is soon stretched to its limit, dies and is destroyed. Extensive radial division in the cortical cells is progressively less essential as the inner cortex is followed inward, and as a rule, by a combination of radial and tangential divisions, the integrity of the cortex is maintained. Toward the periphery of the cortex, and commonly by modification of its outer layer, a secondary meri-

stem arises and produces external and internal secondary tissues. This meristem is the cork cambium or phellogen, and the whole of the tissue it gives rise to is known as periderm (Pl. II, fig. 9). The phellogen is simple in structure as compared with the vascular cambium: it is composed of one kind of cell which is rather short and prismatic. The external product of this meristem is the characteristic tissue known as *cork*. This consists typically of closely fitting layers of cells which quickly die, and when mature, have completely suberized walls. The cork serves to replace the epidermis as an external protective layer when the former is ruptured. The outer layers of the cork are constantly being destroyed, but new layers are in progress of formation within. The internal tissue sometimes formed by the phellogen is known as phelloderm; it augments the cortex, and typically consists of living parenchymatous cells to some extent capable of further division. Indeed, an inward succession of phellogens may arise in the phelloderm and in even more deeply seated living layers. The phellogens arising deeply may cut off parts of cortex and even phloem. These tissue parts then die and together with the cork form the rough bark on the surface of the tree. In certain plants the epidermis becomes the phellogen. To the great activity of the phellogen, and to the power of formation of a series of phellogens in deep layers, the value of the cork oak as a source of cork is due. Certain areas of the periderm show loosely arranged cells whose walls are not suberized. These areas are the *lenticels* through which gaseous interchange between the stem tissues and the outside air is possible (Pl. II, fig. 9).

Thus throughout the vascular plants there are definite and orderly methods of production and distribution of the tissues that play their roles in the major or minor processes of life.

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PLANT PHYSIOLOGY

Plant physiology is the division of botanical science which comprises knowledge of the processes occurring in plants and the influence of environmental conditions on those processes. Since experimental analysis of plant processes has invariably shown that each such process can be resolved into a number of relatively simpler physical and chemical processes, it is customary for the plant physiologist to regard a plant as essentially a complex living mechanism. Adoption of this viewpoint has led to notable advances in our knowledge of the material and energy transformations which occur within plants, and no exception has ever been found in which plant processes do not operate in accord with the fundamental principles of the physical sciences. Given a plant of known heredity, and of known previous history, it is possible by applying the principles of plant physiology to predict with considerable certainty the physiological reactions which will be evoked in that plant upon its exposure to a given complex of environmental conditions.

The following discussion is largely restricted to the physiology of seed plants:

Physiology of the Plant Cell.—Although from one point of view all plant physiology is cellular physiology, most plant processes are considered in relation to larger structural units such as tissues, organs or the entire plant body. Certain topics, however, can most conveniently be discussed under the above heading.

Organization of the Plant Cell.—The typical mature plant cell is a tiny polyhedral-shaped compartment enclosed by a *cell wall.* Lining the inside of the wall is a thin layer of protoplasm, which is the seat of physiological processes. Present as a part of the protoplasm of each cell is a more or less spheroidal body called the *nucleus,* which appears to exert a controlling influence on the processes of the cell. The remainder of the protoplasmic layer is called the *cytoplasm.* Within the cytoplasm are present other organized bodies, smaller than the nucleus. The most important of these are the plastids. The great bulk of the cell cavity is within the protoplasmic layer and is called the *vacuole.* The vacuole contains a complex aqueous solution called the *cell sap.* Present as solutes in the cell sap are sugars, salts and many other compounds.

Plant cells vary greatly in size and configuration. Some are essentially isodiametric, others are considerably or greatly elongate. A cubic centimetre of compact plant tissue may contain a million or more cells. The protoplasts of individual cells are not entirely isolated from each other by the imprisoning walls, but are interconnected by minute strands of cytoplasm called *plasmodesms,* which extend from protoplast to protoplast through pores in the separating wall.

The cell wall between two adjacent cells consists of two or more layers: (1) the middle lamella, (2) the primary cell wall of each cell, and (3) secondary layers which are not present in all cells. The middle lamella is the first cell wall layer formed in the process of cell division and is bounded on each side by the primary walls of two adjacent cells. This layer is composed of pectic compounds of which calcium pectate is one of the more important. The primary cell wall, which also develops largely during and immediately subsequent to cell division, is composed of cellulose and pectic compounds. The structural framework of such walls seems to consist of irregularly overlapping but interlocking submicroscopic micelles, each composed of a bundle of about 60 chainlike cellulose molecules bound together in a parallel arrangement. The pectic compounds in the primary wall appear to occupy only the irregular spaces between the micelles. In some kinds of cells a secondary wall may be formed on the inner surface of the primary wall. Unlike primary cell walls, secondary walls lack elasticity, and fail to manifest reversible changes in thickness which are characteristic of many primary walls. Secondary cell walls often contain a smaller proportion of pectic compounds to cellulose than primary cell walls. A number of other constituents are also found in plant cell walls. The most important of these are lignin, suberin and cutin. Lignin, the characteristic constituent of the walls of the cells of woody tissues, is a brownish substance whose exact chemical composition is unknown. It occurs in the intermicellular spaces of the cellulosic wall. Suberin is a fatlike substance which is the characteristic constituent of cork cells; cutin is another fatlike substance which occurs as a thin varnish over the epidermis of most aerial plant organs.

As observed at high magnification, protoplasm appears as a clear fluid in which are suspended numerous granules or droplets of insoluble materials. This visible gross structure of the protoplasm does not, however, represent the physical organization which accounts for its unique properties. Portions of the protoplasm which contain no suspended granules exhibit all of its fundamental properties. Hence the ultimate structure with which most of the distinctive properties of protoplasm are associated is submicroscopic and resides in the hyaline, optically empty fluid which is its basic constituent.

Chemical analyses of protoplasm tell us no more of its organization than the analysis of a ground-up watch would tell us of its mechanical construction. The protoplasmic system is destroyed the moment it is subjected to chemical analysis. Nevertheless such analyses do yield the best available information on the proportionate amounts of various ingredients present in protoplasm. Water is the chief component of the protoplasm of all active cells, usually constituting 90% or more of its total weight. Most detailed chemical analyses of protoplasm have been made upon the plasmodia of slime moulds. These are naked masses of labile protoplasm often found flowing over rotting logs in damp woods. Because of the absence of cell wall material, and because the protoplasm can be collected in relatively large quantities, such plasmodia have been favourite materials for this purpose. Analysis of a myxomycete plasmodium shows that proteins and chemically related substances constitute about 67%, lipids about 11%, minerals about 4%, and sugars about 14% of the total dry weight.

The sugars, however, appear to be entirely restricted to the vacuoles, as is also true of a part of the minerals and some of the nitrogenous compounds, especially the amino acids. The properties of protoplasm are clearly as much a function of its ultimate physicochemical organization as of the specific compounds of which it is composed. A number of the properties of protoplasm are similar to those of hydrophilic colloids. Among these are its elasticity, its variable viscosity, its imbibitional capacity, its capacity for reversible gelation, and the fact that its physical state may be markedly influenced by mechanical disturbances, high or low temperatures, or certain concentrations of electrolytes. Protoplasm, therefore, appears to have the organization of a hydrophilic colloid, but its structural and dynamic complexity far transcends that of nonliving hydrophilic systems such as agar or gelatin sols or gels. William Seifriz and others postulate that protoplasm has a basically fibrillar structure, the submicroscopic fibrils (composed largely or entirely of complex proteins) overlapping and interlocking through molecular side chains within an aqueous medium. Electrolytes, carbohydrates, lipids and other constituents of the system may be dissolved or dispersed in the aqueous medium, dissolved in water held within the fibrils, or adsorbed at interfaces within the system.

Protoplasmic Streaming.—In many plant cells the protoplasm is in active motion. In the simplest cases this movement consists of a rotation around the inner surface of the cell wall. Rates of cytoplasmic streaming may range up to at least 19 in. per hour. Protoplasmic streaming (cyclosis) is accelerated by increases in temperature up to the point at which injury occurs, and is retarded at lower temperatures, ceasing just above freezing. Cyclosis also ceases in the absence of oxygen. The exact mechanism of protoplasmic streaming is unknown.

Permeability.—Unlike the cell walls, which in most living cells are quite freely permeable to water and solutes, the cytoplasmic layer is more permeable to some substances than to others. In other words, cytoplasm is *differentially permeable*. This property of differential permeability resides largely in the surface layer of the cytoplasm in contact with the cell wall (plasmalemma), and the surface layer in contact with the vacuole (tonoplast). The cytoplasmic layers are usually relatively permeable to water and to certain solutes such as dissolved gases, and to some types of organic compounds. On the other hand, they are usually much less permeable to sugars and mineral salts. The permeability of the cytoplasmic membranes is a variable property, however, and under certain conditions solutes which ordinarily penetrate through these membranes slowly or not at all may enter or leave cells very rapidly.

Osmotic Relations of Plant Cells.—The osmotic pressures of plant cell saps mostly lie within a range of 5–40 atm. (atmospheres). Much higher values occur in some halophytes, the maximum on record being 202.5 atm. in the leaf cells of saltbush (*Atriplex confertifolia*). The osmotic pressures of the cells of a given plant tissue may vary considerably with environmental conditions and the metabolic status of the cells; more or less regular diurnal or seasonal variations in osmotic pressure occur in the cells of many tissues.

If a flaccid plant cell (*i.e.*, one in which the cell sap exerts no pressure against the encompassing protoplasmic layer and cell wall), is immersed in pure water, inward diffusion of water (osmosis) occurs into the cell sap. Diffusion of the water takes place because the diffusion pressure of the water in the cell sap is less than that of the surrounding pure water by the amount of its osmotic pressure. If the osmotic pressure of the cell sap is 12 atm., the diffusion pressure of the water in the cell sap is 12 atm. less than that of pure water at the same temperature and under the same pressure. The lower diffusion pressure of the water in the cell sap results from the presence of solutes. As water enters the cell it exerts a *turgor pressure* against the protoplasm and cell wall, a pressure which also prevails throughout the mass of water within the cell. If the cell wall is elastic, as it usually is, some expansion will occur in the volume of the cell. As diffusion of water into the cell continues, turgor pressure gradually increases until eventually it is equal to the final osmotic pressure of the cell sap. At this point of dynamic equilibrium the diffusion pressures of the water in the cell sap and the surrounding water are equal, and the number of molecules entering the cell exactly equals the number passing out of the cell per unit of time. Subjection of water to an imposed pressure increases its diffusion pressure by the amount of the imposed pressure. In this example, disregarding the usually small effect of sap dilution as the cell expands, the diffusion pressure of the water in the cell sap is reduced 12 atm. because of the presence of solutes (the osmotic pressure is the index of this effect) and raised 12 atm. by the turgor pressure; hence its equilibrium diffusion pressure is the same as that of the pure water bathing the cell. If the same cell in a flaccid condition is immersed in a solution with an osmotic pressure of 5 atm. inward diffusion of water occurs but does not continue as long as in the preceding example. Disregarding dilution, dynamic equilibrium is attained when a turgor pressure of 7 atm. prevails within the cell, because at that point the diffusion pressure of the water in the cell sap and that of the water in the solution are equal. As exemplified in the preceding examples, the effective physical quantity determining the direction of osmotic movement of water from cell to cell in plants or between a cell and an external solution is the *pressure deficit* of the water, which is equal to the osmotic pressure of the water less the turgor pressure to which it is subjected. Commonly used synonyms for this term are diffusion pressure deficit, turgor deficit, effective osmotic pressure, and suction tension. In an unconfined solution the pressure deficit is equal to its osmotic pressure, since there is no turgor pressure. The pressure deficit and turgor pressure of a plant cell vary reciprocally; in the fully turgid cell the pressure deficit is zero and the turgor pressure equals the osmotic pressure; in the fully flaccid cell the turgor pressure is zero, and the pressure deficit is equal to the osmotic pressure.

In some kinds of cells water may, under certain conditions, pass into a state of tension (negative pressure). In such cells the pressure deficit is equal to the osmotic pressure plus the tension imposed on the water, and sometimes far exceeds the osmotic pressure of the cell sap. As between two plant cells, osmotic movement of water always occurs from the cell of lower to the cell of greater pressure deficit unless some interfering or offsetting condition or mechanism prevents or counteracts such movement. Movement of water in plant tissues commonly occurs from cell to cell along pressure deficit gradients. The osmotic pressure, pressure deficit, and turgor pressure are called the *osmotic quantities* of plant cells; all three of these physical quantities are necessary in any critical evaluation of the water relations of cells.

Plasmolysis.—If an at least partially turgid plant cell be immersed in a solution with a higher osmotic pressure than the cell sap, a slow shrinkage in the total volume of the cell ensues. When the lower limit of elasticity of the wall is reached the protoplasmic layer begins to recede from the wall because of continued loss of water from the cell sap. This recession often continues until the protoplasm has shrunk to a more or less rounded sack in the centre of the cell, the space between the wall and the protoplasm becoming filled with the external solution. This phenomenon is called plasmolysis. Since immersion of a cell in a solution with an osmotic pressure just barely exceeding that of the cell sap should just initiate withdrawal of the protoplasm from the cell wall, this phenomenon is the basis for one of the methods of measuring the osmotic pressure of plant cells.

Enzymes.—Numerous kinds of chemical transformations are constantly occurring in physiologically active plant cells. Many of these chemical reactions can be accomplished artificially, if at all, only by subjecting the reactants to drastic conditions such as high temperatures or extreme degrees of acidity or alkalinity. Yet these reactions occur efficiently and rapidly at ordinary temperatures in a protoplasmic medium which is neither strongly acid nor strongly alkaline. This is possible because of the accelerating effect of certain organic catalysts called enzymes, which are synthetic products of the protoplasm. Two principal groups of enzymes occur in plants. Hydrolytic enzymes catalyze certain hydrolytic decomposition reactions such as digestive processes and also condensation reactions in certain synthetic processes.

Oxidizing-reducing enzymes catalyze various kinds of reactions in which energy shifts occur and participate chiefly in various steps of the process of respiration (*see* below, *Respiration*). A very small amount of an enzyme can catalyze the transformation of an enormous quantity of substrate. The enzyme sucrase, for example, can catalyze the hydrolysis of 1,000,000 times its own weight of sucrose to glucose and fructose, and still retain its catalytic properties apparently unimpaired. Apparently each enzyme affects only one particular type of chemical bond; when a number of compounds possess this bond in common, the same enzyme can act on all of them.

Many enzymes catalyze the same reaction in both directions. For example, lipase catalyzes the hydrolysis (digestion) of fats to glycerol and fatty acids under certain conditions, but under other conditions catalyzes the reverse condensation reaction whereby fat is synthesized from fatty acids and glycerol. Most enzymes are thermolabile and in a liquid medium are quickly destroyed at temperatures between 140° and 158° F. All of the enzymes thus far isolated in an apparently pure state have the properties of proteins.

Transpiration.—In spite of the indispensability of water for their growth and metabolism, most kinds of terrestrial plants—excepting only certain species indigenous to arid habitats—are extremely inefficient in their utilization of water. An overwhelmingly large proportion of the water absorbed from the soil is not retained within the plant or used in metabolic processes, but escapes in the process of transpiration, which is essentially a modified kind of evaporation. Although loss of water vapour, at least in limited amounts, can occur from any part of the plant exposed to the atmosphere, in general most transpiration occurs from the leaves. Foliar transpiration is of two types: (1) *stomatal* transpiration in which water vapour loss occurs through the stomates, and (2) *cuticular* transpiration in which evaporation of water takes place directly from the surface of epidermal cells through the cuticular layer which, although relatively impervious to water, does permit the passage of limited quantities. In most species stomatal transpiration accounts for 90% or more of the water vapour loss from leaves. Thanks to the investigations of Stephen Hales, in 1727, transpiration was the first major plant process studied from essentially a modern experimental viewpoint.

Physiology of Stomates.—The stomates are minute, elliptical pores which occur in the epidermis of plants, being most abundant in leaves. Every stomate is surrounded by two distinctive epidermal cells called *guard cells*. Open stomates are the principal pathways through which gaseous exchanges occur between a leaf and the atmosphere.

The principal gases which diffuse into or out of a leaf through the stomates are water vapour, carbon dioxide and oxygen. When the stomates are closed all gaseous exchanges between a leaf and its environment are greatly retarded. The size of a fully open stomate varies greatly according to species. Among the largest known stomates are those of *Zebrina pendula* whose axial dimensions average 31 × 12 microns. The number of stomates may range from a few thousand per square centimetre of leaf surface in some species to over a hundred thousand per square centimetre in others. In many kinds of plants stomates occur in both the upper and lower epidermis, usually being more abundant in the lower. In numerous other species, especially trees and shrubs, they are present only in the lower epidermis. In aquatic species with floating leaves stomates occur only in the upper epidermis.

The aggregate area of the fully open stomates is only 1–3% of the total leaf area. Despite this fact, rates of stomatal transpiration are often 50%, and sometimes more, of the evaporation from a free water surface under comparable conditions. Much more important is the fact that the rate of diffusion of carbon dioxide, essential in photosynthesis (*see* below), into the leaf through the stomates is much greater than through an equivalent portion of the area of a fully exposed carbon dioxide absorbing surface. H. T. Brown and F. Escombe in 1900 showed that the high diffusive capacity of stomates in proportion to their area is in accord with the principles of the diffusion of gases through multiperforate septa. Diffusion rates through small openings vary as the perimeter, not the area, hence the smaller the aperture the greater its diffusive capacity relative to its area. A gas may diffuse nearly as rapidly, therefore, through a septum pierced with a number of small apertures, whose aggregate area represents only a small proportion of the septum area, as through an open surface equal in area to the septum. Since diffusion of gases through stomates is proportional to the perimeter of the pore, diffusion rates through a partially open stomate are almost as great as when the stomate is fully open.

Increase in the turgidity of the guard cells results in opening of the stomates; decrease in their turgidity results in their closure. In general stomates are open in the daytime and closed at night, although there are many exceptions. The mechanism whereby stomates open in the light and close in its absence seems to be principally an osmotic one. Upon illumination the hydrogen ion concentration of the guard cells decreases. This favours hydrolytic action of the enzyme complex *diastase*, causing insoluble starch in the guard cells to be converted into soluble sugars. The resulting increase in the osmotic pressure of the guard cells causes an increase in their pressure deficit. Osmotic movement of water from contiguous epidermal cells, in which there is no appreciable daily variation in osmotic pressure, takes place into the guard cells. The resulting increase in the turgor of the guard cells causes the stomate to open. With the advent of darkness or even of a markedly reduced light intensity, the reverse train of processes is induced in the guard cells, leading to stomatal closure. Since light of low intensity is relatively less effective in inducing stomatal opening, stomates usually do not open as wide on cloudy as on clear days and often do not remain open for as much of the daylight period. Deficiency of water within the plant induces partial to complete closure of the stomates. During periods of drought stomates therefore remain closed much or all of the time regardless of the light intensity to which the plant is exposed. Stomatal opening does not occur in most species at temperatures approaching 32°F. Hence in cold or even cool weather stomates may remain closed even when other environmental conditions favour their opening. Nocturnal opening occurs at times in some species, but the conditions resulting in such stomatal behaviour have not been adequately investigated.

Dynamics of Stomatal Transpiration.—In most kinds of plants the cells of the mesophyll do not fit together tightly and the intercellular spaces between them are occupied by air. A labyrinth of these air-filled spaces is thus present in a leaf, bounded by the water-saturated cell walls of the mesophyll. Evaporation of water takes place from the wet cell walls into the intercellular spaces. If the stomates are closed the only effect of this evaporation is the saturation of the intercellular spaces with water vapour. When the stomates are open, however, diffusion of water vapour may occur through them into the outside atmosphere. Such diffusion always takes place unless the atmosphere has a vapour pressure equal to or greater than that within the intercellular spaces, an uncommon condition during the daylight hours of clear days. The physical processes of evaporation of water from wet mesophyll cell walls and its subsequent diffusion from the intercellular spaces through the stomates into the atmosphere are, therefore, the two main steps in stomatal transpiration.

Environmental Factors Influencing Rate of Transpiration.—Because of its usually controlling influence on the opening and closing of stomates, light is a factor of prime importance in influencing the rate of transpiration. Stomatal transpiration is largely restricted to the daylight hours; hence daytime transpiration is usually many times greater than night transpiration, which is largely or entirely cuticular. Light also has a secondary effect on transpiration through its influence on leaf temperatures, since leaves in direct sunlight usually have temperatures one to several degrees higher than that of the surrounding atmosphere.

The rate of diffusion of water vapour through open stomates depends upon the steepness of the vapour pressure gradient between the intercellular spaces and the atmosphere. Assuming open stomates, therefore, the greater the atmospheric humidity (vapour pressure) for any given vapour pressure just below the stomatal pores in the intercellular spaces, the less the rate of

transpiration. Temperature affects the rate of transpiration principally because of its differential effect upon the vapour pressures in the intercellular spaces and the atmosphere.

Although leaf temperatures do not follow atmospheric temperatures exactly, in general, increase of atmospheric temperature results in a rise of leaf temperature. Assuming a warm, clear day and an adequate soil water supply, increase in temperature results in an increase in the vapour pressure in the intercellular spaces. Such a rise in vapour pressure occurs because the vapour pressure necessary to saturate air increases with rise in temperature, and the extensive evaporating surfaces of the cell walls bounding the intercellular spaces make it possible for the intercellular spaces to be maintained in an approximately saturated condition most of the time. Rise in temperature ordinarily has little or no effect on the vapour pressure of the atmosphere. Hence the vapour pressure gradient through the stomates is steepened and the rate of outward diffusion of water vapour increases.

Transpiration rates on windy days are usually greater than on otherwise comparable but quiet days. A gentle breeze is relatively more effective in increasing the transpiration rate than winds of greater velocity. In very quiet air local regions of relatively high humidity may build up in the vicinity of transpiring leaf surfaces. Such localized zones of relatively high vapour pressure retard transpiration unless the air movement is adequate to prevent such an accumulation of water vapour molecules. The bending, twisting and fluttering of leaf blades, and the swaying of branches in a wind also contribute to increasing the transpiration rate.

Soil water conditions also influence the rate of transpiration. Whenever soil conditions are such that the rate of absorption of water is retarded, a corresponding diminution in transpiration rate soon follows.

Magnitude of Transpiration.—Transpiration rates of temperate zone plants may range up to values of about 5 g. per dm.^{2} of leaf area per hour. Considerable interest also attaches to the quantities of water transpired per acre of crops, grassland or forest. An acre of corn, for example, transpires water equivalent to 15 acre inches in a growing season. Tremendous variations occur in such values from season to season, however, depending upon climatic conditions. The quantities of water vapour transpired by vegetation-covered areas of the earth's surface are often of sufficient magnitude to have important effects on meteorological conditions.

Significance of Transpiration.—Much fruitless discussion has raged over the question of whether transpiration is detrimental or beneficial to plants. The extreme viewpoints are (1) that the process is an unavoidable evil, and (2) that it is a physiological necessity. Some of the incidental effects of transpiration are advantageous to the plant, but none is indispensable for its survival or even for its normal physiological operation. Likewise, some of the incidental effects of transpiration are detrimental to the plant, but plants have transpired and survived for untold centuries.

Transpiration is a necessary consequence of the relation of water to plant structure. Terrestrial green plants cannot survive unless they obtain carbon dioxide from the atmosphere. Whatever course the evolution of green plants might follow, their structure must always remain such that carbon dioxide can reach interior cells of the leaf. The principal carbon dioxide absorbing surfaces of terrestrial vascular plants are the moist mesophyll cell walls bounding the intercellular spaces of the leaves. Ingress of carbon dioxide to these spaces occurs almost entirely through open stomates. When the stomates are open outward diffusion of water vapour is unavoidable, and this process of stomatal transpiration accounts for most of the loss of water by plants. Transpiration is, therefore, in itself an incidental phenomenon. Despite this fact it often has marked indirect effects on other physiological processes occurring in the plant, especially photosynthesis and growth, because of its influence on the internal water relations of the plant.

Guttation.—The exudation of drops of water at the tips or margins of the leaves of many species of herbaceous plants can often be observed, especially in the early morning on a spring day. This phenomenon, called guttation, also occurs in some woody plants. The exuded water is not pure but contains traces of sugars and other solutes. Guttation occurs from special structures called *hydathodes,* which resemble enlarged stomates. In most species water loss by guttation is negligible compared with water loss by transpiration.

Translocation of Water.—In terrestrial plants the water absorbed from the soil moves to all living parts of the plant. The most striking examples of upward translocation of water occur in trees. The tallest known living tree is a specimen of coast redwood (*Sequoia sempervirens*) which has attained a height of 364 ft. In this tree water ascends to an elevation of nearly 400 ft., since the roots extend for at least a few feet into the soil. Many other individual trees of this species and of several others exceed 300 ft. in height. The mechanism of the ascent of sap in plants, and especially in tall trees, has long been one of the classical problems of plant physiology.

Path of Water Movement.—The upward movement of water in plants occurs in the xylem, which in the stems of trees and shrubs is identical with the wood. In the trunks and larger branches of a tree, however, sap movement is restricted to a few of the outermost annual layers of wood. For this reason hollow trees, in which most of the central core of heartwood has disintegrated, can remain alive indefinitely. The xylem of any plant constitutes a unit system which extends from just back of every root tip through all the intervening root and stem branches to the mesophyll of the leaves. In angiosperms most translocation of water occurs through *vessels,* which are elongated tubelike structures in which cross walls are of relatively infrequent occurrence. In gymnosperms movement of water occurs solely through spindle-shaped cells called *tracheids,* which may be as much as 5 mm. in length. Small, often rounded, thin areas occur in the walls of vessels and tracheids which are contiguous with other vessels or cells; these *pits* are structurally of several types but all of them appear to facilitate passage of water from one xylem element to adjacent ones.

Root Pressure.—If the stem of an herbaceous plant be cut off, a slow exudation of sap often occurs from the xylem tissues at the cut surface of the stump. A similar phenomenon occurs in many woody plants, such as the maple, birch, currant and grape, especially in the spring. A vigorous grapevine often loses a quart or more of sap per day after spring pruning. The exudation of sap results from a pressure originating in the roots, called *root pressure.* There are several reasons, however, why root pressure cannot be the principal mechanism operating in the upward transport of water in plants: (1) there are many species in which this phenomenon does not occur; (2) the magnitude of measured root pressures seldom exceeds 2 atm., which could not motivate a rise of water for more than about 60 ft.; (3) known rates of flow under the influence of root pressure are inadequate to compensate for known rates of transpiration; (4) root pressures are usually present in woody plants only in the early spring; during the summer period when transpiration rates, and hence rates of sap transport, are greatest, root pressures are negligible or nonexistent. Root pressure does account for some upward movement of water in certain species of plants at some seasons, but it represents only a secondary mechanism of water transport.

Cohesion of Water and the Ascent of Sap.—Molecules of water, although ceaselessly in motion, are also strongly attracted to each other. This property of a liquid is called cohesion. The cohesion of water is the cornerstone of an important theory of the ascent of sap in plants (H. H. Dixon, 1914). The postulated mechanism is relatively simple. Evaporation of water from the walls of the mesophyll cells of leaves results in an increase in the pressure deficit of the mesophyll cells. Resulting intercellular movements of water cause an increase in the pressure deficit even of those mesophyll cells not directly exposed to the intercellular spaces. The increased pressure deficit of the cells abutting directly upon xylem elements in the veinlets of the leaf induces movement of water from the vessels or tracheids into the adjacent cells. Since, whenever transpiration is occurring at appreciable rates, water

does not enter the lower ends of the xylem conduits in the roots as rapidly as it passes out of the xylem vessels or tracheids into mesophyll cells at the upper end of the water-conductive system, the water in the xylem ducts is stretched into taut threads, *i.e.*, passes into a state of tension. Each column of water behaves like a tiny steel wire which is stretched. Because of their saturated condition, cross walls in the xylem do not interfere with the continuity of the water. The tension is propagated along the entire length of the water columns to their terminations just back of the root tips, causing entry of water from adjacent root cells (*see* below, *Absorption of Water*). The tension can be sustained by the water threads because of the cohesion between the water molecules, operating in conjunction with adhesion of the boundary layers of water molecules to the walls of the xylem ducts. The existence of water under tension in vessels and tracheids has been confirmed by direct microscopic observation and in other ways. Conservative calculations indicate that a cohesion of 30 to 50 atm. would be adequate to allow conduction of water to the topmost leaf of the tallest known tree. However, under conditions of internal water deficiency, tensions considerably in excess of 50 atm. probably prevail in the water columns of many plants. Actual measurements of the cohesion of water yield values of 300 atm. or more, which allows an ample margin above the magnitude of any tensions which ordinarily develop in water columns. This theory is the most satisfactory yet suggested to account for the translocation of water in plants.

Absorption of Water.—*Soil Water Conditions.*—Since soil particles never fit together tightly, there is a certain amount of space between them. This *pore space* varies from about 30% of the soil volume in sandy soils to about 50% in clay soils. The pore space may be occupied entirely by air, as in desiccated soils, or entirely by water, as in saturated soils, but is commonly occupied partly by air and partly by water. In a soil in which the water table lies relatively close to the surface, considerable quantities of water may rise into its upper layers and become available to plants. In many soils, especially in arid regions, there is no water table, and in many others, even in humid regions, the water table is continuously or intermittently too far below the soil surface to be an appreciable source of water for most plants. In such soils the only water available to plants comes through natural precipitation or artificial irrigation. If rain falls on a dry, homogeneous soil the water will become rapidly distributed to a depth which will depend on the amount of water which falls per unit area and the type of soil. After several days, further deepening of the moist blanket of soil extending down from the ground surface will virtually cease because downward capillary movement of water has become extremely slow or negligible. The boundary between the moist layer of soil and the drier zone underneath will be quite sharp. At this equilibrium condition the water content of the moist soil layer is essentially uniform throughout. The water content of a soil in this condition is termed the *field capacity*. A soil at its field capacity, although relatively moist, is also well aerated; hence soil water contents in the vicinity of the field capacity are the most favourable for the development of most kinds of plants.

A considerable proportion of the water in any soil is unavailable to plants. The *wilting percentage*, an index of unavailable soil water, is measured by allowing a plant to develop with its roots in a sample of soil enclosed within a waterproof pot until the plant passes into a state of *permanent wilting*. The water content of the soil at this point is its wilting percentage. The range of wilting percentages is from less than 5% in very sandy soils to about 20% in clay loams. The wilting percentage of a given soil is found to be about the same regardless of the kind of plant used in making the test.

The pressure deficit of the water in soils varies with the soil water content. In a saturated soil the pressure deficit is virtually zero, at the field capacity less than 1 atm., and at the wilting percentage, on the average, about 15 atm. As the water content of a soil drops below its wilting percentage, its pressure deficit increases at a rapidly accelerating rate, soon attaining a value of hundreds of atmospheres; it is for this reason that the wilting percentage is the approximate measure of the unavailable water in soils.

Relation of Root Growth to Water Absorption.—The successively smaller branches of the root system of a plant ultimately terminate in the *root tips*, of which there may be thousands or millions on a single plant. The term root tip refers to the region extending back from the actual termination of the root for a distance of several to many centimetres. The terminal zone of a root tip is the dome-shaped *root cap*, just back of which are the regions of cell division and elongation (*see* below, *Growth*). Just back of these regions, in most species, is the root hair zone. Each root hair is a projection from an epidermal cell of which it remains an integral part. A single root tip may bear thousands of root hairs, each of which may be from a few millimetres to a centimetre or more in length. A root hair is generally a short-lived structure, but new ones are constantly developing as the root advances through the soil. Most absorption of water occurs at the root tips, especially in the root hair zone, since the older portions of roots become covered with cutinized or suberized layers which are virtually impermeable to water. Whenever the pressure deficit of root hairs and other peripheral cells of the root tip exceeds that of the soil water, movement of water into the root cells occurs. If the soil is relatively wet, in general if above the field capacity, water may move by capillarity toward the region of absorption from more remote portions of the soil, and the supply of water to root tips is largely or entirely maintained in this way. Elongation of the root tips, although slower in most species in relatively wet soils, also helps maintain their contact with untapped portions of the soil water. Many plants, much of the time, grow in soils with a water content between the field capacity and the wilting percentage. In this range of soil water contents capillary movement of water is too slow to maintain an adequate supply of water to rapidly absorbing root tips and is often nonexistent. Once most of the water on the soil particles in contact with a root tip is absorbed it cannot be replaced in significant quantities by capillary movement. In such soils it is the continued elongation of the root tips which maintains their contact with available soil water. Mature root systems of many species of plants bear millions of root tips, each of which may be pictured as slowly progressing through the soil, absorbing water from the particles with which it comes in contact. The aggregate increase in length of the root system of a rye plant averages 3.1 mi. per day. Calculations by P. J. Kramer and T. S. Coile (1940) show that daily root growth of this plant apparently would permit sufficient absorption of water from soils at the field capacity to compensate for daily transpirational water loss.

Mechanism of Water Absorption.—The tension generated in the water columns of a plant as an indirect result of transpiration is propagated to the ultimate terminations of the xylem ducts in the root tips. As soon as the tension in the water columns exceeds the pressure deficit of adjacent cells in the root tip, water passes from those cells into the xylem. This engenders further cell to cell movement of water in a lateral direction across the root tip with the presumable result that a gradient of pressure deficits, consistently increasing from the epidermal cells to the root xylem, is established. As soon as the pressure deficit of the peripheral cells of the root exceeds that of the soil water, entrance of water from the soil begins.

The process just described accounts for most of the absorption of water by plants. The phenomenon of root pressure, previously described, involves an absorption mechanism which is localized in the roots. Absorption of this type occurs only when transpiration is low and the soil is relatively moist. Although xylem sap is relatively dilute, its osmotic pressure is often greater than the pressure deficit of the soil water. This leads to the establishment of a gradient of pressure deficits across the cortex and other tissues of the root tip along which water moves from the soil to the xylem. There are also some indications that other factors play a part in the mechanism of root pressure.

Environmental Factors Influencing Water Absorption.—Because of their reciprocal relation any factor which influences the rate of transpiration influences the rate of absorption. The con-

verse of this statement is also true. In addition the rate of absorption is also influenced by certain soil conditions. Within limits the greater the available soil water supply the greater the possible rate of absorption. Extremely high soil water contents decrease absorption rates in many species because of deficient soil aeration. Low soil temperatures retard the rate of absorption of water by many species. The rate of water absorption by sunflower plants, for example, is rapidly reduced as the soil temperature drops below 55° F. Deficient aeration, characteristic of wet soils, retards water absorption in many species. In such soils the oxygen concentration is lower and the carbon dioxide concentration is higher than in the atmosphere. This retarding effect on water absorption is correlated with a retardation in the rate of root respiration. The presence of solutes in appreciable concentrations in the soil solution also retards or checks water absorption by roots. In most soils the solute concentration is too low to have any appreciable effect on water absorption, but in saline or alkaline soils the influence of this factor may be so pronounced that only a few species of plants are able to survive.

Relative Rates of Water Absorption and Transpiration.—On a clear, warm day, when transpiration rates are high, the rate of water absorption usually lags behind the rate of transpiration, largely because of the resistance of the root cells to the passage of water. As a result there is a gradual increase in the tension in the water columns and a gradual diminution in the water content of the plant, especially of the leaves, during the day. This leads to the partial loss of turgor pressure by the leaf cells, a condition called *incipient wilting.* Sometimes, especially on clear, hot summer afternoons, the decrease in water content of the leaves is sufficient to induce visible wilting. If the soil water supply is adequate, absorption of water during the night exceeds nocturnal transpiration loss, and the leaf cells gradually regain their turgor. Visible wilting caused by a temporary excess of transpiration over absorption is called *temporary wilting,* which is distinguished from *permanent wilting,* caused by a soil water deficiency. Plants automatically recover from temporary wilting during the night, but will not recover from permanent wilting unless the soil water supply is replenished.

Carbohydrate Metabolism.—The dry matter content of a plant tissue can be determined by drying it at 212° F. The dry residue remaining after the evaporation of water can be further separated into two fractions by incinerating it at about 1,100° F. The bulk of the dry matter, representing combustible organic constituents, disappears, leaving only a small mineral residue called the *ash,* which is derived from mineral salts absorbed from the soil.

An adequate explanation of the origin of the bulk of the dry matter of plants long eluded students of plant life. As a result of the investigations of Joseph Priestley, Jean Senebier, Jan Ingen-Housz, N. T. de Saussure and others in the late 18th and early 19th centuries, the gaseous exchanges between green plants and the atmosphere were first clearly envisaged. Green parts of plants, exposed to light, were found to utilize carbon dioxide and release oxygen. Nongreen parts, whether in light or dark, and green parts in the dark were found, like animals, to release carbon dioxide and consume oxygen. These gaseous exchanges are the external manifestations of the processes now known as *photosynthesis* and *respiration,* respectively. Photosynthesis occurs only in green plant organs exposed to light. Respiration occurs in all living plant tissues, green or nongreen, in light or dark. The fact that green plants usually lose oxygen and use carbon dioxide in the light does not mean that no respiration occurs in such organs in the light, but merely that the rate of photosynthesis exceeds the rate of respiration. Although de Saussure in 1804 recognized that utilization of carbon dioxide by plants contributed to their increase in dry weight, it was not until Julius von Sachs, in 1862, discovered the appearance of starch in the chloroplasts of leaf cells as an accompaniment of the consumption of carbon dioxide that the relation of the gaseous exchanges of plants to their carbohydrate metabolism began to be adequately realized.

Photosynthesis.—In the process of photosynthesis (*q.v.*), hexose carbohydrates are synthesized from carbon dioxide and water in the chloroplasts of living plant cells, oxygen also being a product, and light the source of energy. The summary chemical equation for the process is:

$$6CO_2+6H_2O+673 \text{ kg. cal. (of radiant energy)} \longrightarrow C_6H_{12}O_6+6O_2$$

Most of the carbon dioxide used diffuses into the leaf through the stomates and dissolves in wet cell walls bordering the intercellular spaces, whence it diffuses in solution to the chloroplasts. In most species less than 1% of the water absorbed is used in photosynthesis. Most of the oxygen liberated, in excess of a portion used by the green cells in respiration, passes out of solution into the intercellular spaces, whence it diffuses through the stomates into the atmosphere. Hexose sugar, most probably a mixture of glucose and fructose, is the first product of photosynthesis which can be detected in plant cells.

Plant Pigments.—In the higher plants photosynthesis occurs only in the *chloroplasts,* which are green ellipsoidal bodies about 5 microns in diameter. A single mesophyll cell may contain hundreds of chloroplasts. The green colour of chloroplasts and of leaves is due to the presence in the plastids of chlorophyll, of which there are two kinds: chlorophyll *a* ($C_{55}H_{72}O_5N_4Mg$) and chlorophyll *b* ($C_{55}H_{70}O_6N_4Mg$). Most leaves contain from two to three times as much chlorophyll *a* as chlorophyll *b*. Both chlorophylls have been extracted in pure form from the leaves of over 200 species (R. Willstätter and A. Stoll, 1928). The structural formulas of the chlorophylls were determined in 1936 by H. Fischer and S. Breitner. In the angiosperms chlorophyll is, with rare exceptions, synthesized only in the light; in plants of all other groups it can be made either in light or dark. Among the substances which must be present in the cells for normal chlorophyll synthesis are oxygen, carbohydrates, nitrogen, magnesium, iron and water.

The role of chlorophyll seems to be a twofold one: it absorbs light of certain wave lengths, principally in the blue-violet and short red regions of the spectrum, which is used as a source of energy in photosynthesis, and it is a transitory participant in some step of the reaction, presumably acting as a catalyst. The chloroplasts also contain the yellow pigments carotene ($C_{40}H_{56}$), and the xanthophylls (mostly $C_{40}H_{56}O_2$). The leaves of any angiosperm which have developed in the dark are yellow as a result of the presence of these pigments. Carotene is the precursor of vitamin A, one molecule of carotene being split into two molecules of vitamin A by a simple hydrolysis reaction. Carotene, the xanthophylls and certain other chemically related red and yellow pigments are collectively called the carotinoids. In some plant organs, such as carrot roots, carotinoid pigments occur in the amorphous or crystalline state. The cell sap anthocyanins constitute the other principal group of plant pigments; they are responsible for most of the red, blue and purple colourations of flowers, fruits and other plant parts. Both the carotinoids and anthocyanins play a prominent part in the autumnal colouration of leaves.

Factors Influencing the Rate of Photosynthesis.—F. F. Blackman's (1905) "principle of limiting factors" has assisted materially in the interpretation of the effects of various factors on the rate of photosynthesis. This principle was stated by its author as follows: "When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the 'slowest' factor." This principle, which also holds for other physiological processes, does not admit of too rigorous an application, but in general the concept is valid that the rate of a physiological process is largely controlled by the factor present in relative minimum, the so-called "limiting factor."

Carbon dioxide constitutes only 0.03% by volume of the atmosphere, marked deviations from this value seldom occurring In the air stratum just above the surface of rich forest or agricultural soils, however, concentrations several times the usual one sometimes occur, as a result of the upward diffusion of carbon dioxide released in the respiration of soil organisms. With increase in the carbon dioxide concentration of the atmosphere the rate of

photosynthesis increases until some other factor becomes limiting. If the natural concentration of carbon dioxide in the atmosphere were higher than 0.03%, most plants, much of the time, would photosynthesize at a more rapid rate than they do. Very high concentrations of carbon dioxide (15% or more), however, cause a retardation in photosynthesis.

Photosynthesis can occur in visible light from any source, provided its intensity is sufficiently great. The minimum light intensity at which sufficient photosynthesis occurs during an average day's length to be in excess of the consumption of carbohydrates in respiration during 24 hours—no plant can long survive at intensities less than this—differs according to species. In tree seedlings this minimum light intensity ranges from about 1% of full sunlight intensity in some shade species to about 5% in some sun species; in larger plants the minima are probably greater. For measurements made on a leaf or group of leaves, all of which are well exposed to light, the rate of photosynthesis rises with increase in light intensity until some other factor becomes limiting. At the atmospheric concentration of carbon dioxide, maximum rates of photosynthesis in single leaves are attained in many species at one-fourth to one-third of full sunlight intensity, and in some shade species at still lower values. Very high light intensities cause a retardation in photosynthesis, a phenomenon termed *solarization.*

The rate of photosynthesis for an entire tree, or for a plot of vegetation, increases consistently with increase in light up to the maximum sunlight intensity, which at noon on a clear summer's day in mid-temperate latitudes approximates 1.3 g.cal./cm²/min. (equivalent to about 9,000 foot candles). Even in full sunlight many interior leaves of an apple tree, for example, cannot photosynthesize at their maximum capacities because they are shaded by peripheral leaves. The lower the light intensity, the greater the proportion of the leaves of which this will be true. Hence the greater the intensity of the light, the greater the average photosynthesis per unit of leaf area and the greater the total photosynthesis per tree up to the limits of sunlight intensity. All wave lengths of light are not equally effective in photosynthesis. For equal intensities of light incident on the leaf, maximum photosynthesis occurs in the orange–short red region, with a secondary maximum in the blue. Rates in the green and yellow regions are lower, but still very appreciable. The daily rate of photosynthesis is also influenced by the daily duration of the light period (photoperiod). One reason certain crops can develop to maturity during the short growing seasons of high latitudes is that more sugar can be synthesized during the long photoperiods than during the shorter photoperiods of lower latitudes.

Photosynthesis has been recorded as occurring at temperatures below 32° F. in some species and, in algae of hot springs, apparently can take place at temperatures close to 160° F. Most occurrence of photosynthesis in temperate zone plants at relatively rapid rates is within the temperature range of 50°–95° F. In general, increase in temperature results in an increase in the rate of photosynthesis (an approximate doubling for each 18° F. rise) up to an optimum which is not the same for all kinds of plants, but which in most temperate zone species lies within the range of 68°–86° F. Temperatures higher than the optimum, if maintained for any sustained period, cause a diminution in rate below that of the optimum.

Reduction in the water content of a plant causes a retardation in the rate of photosynthesis. This effect is not primarily a result of a deficiency of water as a raw material used in photosynthesis, but of certain indirect effects such as a reduction in the diffusive capacity of the stomates, and a decrease in the hydration of the protoplasm. In young apple trees marked diminution in the rate of photosynthesis occurs long before wilting is apparent, although even in wilted leaves some photosynthesis continues. When water is applied to the soil, wilted apple leaves recover their turgidity in a few hours, but the original rate of photosynthesis is not regained for several days (G. W. Schneider and N. F. Childers, 1941).

Conditions within the plant also affect the rate of photosynthesis. Among the internal factors which may influence photosynthesis are peculiarities of leaf anatomy, chlorophyll content of the cells, hydration of protoplasm, other "protoplasmic factors," and the accumulation of carbohydrates within the cells.

Mechanism of Photosynthesis.—Apparently there are at least two main reactions in photosynthesis: (1) a photochemical reaction (requiring light), having a temperature coefficient of 1, and (2) a chemical reaction (also called the dark or Blackman reaction), occurring either in light or dark, having a temperature coefficient of 2 to 3. There is also evidence that at least one of the reactions in photosynthesis is enzymatic. The long popular hypothesis that formaldehyde (CH_2O) is an intermediate product in the synthesis of hexoses has been largely abandoned for want of any substantial supporting evidence.

A new approach to the problem of the mechanism of photosynthesis has been made by S. Ruben *et al.* (1940) who used radioactive carbon dioxide in an effort to trace the course of the photosynthetic reaction in the alga *Chlorella.* Most of the radioactive carbon, after the carbon dioxide had been utilized in photosynthesis, was present in –COOH groups on a large molecule. They postulate the following steps in the reaction, R being a molecule of large molecular weight.

(1) $RH + CO_2 \rightleftarrows RCOOH$

(2) $RCOOH + H_2O + 110 \text{ kg. cal.} \xrightarrow{\text{chlorophyll}} RCH_2OH + O_2.$

Reaction (1) is believed to be enzymatic; reaction (2) to be photochemical. Succeeding cycles would proceed as follows:

(1) $R \cdot CH_2OH + CO_2 \rightarrow R \cdot CHOH \cdot COOH$

(2) $R \cdot CHOH \cdot COOH + H_2O + 110 \text{ kg. cal.} \xrightarrow{\text{chlorophyll}} R \cdot CHOH \cdot CH_2OH + O_2.$

Six successive cycles would lead to the formation of a six carbon atom molecular chain of the hexose type. Longer molecular chains could be built by a larger number of repetitions; it is even possible that the hexose sugars are not synthesized as units, but are formed by fragmentation of longer molecular chains.

Other important contributors to modern concepts of the mechanism of photosynthesis include D. Burk and H. Lineweaver (1935), J. Franck and K. F. Herzfeld (1937), and H. Gaffron (1939); for further discussion *see* PHOTOSYNTHESIS.

Biological Significance of Photosynthesis.—World-wide cessation of photosynthesis would soon result in the disappearance of all plants and animals, including man, with the negligible exception of a few species of autotrophic bacteria, because this process provides both the energy and organic substance capital of the biological world. Directly or indirectly, all plants and animals, with the minor exception just noted, obtain from green plants oxidizable carbon compounds ("food"), which alone can be used as a source of energy (*see* below, *Respiration*) by living organisms in growth, movement and the accomplishment of metabolic processes. All such oxidizable carbon compounds are the direct or derivative products of photosynthesis. Carbohydrates, fats and proteins all are synthesized by chains of chemical transformation from the hexose sugars produced in photosynthesis, and retain within their molecules chemical energy primarily incorporated in hexose molecules by the transformation of radiant energy from the sun. In some food chains carnivorous animals prey upon smaller or weaker carnivorous animals, which in turn prey upon smaller or weaker animals, but ultimately all such chains always lead to animals which obtain their food from green plants. Photosynthesis not only supplies the energy upon which living organisms operate, but all of the organic substance out of which bodies of plants and animals are constructed consists of the direct or derivative products of photosynthesis.

Magnitude and Efficiency of Photosynthesis.—Under favourable conditions rates of photosynthesis often approximate 10–15 mg. of hexose per dm.² of leaf surface per hour. Corn plants yielding 100 bu. to the acre synthesize about 8,700 kg. (nearly 10 tons) of sugar in a growing season. This represents the transformation of about 33,000,000 kg. cal. of radiant energy into chemical energy. Nearly one-fourth of this is oxidized in respiration and most of the rest has been transformed into starch, cellulose and

other compounds before the plants are mature. The world production of sugar by land plants has been estimated by H. Schroeder (1919) at 4×10^{13} kg. annually which represents the transformation of 1.6×10^{17} kg. cal. of radiant energy into chemical energy.

Despite the utter dependence of the entire organic world upon photosynthesis, only a relatively small percentage of the light incident on plants is used in the process. Of the radiant energy falling on the acre of corn mentioned above only 1.6% is utilized in photosynthesis. Under certain conditions, particularly when the light intensity is low, the efficiency of the process in utilizing incident light may be as high as 5%, but rarely, if ever, is greater than that under natural conditions. From a theoretical standpoint the *quantum yield* of photosynthesis is of considerable significance. Investigations by W. M. Manning *et al.* (1938) and R. Emerson and C. M. Lewis (1941) indicate a maximum value of about 0.1 molecule of carbon dioxide reduced per quantum of light absorbed.

Synthesis of Other Carbohydrates.—Sucrose is universally present in plants, and is the most abundant of the plant sugars. In some plant tissues (sugar cane, sugar beet) it may constitute as much as 20% of the fresh weight, but its concentration is usually lower. Sucrose synthesis occurs by the condensation of glucose and fructose molecules, probably under the influence of the enzyme *sucrase,* according to the equation:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6} \rightarrow \underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O$$

In rapidly photosynthesizing leaves the sucrose content usually increases during the daytime; during the night hours the concentration decreases because of its continued translocation out of the leaves to other parts of the plant. Starch is a complex, insoluble carbohydrate which is synthesized in many, but not all, species of plants. In green leaves starch synthesis occurs in the chloroplasts and apparently is initiated whenever the concentration of hexoses exceeds a certain critical value. Starch is synthesized by the condensation of large numbers of glucose molecules, probably under the influence of the enzyme complex diastase, according to the equation:

$$\underset{\text{glucose}}{n\ C_6H_{12}O_6} \rightarrow \underset{\text{starch}}{H(C_6H_{10}O_5)_n \cdot OH} + (n-1)\ H_2O$$

Considerable quantities of starch accumulate in green leaves during the occurrence of photosynthesis, but most of it is converted into soluble sugars and translocated out of the leaves at night. Starch is also synthesized in many other organs of the plant, as for example in potato tubers, from glucose translocated from the leaves. In the nongreen organs of plants, starch synthesis occurs in the colourless *leucoplasts.* Starch usually occurs in plant cells as microscopically visible starch grains. Cellulose, the importance of which as a cell wall constituent has already been mentioned, is also synthesized from glucose. The equation representing this reaction is exactly the same as for starch synthesis, except that starch is made from α d-glucose molecules, cellulose from β d-glucose molecules. Cellulose is the most abundant organic compound present on the earth. Among the other more important carbohydrates synthesized in plants are pentosans, dextrins, inulin, hemicelluloses, pectic compounds, gums, mucilages, glycosides and tannins.

Fat Metabolism.—Fats and fatlike substances, collectively called lipids, are universal constituents of plant cells. All lipids contain the elements carbon, hydrogen and oxygen; some of the more complex ones, the phosphatides, also contain phosphorus and nitrogen. Phosphatides and perhaps other lipids are essential ingredients of the protoplasm. Fats (called oils in the liquid state) accumulate in various organs of plants, especially in seeds and fruits, in which they constitute a reserve supply of food. Upon germination of fatty seeds the oils are digested and used in the processes of respiration and assimilation. Many vegetable oils are important items of commerce; among these are castor bean, rape, sunflower, linseed, peanut, corn, cotton, coco-nut, palm and olive oils. Lipids apparently can be synthesized in any living plant cell.

Only the synthesis of the fats is well enough understood to warrant discussion. There are three main steps in this process: (1) synthesis of glycerol from carbohydrates, (2) synthesis of fatty acids from carbohydrates, and (3) condensation of glycerol and fatty acid molecules. The detailed chemistry of the first two steps is not known, except that in both there is a chemical reduction with the result that both glycerol and fatty acids contain more energy than the carbohydrates from which they are made. This energy is derived from respiration. The condensation of fatty acids and glycerol to form a fat, using palmitic acid as an example, proceeds as follows under the influence of the enzyme lipase:

$$\underset{\text{palmitic acid}}{3\ C_{15}H_{31}COOH} + \underset{\text{glycerol}}{C_3H_5(OH)_3} \rightarrow \underset{\text{palmitin}}{(C_{15}H_{31}COO)_3C_3H_5} + 3H_2O.$$

In this condensation reaction there is very little energy change, but because of the endothermic nature of the reactions by which fatty acids and glycerol are made, a fat contains about 2¼ times as much energy as an equal weight of carbohydrate.

Mineral Metabolism.—Although many other chemical elements are constituents of plants, only 14 are definitely known to be necessary in chemically detectable quantities for most kinds of plants. These are: carbon, oxygen, hydrogen, nitrogen, magnesium, potassium, calcium, phosphorus, sulphur, iron, boron, manganese, zinc and copper. The first three are obtained by plants from atmospheric gases or soil water. The remainder are obtained from mineral salts which are absorbed from the soil. The last five of the elements listed above are often called trace elements because they constitute a very small proportion of the necessary mineral ration of plants. There is some evidence that the element molybdenum should be added to the list of trace elements. In agricultural soils the elements most likely to be deficient are nitrogen, phosphorus and potassium; hence most commercial fertilizers consist of mixtures of compounds of these three elements. There are many soils, however, to which one or more of the other essential elements must be added if satisfactory growth of plants is to be obtained.

Absorption of Mineral Salts.—A part of the mineral salts used by plants is absorbed from the soil solution. Another and, at least for cations, more important source of mineral elements is the clay fraction of the soil. The clay particles are largely of colloidal dimensions and bear negative charges, having associated with them certain cations in large numbers, the most common of which are hydrogen, calcium, magnesium, potassium and sodium ions. Of all these cations the hydrogen ion is held most tenaciously by the clay particles. As a result of respiration, carbon dioxide is continuously being generated in root cells. Part of this carbon dioxide reacts with water, forming carbonic acid, which in turn dissociates, forming hydrogen ions. If a root hair or root epidermal cell is in intimate contact with a clay particle, hydrogen ions from the cell exchange places with cations associated with the clay particles. This process of *cation exchange* is one of the mechanisms of absorption of ions by the roots of plants. Similar cation exchanges often occur following the addition of a fertilizer to a soil, the displaced cations passing into the soil solution.

Some of the absorption of mineral salts from the soil solution undoubtedly occurs by a simple diffusion, but a larger proportion of the absorption results from the operation of a more complex mechanism, called *accumulation* of salts. Many of the kinds of ions in the cell sap of large-celled species of submersed water plants such as *Nitella, Chara* and *Valonia* are present in a much greater concentration than in the water in which the plants live. A similar situation appears to exist in cells of root tips, which contain various kinds of ions—apparently in a freely dissolved state—each in a concentration much greater than in the medium from which they have been absorbed. Many kinds of plant cells, including those of root tips, appear to possess such a capacity of accumulating salts, *i.e.,* in causing their net movement from a medium of their lesser concentration to one of their greater concentration, which is directly opposite to the direction in which they would move if simple diffusion were the mechanism of movement. Furthermore, such cells possess the capacity of retaining accumulated salts in the cell sap in a higher concentration than in the surrounding medium. In this process, unlike the

cation exchange process, both the anions and cations of a salt usually pass into a cell in electrostatically equivalent quantities. The accumulation of salts and their retention in the cell in a higher concentration than in the surrounding medium is correlated with an adequate rate of aerobic respiration within the cells. Presumably energy released in respiration is utilized in the process. Absorption of water and absorption of mineral salts both occur principally through the root tips although the mechanisms of the two processes are entirely different. Continued growth of the root tips through the soil is an important factor in the absorption of mineral salts, particularly in soils at water contents below the field capacity.

Roles of Mineral Elements in Plants.—Plants absorb many kinds of ions which are not necessary for their development, and commonly absorb necessary ions in quantities greater than are utilized in the metabolism of the plant. Absorption of ions, therefore, is not necessarily followed by their utilization. Generally speaking, however, most of the ions of essential elements which are absorbed are utilized in one manner or another in metabolic processes, or else have important influences upon physiological conditions within the plant. Many of the mineral elements are important constituents of protoplasm, cell walls, or accumulated foods within the plant. The osmotic pressure, hydrogen ion concentration, buffer action, and permeability of plant cells are all influenced by mineral salts or their constituent ions. Some mineral elements act as catalysts in the plant. Others have, in certain concentrations, toxic effects which often may be offset by the presence of other ions, a phenomenon known as *antagonism.* Examples of specific roles of most of the essential mineral elements are given at other places in this article.

Absence or deficiency of any of the essential mineral elements sooner or later becomes apparent in the plant as aberrations in growth or pigmentation. Characteristic visible symptoms of the deficiency of each of the essential elements have been recognized for a number of kinds of plants. Ability to identify such symptoms is of value in diagnosing developmental disorders in plants under natural or cultural conditions.

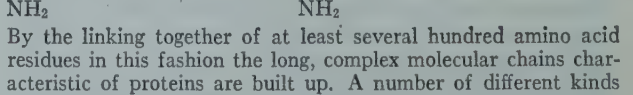
Hydroponics.—J. von Sachs in 1860 and W. Knop in 1865 were the first to use the method of water culture (solution culture) for studying the mineral salt relations of plants. In this method the plants are grown with their roots immersed in dilute solutions containing dissolved salts (so-called nutrient solutions). An alternative procedure is to grow plants with their roots in pure quartz sand or gravel which is kept moist with the solutions. By comparing the development of plants in solutions containing different kinds and proportions of ions, or the growth reactions of plants in a solution markedly deficient in one of the necessary elements with its growth in a complete solution (one containing all necessary elements) many important facts concerning the mineral nutrition and metabolism of plants have been discovered.

Solution and sand cultures have been used by plant physiologists as a laboratory technique for many years, but it was not until about 1936 that the extension of these methods to the commercial culture of plants in large tanks was attempted, a procedure for which the name hydroponics has been proposed. In one such method plants are supported in a matrix of peat, excelsior or some similar material on a wire screen with their roots projecting into a tank of solution below. Provision for adequate aeration of the solution is necessary if suitable development of the plants is to be insured. In another method the plants are rooted in a medium of coarse sand, gravel, or haydite (fused shale) contained in large shallow tanks into which the solution is automatically pumped at intervals from a reservoir, to which it drains back after each cycle of pumping. Considerable success in the culture of certain greenhouse crops by these methods has been reported by commercial growers. The principal salts used in preparing solutions suitable for use in "soilless" plant culture are potassium dihydrogen phosphate, calcium nitrate, potassium nitrate, magnesium sulphate, ammonium sulphate and iron tartrate. Technical details of such culture methods are given in special handbooks (W. I. Turner and V. M. Henry, 1939; C. Ellis and M. W. Swaney, 1938; A. Laurie, 1940)

Nitrogen Metabolism.—Proteins, as already noted, are, next to water, the most abundant constituent of protoplasm. Proteins also accumulate in certain plant organs in considerable quantities, especially in the seeds of legumes. Upon germination of such seeds the proteins present are digested and utilized in the processes of assimilation and respiration. All molecules of plant proteins contain the elements carbon, hydrogen, oxygen and nitrogen. Sulphur also appears always to be a constituent, although present in relatively small quantities. Phosphorus is also a component of certain plant proteins.

In spite of the fact that nitrogen gas constitutes about 79% of the atmosphere, green plants are not able to utilize nitrogen from this source. Leguminous plants, an apparent exception to this statement, obtain atmospheric nitrogen indirectly through metabolic activities of symbiotic bacteria living in nodules on their roots. The well-known influence of legumes in enhancing the nitrogen content of soils is dependent upon the action of these bacteria. Most green plants obtain their nitrogen as a constituent of the nitrates or ammonium compounds which they absorb from the soil.

Protein molecules are synthesized by the condensation of large numbers of molecules of *amino acids.* More than 15 different amino acids occur in plants. The simplest amino acid is glycine: $CH_2 \cdot COOH$ (with NH_2 attached to the CH_2). Most amino acids have a more complex molecular structure; at least one plant amino acid (cystine) also contains sulphur. Amino acids are apparently synthesized from organic acids derived from carbohydrates and from the nitrogen absorbed as nitrates or ammonium compounds. The sulphur present in cystine and possibly other amino acids is absorbed by the plant as sulphates. In some species of plants (apple, asparagus, certain grasses) synthesis of amino acids occurs principally in the roots, while in others (pea, soybean, tomato) it occurs principally in the aerial parts. The principal regions of protein synthesis do not necessarily correspond with the principal regions of amino acid synthesis. Amino acids may be made in one part of a plant, translocated to other parts, and used there in protein synthesis. Condensation of amino acids resulting in the formation of proteins occurs chiefly in the meristems and in certain storage tissues, especially in seeds. The condensation of amino acid molecules occurs mainly by their union through the *peptide linkage.* Using two glycine molecules for illustration, this process occurs as follows:



By the linking together of at least several hundred amino acid residues in this fashion the long, complex molecular chains characteristic of proteins are built up. A number of different kinds of amino acids enter into the constitution of each protein molecule; these are not arranged in a haphazard manner, but according to definite linear sequences, which are different and characteristic in each kind of protein. Many of the proteins found in the nuclei of plant cells contain phosphorus. Such proteins are complex compounds formed by the combination of proteins and the phosphorus-containing nucleic acids. Among the compounds important in the protein metabolism of plants are asparagine and glutamine, chemically very closely related to aspartic acid and glutamic acid, respectively, both of which are important plant amino acids. Organic nitrogen is often translocated from one part of the plant to another as asparagine, and this compound also commonly occurs as a temporary storage food. Alkaloids, complex nitrogen-containing compounds, very different in chemical constitution from the proteins, occur in some species of plants. Examples are nicotine, quinine, strychnine and morphine. These compounds are apparently only incidental products of plant metabolism; many of them, however, are important in therapeutics.

Translocation of Solutes.—*Downward Translocation of Or-*

ganic Solutes.—Organic solutes, principally carbohydrates synthesized in the leaves, are translocated in a downward direction in plants to the tissues of stems and roots through the phloem. In the stems of woody plants downward translocation occurs only in the youngest layers of phloem, corresponding roughly to the inner bark adjacent to the cambium. In tall trees the carbohydrates entering the root tips may have moved hundreds of feet through the continuous phloem from the leaf cells in which they were made. Most of the translocation of solutes through the phloem occurs in the sieve tubes, which consist of linear series of elongate cells joined together end to end. The exact mechanism of the downward translocation of solutes through the phloem is not known. One theory is that it is accomplished by cyclical streaming of the cytoplasm in the sieve tube cells, the solutes passing from one cell to the next by diffusion. Another theory is that there is a mass flow of solution in a downward direction through the phloem, movement from cell to cell being assumed to occur through the interconnecting cytoplasmic strands. There are a number of objections to both of these theories, one of the most serious being that neither of them can account for the rapidity with which translocation occurs in some plants. There are indications that the movement of solute molecules is in some manner greatly accelerated by the metabolic activity of the phloem cells through which translocation occurs, and that energy is actually expended in the accomplishment of solute movement (H. F. Clements, 1940).

Upward Translocation of Organic Solutes.—Under certain conditions considerable quantities of carbohydrates and other soluble foods are translocated in an upward direction through plants. This occurs, for example, in the stems of woody species when the buds resume growth in the spring. The tissues of the shoots formed shortly after initiation of growth are constructed largely from foods which move in an upward direction from storage tissues of the older stems. Translocation of foods in an upward direction also occurs toward developing flowers or fruits located in a terminal position, in seedlings as food moves from the endosperm or cotyledons toward the apical growing regions, and during the earlier stages in the development of leaves or shoots from bulbs, corms, rhizomes and tubers. Upward translocation of organic solutes occurs largely in the phloem. It is not certain whether solutes can move simultaneously in the phloem in both directions or can only move in an upward direction under certain conditions and in a downward direction under others. The comments previously made regarding lack of knowledge of the mechanism of downward translocation apply equally well to upward translocation of organic solutes.

Translocation of Mineral Salts.—The mineral salts absorbed from the soil by the roots are mostly translocated in an upward direction in plants, a large proportion of them ultimately reaching the leaves. Considerable controversy has flourished over whether upward movement of the mineral salts occurs principally in the xylem or principally in the phloem, but the preponderance of the evidence at present indicates that the xylem is the chief tissue through which mineral salt transport occurs (P. R. Stout and D. R. Hoagland, 1939). The dissolved mineral salts, generally in very low concentration, are passively carried in an upward direction through the ascending streamlets of water in the xylem ducts. The possibility of some upward movement of certain mineral elements in the phloem, particularly if in organic combination, cannot, however, be entirely excluded. Not all of the mineral salts translocated into a leaf or other lateral organ of a plant necessarily remain in that organ permanently. Re-translocation of certain mineral elements either as ions or as constituents of organic compounds out of the leaf and their subsequent distribution to other organs, often younger leaves, is of frequent occurrence in plants. Just prior to the abscission of leaves or floral parts a considerable proportion of the nitrogen, phosphorus, potassium, sulphur and magnesium present is translocated back into the stems. Such movements of minerals out of leaves occur through the phloem. There are also indications of a periodic daily "circulation" of at least certain of the minerals in the plant. Mobile phosphorus compounds, for example, apparently can move from root to leaf through the xylem, and from leaf to root through the phloem within a 24-hour period (O. Biddulph, 1941).

Respiration.—The gaseous exchanges — consumption of oxygen and release of carbon dioxide—accompanying respiration are only external manifestations of this process. The essential and only invariable feature of respiration in green plants is that this process results in the oxidation of foods in living cells. The summary equation for the most usual course of respiration is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 673 \text{ kg.-cal.}$$

This process is often termed *aerobic respiration* because it proceeds only in the presence of atmospheric oxygen. Hexose sugars are most commonly the substrate of respiration and the equation given above, representing their complete oxidation, is the exact opposite of the photosynthetic equation. Fats and proteins can also be oxidized in plant cells after conversion into soluble hydrolytic products. Oxidation of fats usually is not initiated until the soluble carbohydrates in the cell are exhausted. Oxidation of proteins apparently seldom occurs until the cells have been depleted of both carbohydrates and fats. The respiratory ratio (ratio of volume of carbon dioxide released to volume of oxygen consumed) of a plant tissue depends upon the type of substrate being oxidized. Oxidation of carbohydrates results in a respiratory ratio of approximately 1, of fats a ratio of about 0.8, of proteins about 0.9, and of certain organic acids, such as oxalic and malic acids, a ratio of more than 1. The occurrence of anaerobic respiration in a tissue also results in a respiratory ratio greater than 1. That heat energy is released in respiration can be demonstrated by placing a mass of germinating seeds in a calorimeter and measuring the rise in temperature with a thermometer. The energy which escapes as heat is entirely lost to the plant. An important fraction of the energy released is not transformed into heat, but is used in endothermic synthetic processes, in various translocation phenomena, in protoplasmic streaming, in the accumulation of ions or molecules by plant cells, in various stages of growth and in other ways. All of the energy made available by respiration represents radiant energy previously entrapped in the process of photosynthesis.

Factors Influencing the Rate of Respiration.—In general, young meristematic tissues, relatively rich in protoplasm, have higher rates of respiration than older tissues in which the proportion of cell walls and dead cells is greater. Opening leaf or flower buds, growing root tips and germinating seeds all have relatively high rates of respiration. Germinating poppy seeds at 61° F. may lose 122 cc. of CO_2 per gram of dry weight in 24 hours. The respiration rates of meristematic plant tissues are of the same order of magnitude as the rates in warm-blooded animals. Rates in dormant seeds or other dormant organs, and mature or senescent leaves, fruits or other organs are much lower. Within a temperature range of about 32°–113° F., increase in temperature usually causes an increase in respiration rate (an approximate doubling for each 18° F. rise in temperature), although at the higher temperatures the increased rate often diminishes with time. Starved plant cells respire relatively slowly, and in general, with increase in the soluble carbohydrate content of the cells there is an increase in the rate of respiration up to the point at which some other factor becomes limiting. Very high oxygen contents of the atmosphere result in increased rates of respiration, very low ones result in decreased rates. The oxygen content of the atmosphere can, however, deviate considerably from the usual atmospheric concentration without any pronounced effect on the rate of respiration. An increased carbon dioxide content of the atmosphere results in a decrease in the rate of respiration of some plant tissues and an increase in others. The effect of a shift in the hydration of the tissues on the rate of respiration is exhibited most clearly in seeds. The respiration rate of dry seeds is often vanishingly small, but immediately upon the imbibition of water, the first step in germination, it increases markedly.

Influence of Respiration Rate on Net Rate of Photosynthesis.—The average quantity of hexose produced in photosynthesis by a corn plant during its life history is about 9 g. per photoperiod, while the average amount of hexose consumed in respiration dur-

ing its life history by the entire plant is about 2 g. per 24-hour day. The difference between these two quantities is the *net daily rate of photosynthesis* and represents the amount of hexose which can be utilized by the plant in assimilation or which may accumulate as unused food. The average net daily rate of photosynthesis is an important consideration in evaluating the survival and development of plants, as, in general, the greater this quantity the larger the plant can grow and the more food that can accumulate. Temperature has an important effect on net daily photosynthesis because of its differential influence on the rates of respiration and photosynthesis.

In many and perhaps all species the temperature optimum for respiration is higher than the optimum for photosynthesis. In the potato, for example, the temperature optimum for photosynthesis, under otherwise favourable conditions, is about 68° F., while the optimum for respiration, at least of the leaves, is about 95° F. Hence, the higher the temperature above the photosynthetic optimum, the greater the proportion of the photosynthate which is consumed in respiration in one part of the plant or another, and the smaller the daily net photosynthesis. At relatively high temperatures, therefore, there is relatively less food which can be used in the construction of new tissues and which can accumulate in the tubers or other organs. This is the explanation of the well-known fact that the potato is a cool climate crop. The same principle also applies to other species, although the temperature which results in maximum daily rates of net photosynthesis varies with other environmental factors and with the species, being in general higher in species indigenous to warm climates than to those indigenous to cool climates. Analysis of this effect of temperature on plants is complicated by the fact that plants in nature are exposed to a daily cycle of temperature variations, the general pattern of which varies from season to season and habitat to habitat.

Fermentation.—When a dilute sugar solution becomes inoculated with yeast cells the process of alcoholic fermentation ensues:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 25 \text{ kg.-cal.}$$
hexose ethyl alcohol

This reaction is catalyzed by the enzyme complex zymase, contained in the yeast cells. Although an oxidation reaction, it can proceed in the complete absence of atmospheric oxygen, *i.e.*, it is *anaerobic*. Even when oxygen is present yeast cells carry on relatively little aerobic respiration, still obtaining most of their energy from the relatively much less efficient process of fermentation. A process identical with, or at least closely similar to alcoholic fermentation occurs in the tissues of green plants under certain conditions. If kept in an atmosphere devoid of oxygen many plant tissues continue to release carbon dioxide while ethyl alcohol or other end products accumulate in them. In some plant organs anaerobic respiration occurs even in the presence of oxygen. This is true in the earlier stages of germination of some kinds of seeds and grains (pea, oat, sunflower) because of virtual impermeability of the coats to oxygen. The skin of the grape and some other fruits is also highly impermeable to oxygen, and considerable anaerobic respiration doubtless occurs in such organs. Many tissues of higher plants are soon injured if anaerobiosis continues very long. If corn seedlings, for example, are deprived of oxygen signs of injury will appear in them within a day. The injurious effect of anaerobic respiration on many plant tissues is probably in part a result of the low energy output of this process, and in part of the accumulation of alcohol or other toxic products within the tissues. Some senescent tissues, such as apple and pear fruits, on the other hand, continue to lose carbon dioxide and remain uninjured for months when stored in pure nitrogen or hydrogen.

Mechanism of Respiration.—The process of respiration comprises a complex series of reactions, the details of which cannot be given in a brief discussion. The earlier steps in respiration and fermentation appear to be identical. Apparently hexoses, in an activated form, are first converted into trioses (3-carbon atom sugars) after a temporary combination with phosphates, which play an important role in the process. In the absence of oxygen various other intermediate products are formed, including glyceric acid, pyruvic acid and acetaldehyde, but the ultimate products of the reaction chain are alcohol and carbon dioxide. Most steps in this series of reactions appear to be catalyzed by enzymes of the zymase complex. In the presence of oxygen, fermentation is largely or entirely inhibited and trioses or perhaps other intermediate products of fermentation undergo complete oxidation to carbon dioxide and water, probably largely under the influence of oxidases and dehydrogenases. The highly reactive compounds formed as intermediate products of fermentation or respiration are not all oxidized to the usual end products of these reactions, but a considerable proportion of them are used in fundamental anabolic processes within the cell.

Growth.—The co-ordinated development of plant organs and tissues is just as clearly a type of physiological activity as relatively simpler processes such as photosynthesis and respiration. The tissues and their constituent cells resulting from the complex of physiological processes referred to as growth in turn become factors influencing subsequently occurring physiological processes in those tissues. Growth of plants occurs primarily in meristems, which are tissues in which the cells retain a capacity for cell division. The principal meristems of a vascular plant are the apical stem meristems, the apical root meristems and the cambium (not present in ferns or monocots). An embryo plant has only one apical stem meristem, but with the development of the branching stem system there comes to be such a meristem at every growing stem tip and in every bud. Hence there may be thousands of apical stem meristems on any plant with an extensive system of branching. Likewise there is only one apical root meristem on an embryo plant, but with the branching of the root system the number of such meristems on a single plant may exceed many thousands or even millions, since one is present at every root tip.

Growth of any meristem proceeds by successive microscopically visible stages of *cell division, cell enlargement* and *cell maturation,* which are the three principal morphological phases of growth. The terms for the first two stages of growth are self-explanatory. Cell maturation refers to the final stage in growth during which most of the distinctive structural and chemical differences in the walls of the various kinds of cells develop. It is also the stage in which the protoplasm disappears from many kinds of cells as, for example, most cells of the xylem. An actively growing meristem is a centre of intense assimilatory activity, *assimilation* being the term used to refer to the construction of new cell walls and protoplasm from foods. Protoplasmic proteins are made by the condensation of amino acids, principally during the cell division stage of growth. Cellulose, pectic compounds and other cell wall constituents are synthesized by the condensation of soluble carbohydrates, principally during the cell division and cell enlargement phases of growth. Water is incorporated into the cells in considerable quantities during both cell division and cell enlargement, some entering into the hydration of newly formed cell walls and protoplasm, and larger quantities entering into the expanding vacuoles, particularly during cell enlargement. Translocation of water and soluble foods is, therefore, constantly in progress toward growing meristems. Translocation of essential minerals, as soluble compounds of one kind or another, is also continually occurring toward growing meristems. Certain growth substances must also be present if growth is to occur. Regions of cell division and cell enlargement are also centres of intense respiratory activity, considerable quantities of carbohydrates being oxidized in such cells, much of the resulting energy being utilized in various dynamic and metabolic processes which are integral phases of growth. Respiration rates during the maturation phase are distinctly lower than during the two preceding stages of the growth process.

Growth from primary meristems is called *primary growth* and results in all increase in the length of stems and roots, in the development of their branching system, in the development of the primary tissues of such organs, and in the production of all lateral appendages, such as leaves, floral parts and root hairs. Primary growth of plants is not a continuous but a periodic phenomenon, periods of growth having in general a correlation

with favourable seasons, but varying greatly from one species of plant to another. The periodicity of root growth in a given species is usually different from the periodicity of stem growth, often beginning earlier in the season than stem growth and continuing after the latter has ceased. Most of the *secondary growth* of plants is initiated in the cambium, which is a uniseriate layer of cells located between the xylem and phloem. In most plants in which it occurs the cambium is present as an almost continuous layer of cells extending from just back of every root tip to just below every stem apex. As a result of secondary growth in a lateral direction xylem cells (secondary xylem) are formed on the inner side of the cambium and phloem cells (secondary phloem) on its outer side (the first layers of these two tissues, primary xylem and primary phloem develop during primary growth). In woody perennials secondary tissues may develop from the cambium for hundreds of years, cambial activity being resumed periodically with the advent of each growing season. The diameter of the woody cylinder is thus increased from growing season to growing season, and commonly each season's layer of xylem (wood) can be distinguished in cross sections of the wood as a definite *annual ring*. As new layers of phloem form adjacent to the cambium, the older phloem is displaced outward and, in most woody species, becomes part of the bark, which eventually sloughs off.

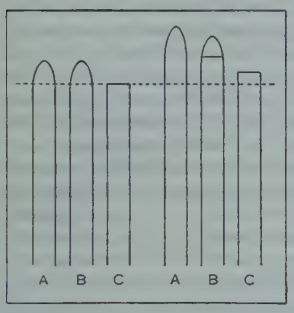


FIG. 11.—EFFECT OF DETIPPING OAT COLEOPTILE ON ITS SUBSEQUENT ELONGATION. (A) INTACT COLEOPTILE. (B) TIP SEVERED AND REPLACED. (C) TIP REMOVED. DIFFERENCES IN ELONGATION OF COLEOPTILES SHOWN AT RIGHT

Leaves develop from the *leaf primordia*, small protuberances of meristematic cells which originate laterally in apical meristems. The zone of attachment of a leaf to a stem is called a *node;* in most kinds of plants the leaves become more or less regularly spaced along the stem axis by elongation of the *internodes*. In the axil of each leaf an offshoot of the terminal meristem develops which in turn becomes a terminal meristem. Such meristems are essentially rudimentary side branches and are called *lateral buds*, usually being covered with bud scales in woody species. The branching stem system of the plant is a result of the development of the lateral buds into side branches. Branch roots, on the other hand, develop from meristems which originate in interior pericycle tissue. In many woody plants scale-enclosed *terminal buds* form annually at the tip of each stem axis. In the woody plants of temperate regions resumption of growth from the terminal buds and from some of the lateral buds occurs each spring, continuing for a few weeks to several months, depending upon the species of plant and the environmental conditions. In most species of plants some of the apical stem meristems sooner or later become differentiated into flower primordia from which develop flowers and, ultimately, fruits and seeds.

Hormones.—Hormones are substances synthesized within an organism which, in very minute concentrations, exert profound effects on its metabolism or growth, often after translocation to parts or organs remote from their centre of production. Although the existence of such substances in plants had been suspected for many years, the first convincingly clear demonstration of the presence of growth hormones (growth substances) in plants was not made until the investigations of F.W.Went in 1928.

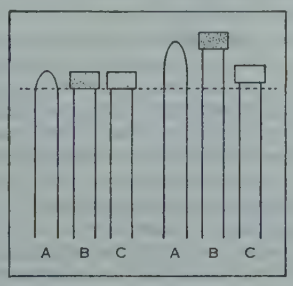


FIG. 12.—EFFECT OF AN AGAR BLOCK CONTAINING AUXIN ON ELONGATION OF OAT COLEOPTILE. (A) CHECK. (B) BLOCK CONTAINING AGAR PLACED ON DETIPPED COLEOPTILE. (C) BLOCK OF PURE AGAR PLACED ON DETIPPED COLEOPTILE. DIFFERENCES IN ELONGATION OF THE COLEOPTILES SHOWN AT RIGHT

The *auxins* have been the most thoroughly studied of the plant hormones. Their action has been investigated mostly in the coleoptile of the oat, which is the first part of the plant that emerges above the ground in germination. This is a cylindrical structure several centimetres in height, which encloses the first leaf. If the tip of an oat coleoptile is removed, elongation of the stump is greatly retarded as compared with an intact coleoptile. If the cut-off tip is replaced on the coleoptile, nearly the original rate of elongation may be regained (fig. 11). Furthermore, if the cut-off tip be placed with its cut surface in contact with a small block of agar gel for about an hour, and the agar block then be affixed on the cut surface of a detipped coleoptile, that coleoptile will elongate at nearly its usual rate. No such effect will be obtained if a block of pure agar is used (fig. 12). Cell divisions cease very early in the development of a coleoptile and the cell elongation which results in its increase in length is restricted to the basal portion. The facts just cited indicate that the tip exerts a controlling influence on the elongation of basal cells of the coleoptile and, furthermore, as shown by the agar block experiment, this controlling influence must be ascribed to some diffusible substance or substances which move from the tip toward the base through the coleoptile. These substances are called auxins. If an agar block containing auxins from one source or another is affixed one-sidedly on a detipped coleoptile, cell elongation is found to be more rapid on a side of the coleoptile below the portion of the tip on which the block is located, resulting in curvature of the coleoptile (fig. 13). Translocation of the auxin is almost strictly longitudinal, the elongating cells on the side of the coleoptile below the block receiving much more than cells on the opposite side, with a corresponding differential effect on growth. Within limits of 0 to 20 degrees, curvature resulting from the eccentric attachment of agar blocks containing auxin to detipped coleoptiles is proportional to the concentration of auxin in the blocks. This proportionality between auxin concentration and coleoptile curvature has made it possible to use the bending of oat coleoptiles as the basis for a quantitative and extremely sensitive biological test for auxins. Auxins are essential for the occurrence of cell elongation in all plant cells. In their absence elongation ceases; in their presence elongation occurs if no other factors are limiting, and within limits, elongation is proportional to auxin concentration. Relatively high concentrations of auxins inhibit cell elongation, and the concentration most favourable for elongation is different in different tissues, being, for example, much higher in stems and coleoptiles than in roots. Three auxins have been isolated from plant tissues in a chemically pure state: auxin *a* ($C_{18}H_{32}O_5$), auxin *b* ($C_{18}H_{30}O_4$) and heteroauxin ($C_{10}H_9O_2N$). A number of synthetic compounds have been discovered which are not known to occur in plants, but which have many of the same effects as auxins.

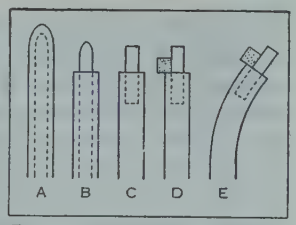


FIG. 13.—STEPS IN TESTING FOR AUXINS QUANTITATIVELY BY DEGREE OF BENDING OF AN OAT COLEOPTILE. (A) INTACT COLEOPTILE ENCLOSING THE PRIMARY LEAF; (B) TIP OF COLEOPTILE REMOVED; (C) PRIMARY LEAF PULLED LOOSE AND ITS TIP CUT OFF; (D) AGAR BLOCK AFFIXED TO ONE SIDE OF DETIPPED COLEOPTILE; (E) CURVATURE RESULTING FROM MOVEMENT OF AUXIN INTO SIDE OF COLEOPTILE BELOW BLOCK. WITHIN LIMITS THIS CURVATURE IS PROPORTIONAL TO THE CONCENTRATION OF AUXIN IN THE BLOCK

Certain auxins influence root formation in plants. More roots form on cuttings of many kinds of plants if they are first immersed in a dilute solution of one of the auxins before placing in a rooting medium than if not so treated. Some of the synthetic auxins, notably indole-butyric acid and *a*-naphthaleneacetic acid, are especially effective in inducing root formation. The hormone may be applied in solution, in a paste, as a vapour, or in a powder. Comprehensive data on the use of hormones for this purpose are given by J. W. Mitchell and R. R. Rice (1942).

The detachment of leaves, fruits and certain other parts of plants from stems usually occurs by the process of *abscission.*

The first step in the abscission of leaves or fruits is the formation of an *absciss layer* across the base of the petiole of the leaf or the peduncle of the fruit. The absciss layer is a transverse zone consisting of several layers of parenchymatous cells. It may form weeks or months before detachment of the leaf or fruit occurs. Abscission proper, which in the leaves of deciduous trees of temperate regions occurs principally in the autumn, takes place as a result of dissolution of the middle lamella between layers of cell in the absciss layer. Artificial introduction of auxin into leaf petioles at a time when they would ordinarily abscise within a short period materially delays the time of abscission. A practical application of this discovery is to spray apples with a solution of *a*-naphthaleneacetic acid shortly before harvest in the fall. Application of such a spray delays abscission of the fruits and makes it more likely that they can be picked before they fall to the ground and deteriorate in quality.

Usually fruit development ensues only after pollination and subsequent fertilization have occurred. If, however, pollination is prevented and any one of several of the auxins is introduced into the pistil by a suitable technique, development of the fruit will occur (F. G. Gustafson, 1936). Such *parthenocarpic* fruits are seedless. A practical application of this discovery has been in the treatment of greenhouse tomato flowers with indole-butyric acid during the winter season of low pollen viability. Larger crops can often be obtained under such conditions by supplementing the normal pollination process with growth substance treatment (F. S. Howlett, 1942). Several other physiological effects of the auxins are described below.

The auxins are not the only growth substances which occur in plants. J. English *et al.* (1939) have isolated traumatic acid from plant tissues, a compound which induces renewed growth activity in parenchymatous cells. Thiamin, known as a necessary vitamin in animal metabolism, acts as a hormone in plants. It is synthesized principally in leaves, whence it is translocated to other parts of the plant (J. Bonner, 1942). Thiamin is necessary for root growth and probably in other ways. There are also indications that other vitamins of the B complex may be necessary for root development. The extravagant claims sometimes made for thiamin (vitamin B_1) as a promoter of overall plant growth have not been substantiated by critical experiments (D. I. Arnon 1940, C. L. Hamner 1940). Coco-nut milk has been found by J. van Overbeek *et al.* (1942) to contain a growth substance which is necessary for the development of plant embryos. This substance induces repeated cell divisions in the embryo. Very minute embryos of *Datura* developed into fully formed embryos when placed in a synthetic medium containing coco-nut milk, but failed to develop when placed in the same medium without coco-nut milk. Indications of the existence of certain growth substances which specifically promote leaf growth have also been obtained (D. M. Bonner and J. Bonner, 1940).

Factors Influencing Growth.—The process of growth is so complex that it is impossible to characterize it by any single index. Quantitative measurements may readily be made of such aspects as increase in lengths of stems or roots, increase in diameter of a stem, increase in volume of a fruit, or increase in dry or fresh weight of a plant organ. However, qualitative differences in growth are often of greater significance than quantitative differences. The relative development of vegetative and reproductive growth, for example, or whether the vegetative growth is soft and succulent or hard and woody are often of greater import from a physiological or practical standpoint than the absolute development of any plant organ or organs, measured as length or weight. Such developmental differences must be characterized largely in descriptive terms rather than in quantitative measurements.

The growth and reactions of a plant are the result of the coordinated interplay of its hereditary factors and the environmental conditions to which it is exposed upon its internal physiological processes. Genetic factors have as much influence on the development of a plant as environmental factors, but a detailed consideration of their effects cannot come within the scope of this article. The environment of plants is too complex to be subjected to any completely logical analysis, but the following are the principal factors of the physical environment which have effects upon the rate and type of growth of plants: radiant energy (intensity, quality, duration), temperature of air and soil, atmospheric humidity, soil water supply, soil aeration, supply of available minerals in the soil, concentration of gases in the atmosphere, gravity and atmospheric pressure. Since an individual factor can vary in more than one way, since various interrelations exist among the different factors, and since each factor can induce various chains of reactions in a plant, interpretation of the effects of an individual environmental factor on the growth of plants is usually a complex problem. The principle of limiting factors can be applied in the approximate analysis of many growth phenomena. In this epitomized discussion the influence of only a few of these environmental conditions can be considered in detail.

Photoperiodism.—The reaction of plants to the length of the daily period of illumination is called photoperiodism. The daily length of the photoperiod varies from latitude to latitude and from season to season in the same latitude. In the tropics, seasonal variations in the photoperiod are small, day lengths approximating 12 hours the year round. In mid-temperate regions, photoperiods vary in length from 8 or 9 hours in December to 15 or 16 hours in June. In arctic regions the photoperiod drops to a zero value in December, and is of 24 hours' duration in June. Although the length of the photoperiod has certain effects on the vegetative development of plants, its most noteworthy influence is upon reproductive development. W. W. Garner and H. A. Allard, in 1920, showed that plants fall into three classes: (1) "short-day" plants which flower more or less readily in a range of day lengths shorter than a certain critical photoperiod, flowering being inhibited or at least greatly retarded at all longer photoperiods, (2) "long-day" plants, which flower more or less readily only in a range of day lengths longer than a certain critical one, flowering being inhibited or at least greatly retarded in shorter photoperiods, and (3) "indeterminate" species which exhibit no critical photoperiod and which develop both vegetatively and reproductively over a wide range of day lengths. The "critical photoperiod" for many species is between 12 and 14 hours. The exact intensity of light is often not very significant in photoperiodism; supplementing a relatively short natural photoperiod with additional hours of much weaker artificial light often has essentially the same effect on reproduction as a long natural photoperiod. Examples of short-day plants include: cocklebur, salvia, aster, dahlia, poinsettia, chrysanthemum and violet; of long-day plants: spinach, radish, dill, lettuce, grains, timothy and hibiscus; of indeterminate plants: sunflower, tomato, cotton, chickweed, dandelion and buckwheat. Spring-flowering plants are mostly of the short-day type, the flower primordia having been formed during the shortening days of the preceding late summer and autumn. Autumn-flowering plants fall into a similar category, except that the flower primordia are initiated during the current instead of the preceding season. Summer-flowering plants are mostly of the long-day type. Indeterminate species may flower at any season during which other environmental conditions are favourable.

The daily length of the photoperiod is one of the important factors influencing the ecological distribution of crop plants and plants in nature. Species of the pronounced long-day type cannot survive under natural conditions in the tropics, and similarly, species of the pronounced short-day type can not survive under natural conditions in more northern latitudes, excepting only those which are maintained by vegetative propagation. Biloxi soybeans (a short-day variety), for example, fruit readily in the gulf states of the United States, but not in the latitude of Washington, D.C. In the latter region days short enough to induce flowering come so late in the season that fruits are killed by frost before they can ripen. Indeterminate species can develop over such a wide range of day lengths that their ecological distribution is controlled by factors other than length of the photoperiod.

The fundamental difference between short-day plants and long-day or indeterminate plants seems to be that the former require an alternating cycle of light and dark periods if flowers are to de-

velop, while the latter do not. In the Biloxi soybean, a dark period at least 11 hours long must alternate with photoperiods which may be from 4 to 18, but optimally from 10 to 12 hours in length if flower primordia or flowers are to form (K. C. Hamner, 1940). Most and perhaps all long-day and indeterminate species, on the other hand, can flower even under continuous illumination, although the plants do not necessarily reach their best development under such conditions. The principal difference between the plants of these two groups appears to be that the indeterminate species can flower under shorter photoperiods than the long-day species.

When the leaves of short-day Biloxi soybean are exposed to short photoperiods while apical growing regions are kept under long photoperiods or in total darkness, initiation of flower primordia occurs. If the growing tip of the plant is exposed to short photoperiods and the leaves to long photoperiods, no such initiation occurs (H. A. Borthwick and M. W. Parker, 1938). Similar results have been obtained in experiments with short-day cocklebur plants (K. C. Hamner and J. Bonner, 1938). Likewise, if only the leaves of a long-day dill plant are exposed to photoperiods of suitable length, flower initiation occurs (Hamner and A. W. Naylor, 1939). These facts indicate that the leaves are the loci of the reactions which lead to the flowering of plants, and that the effects of processes which occur in the leaves are transmitted to the apical meristems, causing them to differentiate into flower primordia. Under the influence of photoperiods of the proper duration it seems likely that a substance (or substances) is made in the leaves, whence it is translocated to the terminal meristems, inducing flower formation. The name "florigen" has been proposed for this postulated flower-inducing hormone.

It is not necessary for plants to be exposed continuously to photoperiods of the proper length for the initiation of flowers to occur. Biloxi soybeans, which have been growing under long days will initiate flower primordia after exposure to only two short-day cycles and a return to long days. Similarly in the cocklebur, one short-day cycle, and in the morning glory, four short-day cycles, are adequate to induce formation of flower primordia. Likewise, four long-day cycles are sufficient to initiate flowering in long-day dill plants which are kept under short days before and after the exposure to long days. However, more primordia are usually initiated if plants are exposed to a longer series of suitable photoperiods than the absolute minimum. Continued exposure to photoperiods of the proper length is also often necessary for development of flowers beyond the primordia stage.

The influence of temperature must also be considered in evaluating the photoperiodic behaviour of plants. In short-day species the temperature of the dark period has a much more pronounced influence than the temperature of the light period. Initiation of flower primordia in Biloxi soybean occurs much more abundantly at a dark period temperature of 65° F. than at 55° F., at any one of the light period temperatures of 65°, 75°, or 85° F. (Parker and Borthwick, 1939). As shown by R. H. Roberts and B. E. Struckmeyer (1939), night temperatures have a modifying effect on the photoperiodic reactions of many plants. A number of practical applications of the principles of photoperiodism have been made. By artificially increasing or decreasing the length of the photoperiod, for example, many floricultural plants can be brought into bloom sooner than if exposed to natural photoperiods.

Temperature Effects on Growth.—Within limits a rise in temperature favours increased rates of elongation or enlargement of plant organs. The range of temperatures within which this occurs is usually higher in tropical than in temperate zone species, and higher in plants of the latter group than in subarctic species. In temperate zone species, the temperature range over which such an effect occurs approximates 40°–95° F. With further rise in temperature above the optimum, elongation or enlargement rates decrease, falling to zero at about 105°–115° F. The temperature most favourable for one stage of development of a plant is often not the most favourable for another stage.

Relatively low temperatures favour initiation of flowers in some species, relatively high temperatures favour flower initiation in other species, and flowers are initiated in still other species over a wide range of temperatures (H. C. Thompson, 1939). Celery plants which have been exposed to a temperature range of 40°–50° F. or 50°–60° F. for 10–15 days will develop flowers, fruits and seeds if subsequently grown at 60°–70° F., a range of temperatures too high for the initiation of flowering. On the other hand, lettuce plants (White Boston) develop flowers, fruits and seeds without forming heads if grown at 70°–80° F. Similar plants grown at 60°–70° F. first form heads and subsequently go to seed. Other species for which exposure to a relatively low temperature seems essential to induction of flowering include rutabaga, onion, cosmos and stock; other species for which exposure to a relatively high temperature seems essential to induction of flowering include pepper, phlox and cleome.

Growth Correlations.—The influence of one part of a plant upon the development of another part of the same plant is called a growth correlation. The harmonious development of the plant body as a whole is controlled by correlative influences operating reciprocally from organ to organ, tissue to tissue, and cell to cell. Innumerable examples of growth correlations can be cited. A familiar one is the phenomenon of *apical dominance.* As long as the terminal bud on a woody stem remains intact or continues to grow, development of lateral buds, at least on the current season's shoots, fails to occur. If the terminal bud is injured or destroyed, however, development of the lateral buds usually ensues. Obviously the terminal bud has some sort of an influence on the lateral buds which prevents their development. Apical dominance also occurs in the growing shoots of herbaceous plants. When the terminal bud is removed from a broad bean and replaced with a block of agar gel containing auxin *b* or heteroauxin, inhibition of lateral bud development continues just as if the terminal bud remains intact. If the terminal bud is replaced with a block of plain agar, however, lateral buds begin to develop immediately. It is obvious that auxins play a role in apical dominance, but the exact mechanism of their action has not been worked out. Many, but not all correlative influences of one plant organ on another result from the action of growth substances. One part of a plant often has an influence on the relative quantities of certain foods, of mineral compounds, or of water which reach other parts of the plant, and correlative influences on growth often result from such effects. For example, if the nitrate supply is low, the root system of a plant is large in proportion to its top. Under such conditions absorbed nitrates are largely used in the synthesis of amino acids in the roots and these amino acids are used in protein synthesis accompanying root growth. Only small quantities of nitrogenous compounds escape utilization in the roots and are translocated to the tops. Hence the growth of the tops is checked by a deficiency of nitrates or amino acids, even though they may contain an abundance of carbohydrates, some of which are translocated downwards and used in amino acid synthesis and other processes in the roots. If the supply of nitrates is more abundant, however, more nitrogenous compounds are translocated to the tops, where most of them are used in the synthesis of protoplasmic proteins. The resulting enhanced vegetative growth of the tops results in a greater proportionate development of the aerial portions of the plant as compared with the roots than occurs when the nitrogen supply is deficient.

Dormancy.—Many kinds of seeds, apparently mature, fail to sprout even when brought under environmental conditions favourable for germination. This state of internally inhibited growth of seeds or other plant organs is called dormancy. The following are the main causes of dormancy in seeds: (1) seed coats impermeable to water; (2) seed coats mechanically so strong that they cannot be ruptured by swelling of the embryo; (3) seed coats impermeable to oxygen; (4) seed coats containing a specific chemical inhibitor of germination; (5) embryos in a rudimentary state at the time seeds are shed; (6) embryos fully formed at seed maturity but in such a physiological condition that they will not develop further until they have passed through a period of "after-ripening." More than one of these conditions is present in some kinds of seeds. Methods of "breaking" the dormancy,

or at least shortening the period of dormancy, have been devised for a number of kinds of seeds and are of considerable practical utility. The method used with a given kind of seed depends upon the cause of dormancy in that particular seed.

The phenomenon of dormancy is also exhibited by buds. The buds on stems of woody temperate zone species ordinarily do not develop during the summer in which they are formed, even under favourable environmental conditions. This condition of dormancy is maintained in most such species until the following autumn or winter. Exposing stems to vapours of ether, ethylene chlorohydrin, or ethylene dichlorid is an effective method of breaking bud dormancy in many woody species. The buds of many kinds of tubers, rhizomes, corms and bulbs likewise may remain dormant for a considerable period. Freshly harvested potato tubers, for example, ordinarily do not sprout at once because of bud dormancy. The duration of dormancy in potato tubers can be greatly curtailed by treatment with certain chemicals.

Vernalization.—This term refers to a low temperature treatment given seeds before sowing which results in shortening the time until flowering of plants that develop from them. Less commonly, it is also applied to treatment of seeds at relatively high temperatures, or to temperature treatments of plant organs other than seeds (H. H. McKinney, 1940). Although seeds of a number of kinds of plants can be vernalized, this technique is employed principally with cereals, and especially with winter wheats. Vernalization of the grains of a winter wheat so speeds up the completion of its life cycle that it can be grown as a spring wheat. Grains of the Turkey Red variety of winter wheat, for example, are vernalized by soaking to a moisture content of about 60%, which just permits initiation of germination, holding them at approximately that water content, and exposing them to a temperature of 33°–37° F. for 9–10 weeks before sowing. The plants developing from these seeds reach the heading stage in 110–120 days from the beginning of the cold treatment. Unvernalized seeds of the same variety require 150 days from sowing to attain the same stage of development in the same environment. This effect of low temperature treatments on pre-germinated seed, now called vernalization, has been known for many years, but gained new prominence beginning about 1930 because of its advocacy as a practical measure by Russian agriculturalists. Because of the particular climatic conditions prevailing over large portions of Russia, the vernalization of winter wheats has proved an advantageous agricultural procedure in some parts of that country. In other parts of the world, however, vernalization has not proved to be a practice of commercial value.

Plant Movements.—The existence of autonomous movements in plants usually escapes notice because most of them occur too slowly to permit their detection by casual observation. That movements of plant organs actually do occur can be readily confirmed by a series of observations of certain plant organs under suitable conditions. The reality and vigour of plant movements can also be demonstrated strikingly by time lapse motion picture technique in which pictures of the moving plant organs are taken at relatively long intervals and the resulting film projected at such a speed that the movements are greatly accelerated. Most movements in the vascular plants may be classified into growth movements or turgor movements.

Growth movements, many of them curvatures of plant organs, result from differential rates of growth. Growth movements may be classed as tropic movements, nastic movements and nutations. Tropic movements such as phototropism occur under the influence of an environmental factor acting with greater intensity from one direction than another. Nastic movements are those in which the direction of the movement is limited by the structural symmetry of the plant organ. The more rapid growth of the upper side of a plant organ such as a leaf or flower part is called epinasty; the more rapid growth of its lower side hyponasty. Opening of flowers is caused by epinastic movements of the sepals and petals; closing of flowers, such as occurs in some species at night or at low temperatures, results from hyponastic movements of the floral parts. Careful observation of a growing stem tip reveals that it does not grow straight ahead through space, but moves in an irregular spiral pathway as it elongates. Such growth movements are called nutations.

Turgor movements are those caused by reversible changes in cell volume. Many such movements result from turgor changes in structures called *pulvini*, located at the base of the blade or petiole, or both in some kinds of plants. The well-known and spectacular reactions of the sensitive plant result from turgor changes in cells of pulvini located at the base of the petiole and the base of each leaflet.

Phototropism.—When a plant, such as a potted plant on a window sill, is illuminated more strongly on one side than on others, the stems usually bend towards the brighter light. Two mechanisms of this phenomenon of phototropism have been recognized. One is a retarding effect of light on the elongation of the cells. Hence the cells on the more brightly illuminated side of the stem elongate less than cells on the opposite side, and the stem bends towards the light. The other mechanism of phototropism has been studied principally in the coleoptiles of grasses. Charles Darwin showed many years ago that, although bending occurs in the basal portions of a coleoptile, shading its tip with a tinfoil cap prevents curvature of the coleoptile when unilaterally illuminated. Detipped coleoptiles likewise evince little or no phototropic reaction. Bending of the basal portions of the coleoptile is, therefore, subject to a controlling influence of the tip. Subsequently it was shown that auxin in the tip of an oat coleoptile migrates laterally across the tip from the more strongly illuminated to the shaded side. Some inactivation of auxin on the illuminated side may also occur. Since downward translocation of the auxin is almost strictly longitudinal, the cells on the shaded side of the coleoptile receive more auxin than those on the lighted side. The cells on the shaded side therefore elongate more than those on the illuminated side, and the coleoptile bends toward the light.

Geotropism.—If a potted plant be placed in a horizontal position, the stem bends upward away from, and the root bends downward toward, the force of gravity. These are examples of negative and positive geotropism, respectively. In a horizontally oriented oat coleoptile, auxin migrates from the upper to the lower side of the tip and thence longitudinally in the usual manner. The greater concentration of auxin on the lower than on the upper side induces greater elongation of cells on the former, and the coleoptile bends upward. In a horizontally oriented root tip, auxin also migrates from its upper to its lower side. Elongation of root cells is favoured by much lower concentrations of auxins than favour elongation of coleoptile cells, and root cell elongation is retarded at all higher concentration. A relatively high auxin concentration on the lower side of the root therefore results in a smaller elongation rate of the cells on the lower as compared with the upper side, and a downward bending of the root results.

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PLANT ECOLOGY

Plant ecology is the science which deals with the interrelationships between plant life and environment. It is a segment of general ecology, the empirical basis of which lies in the common observation that living organisms vary with environment, and whose deeper foundations rest upon the fact that life and environment are inseparable parts of a greater whole. Other aspects of general ecology are animal ecology, human ecology and bioecology, which is defined provisionally as the ecology of plant and animal interrelations. Actually, plants, animals and men are so intimately associated that it is seldom possible for the ecologist to confine his attention to any one of them, although each special field has its own core of knowledge and technique.

This last statement can be emphasized by noting the following subdivisions or facets of plant ecology: (1) autecology, the relation of the individual species or plant to its environment; (2) floristics, the distribution in time and space of the various kinds (*i.e.*, species, genera, etc.) of plants; (3) ecological plant geography, the distribution of plant communities; (4) plant sociology, or synecology, the characteristics of plant communities; (5) ecological measurement or habitat analysis, the analysis of the nonliving environment; (6) applied plant ecology.

Throughout the following discussion of these phases of ecology it should be kept in mind that earth, atmosphere, individual organism and communities of organisms all represent dynamic systems, or processes, whose mutual interplay is the concern of the ecologist.

Autecology.—This subject deals with the types of plant structure and behaviour characteristic of different habitats, and the capacity of plants to adjust themselves to various conditions. These are problems of structure and behaviour as well as of ecology, hence they involve the techniques of morphology and physiology. Genetics is also involved, since the attributes in question depend upon the inherited make-up of the individual.

It is a matter of common observation that plants of arid regions are gray, thick-leaved or leafless, succulent and often thorny, in contrast to those of humid regions which have delicate, bright green, abundant foliage. Every gardener is familiar with the fine texture of lettuce or tobacco leaves grown in moderate light, as against the woody, coarse leaves produced in strong sunlight. Travellers have also noted the rapid decrease in height of wheat and corn in passing from Iowa to Colorado. In a given field of alfalfa, some plants will be killed by winter temperatures which leave others unharmed, partly through local differences in soil moisture, etc., but also in part through inherited differences in different individuals. A field of cabbage or flax may be swept by disease which kills some plants, leaves others unharmed. Such are a few of the countless problems with which autecology must deal.

Every species of plant inherits certain potentialities of adjustment to external conditions. The range of tolerance may be wide or narrow, and differs as regards different factors. The dandelion, which occurs under a wide range of temperature and moisture conditions, has been observed to bloom during ten months of the year at Lincoln, Nebraska. But along the shore of Lake Michigan it thrives only on clay or where lime-bearing clays are mixed with beach sand.

Within the species are to be found varieties with special limits of tolerance. Upon these, as upon the species, environment may act selectively, eliminating in one place, sustaining in another.

A given factor, such as temperature or moisture, does not always act in absolute fashion. The reaction of a plant with respect to it may vary with other conditions. Thus by regulating water supply, etc., a plant may be hardened to resist cold.

Autecology also considers the numerous specialized adjustments of behaviour between different species of plants, or between plant and animal species. Into this category fall such problems as insect pollination, parasitism and mutual relations between legumes and nitrogen-fixing bacteria.

The course of organic evolution has led not merely to increased specialization of animals and plants, but to increasingly specialized relations between and among species of both. Thus the class of insects, although older than flowering plants, has developed to its present amazing complexity (over 500,000 species) along with the flowering plants, with which insects sustain a wide variety of intimate, often mutual relationships. Unquestionably the development of the flowering plants has been, in its turn, profoundly affected by the activities of these invertebrates. Similarly, the rise of hoofed grazing animals was conditioned by the evolution of grasses and the consequent origin of great continental steppes. The grasses, in turn, have become adjusted to grazing as a factor in their normal environment.

Among the interrelations of plants none is more important than competition. The consequences of competition are evident in all plant communities, but the source and means of competition are a part of the subject matter of autecology. The general principle involved is that the intensity of competition increases as requirements become more nearly alike. This implies that competition should be most intense between individuals of the same species, which have practically identical requirements. Especially is this true of plants, since mutual benefit within the species does not appear so clearly among plants as among animals. Some measure of the intensity of competition can be seen in any normal woodland by comparing the density of seedlings, saplings and mature trees of any species. A single mature tree is likely to be the sole survivor of many thousand seedlings. Since the most critical competition is for light, water and soil nutrients, the ultimate adjustment among individual plants is attained through spacing, both of roots and tops. Secondary species commonly root at shallower depths and branch at lower levels than dominant forms.

The absence of mutual aid within the plant species is compensated for in part by the usually prodigious output of reproductive bodies, *e.g.*, seeds, and by the development of often highly specialized means of dissemination, whose study is an important phase of autecology. Seed transport by wind, water and animals is a phenomenon familiar to anyone with the slightest knowledge of plants, and often attains great effectiveness. Hard seeds of edible fruits not only pass through the digestive tract of animals without injury, but may actually germinate better for doing so. The eccentrically weighted fruit of maple acquires in falling a spin which may project it to a considerable distance from the parent tree. The coco-nut, although it cannot germinate after prolonged immersion in salt water, appears to have been transported, by means of ocean currents, to every oceanic isle capable of growing it.

The term "adaptation" is frequently used with respect to autecological adjustments. It should be employed, however, in such a way as not to confuse (a) the fitness of plants which have become adjusted by selection to a given environment, and (b) the plastic adjustments which a given species can make to variations within an environment to which it has long since been generally fitted by selection.

Autecology has numerous practical applications, *e.g.*, in the

selection of drought-, frost-, and disease-resistant varieties of economic plants. It is also of value in diagnosing the character of a habitat under conditions where instrumental studies are not available. Commercial use has been made of it in selecting sweet corn strains with very tight husks through which the larvae of European corn borer can not penetrate to the tender grains within.

Floristics.—With the possible exception of certain microscopic plants, every species has a limited and characteristic range, although there is wide variation among species in extent and continuity of their range. The same statement may be made of larger groups, the genera and, to a considerable degree, of families. Groups with greatly restricted range, such as the genus *Sequoia* which is confined to California, are known as endemic. The opposite extreme is represented by cosmopolitan forms such as the common dandelion.

The pattern of distribution of plant families and their subdivisions finds its explanation in terms of organic evolution and subsequent migration. This migration, in turn, has been subject to changing conditions of earth, climate and biological influence. Theoretically, the older a group, the more extensive should be its distribution; but this principle is subject to so many modifications that every instance has to be investigated on its merits. For example, the present endemic genus *Sequoia* referred to above was once widespread.

Thus a study of floristic patterns must take account of the past as well as the present. It draws upon geology and climatology for explanations, and in turn is a source of valuable clues to students of these subjects by suggesting the position, in time and space, of pathways and barriers. These latter are dependent upon changes of land and water area, changes in land elevation, and shifts in climatic centres.

The term "continental pairing" is sometimes employed to describe the rather frequent appearance of a genus, or even a species, on two continents. Thus closely related forms are to be found in eastern Asia and in North America—a fact correlated with the recent existence of a land bridge in the Bering region and a uniform, favourable circumpolar climate. Similar relationships exist between the floras of Europe and North America and those of Asia and Africa.

On the other hand, members of families common to Africa and South America, or to Australia and other continents of the southern hemisphere, exhibit more distant relationship and hence point to more remote opportunities for migration and to barriers of greater antiquity. These facts are parallel with data obtained from animal distribution—for example, the relatively ancient separation of old and new world marsupials and primates.

The most obvious climatic influence on plant distribution is that of temperature. Few species of seaweeds, if any, have a zone of distribution exceeding a difference of ten degrees in mean annual isotherm. Land species are subject to similar limitations, plus those due to differences in supply of available moisture. Hence continental desert areas may form barriers as effective as mountain ranges or seas.

Numerous biological factors also influence migration of plant species. Apparently the *Yucca* will tolerate a wider range of conditions than the *Pronuba* moth which is essential to its pollination and seed formation. Thus its natural range is limited to that of the symbiotic insect. Again, the evolutionary development of more efficient species will drive older, less efficient species from areas to which they are well adjusted, and hinder their return. This is exemplified in the relation between conifers and deciduous trees in the humid temperate parts of the northern hemisphere. The former, though quite capable of growing in such regions, have been relegated to the less productive margins. Also, the presence of lethal parasites may exterminate a particular species throughout a portion of its natural range especially favourable to the parasite, and thus establish a lacuna or barrier.

The reciprocal relation between human cultures and plant species is of extreme importance. The three great centres of primitive agriculture—eastern Asia, Asia Minor and Central America—are correlated with the original location of three grasses—rice, wheat and maize, respectively. In the subsequent migrations of these and other economic plants, and of numerous ruderals, is to be found much of the record of the shifting of human cultures.

While the subject of floristics deals with the distribution of all species of the plant realm, the greatest interest attaches to seed plants, which are the dominant forms of modern plant life. Considerably more than half the known families are represented within the tropics, which have afforded more or less continuous refuge during periods of climatic stress in more temperate regions. Flowering plants, well established during the Cretaceous, evolved into a wealth of species during the ensuing Tertiary and became widely distributed during that period of comparatively widespread favourable climate. Present patterns of distribution of this great group and the somewhat older conifers are largely due to the impact of glacial Pleistocene conditions upon this Tertiary pattern.

Pleistocene glaciation involved at least four major advances of continental ice sheets, with three more or less prolonged interglacial periods. The comparatively brief time since the last retreat (*c.* 15,000 years), although usually referred to as postglacial, has exhibited some of the qualities of an interglacial period, and at no time since the Tertiary have the mild conditions of that period been attained.

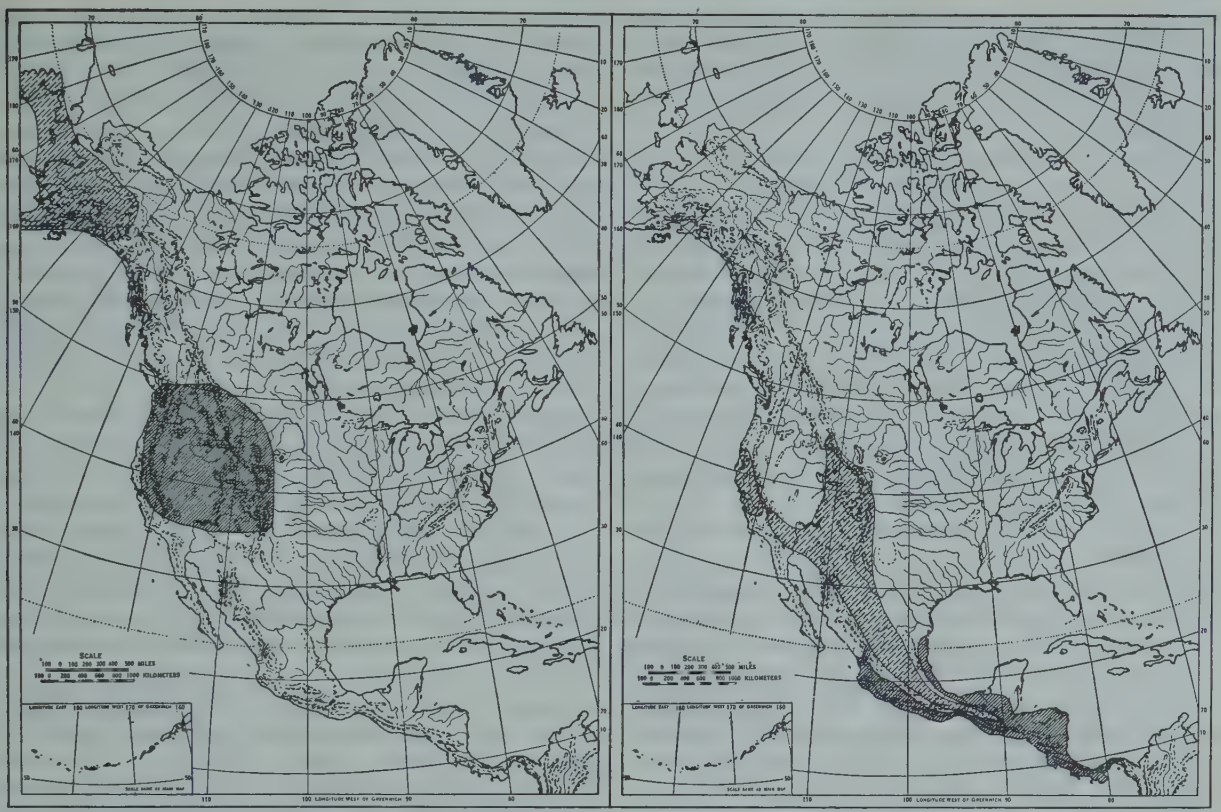
During the Tertiary a remarkably rich temperate flora had become diffused to high latitudes in both hemispheres and may properly be described as circumpolar. This flora was compelled to retreat toward the tropics by the advance of Pleistocene ice. With each glacial recession some of the lost territory was reoccupied, to be lost again with successive advances of the ice. The effect of this upon the Tertiary flora was less disastrous in North America than in Europe, where southerly retreat encountered obstacles, and where today the deciduous forest flora is relatively poor in species.

Glaciated portions of the northern hemisphere exhibit three groups of disjunct species of great interest: (1) boreal species in now temperate southerly regions; (2) southern plants occurring in isolated stations north of their present main range; and (3) continental steppe or grassland species in more humid or oceanic regions than they normally occupy. The boreal species, notably bog plants, are now usually regarded as true relicts left behind following the last glacial retreat. The northern outliers of southern plants are still a subject of controversy. One school holds that they represent vegetation which persisted in place on nonglaciated elevations or nunataks throughout glaciation. Critics of this belief hold that this was impossible, questioning the nunatak nature of the areas in question and also the ability of southern plants to survive the glacial climate. Both botanists and geologists are divided in opinion.

In view of this problem, the third group of disjunct species takes on considerable interest. There is a growing belief that they represent relicts from a postglacial time that was warmer and drier than the present—a so-called xerothermic period or periods. Given such climatic conditions and a suitable pathway for migration—for example, the formerly elevated but now submerged Atlantic coastal shelf—southern plants may well have moved northward, leaving relicts behind them during the subsequent cooling and subsidence. At any rate evidence is accumulating from a variety of sources, including modern glaciers and microfossils in peat deposits, to substantiate the existence of postglacial xerothermic conditions.

While the chief contributions to floristics are made by students of plant classification (taxonomy), the knowledge itself is an essential segment of ecology. For example, composite maps of the ranges of characteristic plants of great formations reveal with clarity the dynamic centres of climate and plant distribution in such regions as the eastern deciduous forests and tall-grass prairies of North America and the Mediterranean zone of Europe.

Moreover the Danish botanist, C. Raunkiaer, has developed a method of climatic analysis through floristic lists of any region. He has classified plants according to the depth of burial or height of exposure of their delicate perennial growing points. Each species falls into a definite category according to the degree



FROM R. W. CHANEY, "PLANT DISTRIBUTION AS A GUIDE TO AGE DETERMINATION" FROM "JOURNAL OF THE WASHINGTON ACADEMY OF SCIENCES"

FIG. 14.—SHOWING DISTRIBUTION OF SUBTROPICAL AND TEMPERATE FOREST UNITS DURING THE CENOZOIC OF WESTERN AMERICA. LEFT, EOCENE; RIGHT, RECENT. IN BOTH MAPS, CLOSELY SPACED CONTINUOUS LINES INDICATE A SUBTROPICAL, AND BROKEN LINES A TEMPERATE FOREST

of exposure or protection, and the percentage of species in each category constitutes what he calls the "biological spectrum" of a given regional flora. By comparison with a standard spectrum which he has devised, inferences may be drawn concerning the climatic characteristics of a region whose flora has been thus analyzed.

Ecological Plant Geography.—Much that has been said concerning the distribution in space and time of species will apply to communities of plants as well. For a discussion of the nature of communities, see *Plant Sociology* below.

The major communities of the earth can be grouped roughly as follows: (1) *tundra,* or treeless, largely moss and lichen vegetation found in the arctic and above timberline on mountains; (2) *taiga,* or coniferous evergreen forest, ranging from sparse and stunted to dense and thrifty, characteristic of cool regions bordering the tundra; (3) *forests* of other types, including temperate-deciduous and evergreen forests, tropical rain forest, and tropical monsoon (deciduous) forest; (4) *grassland,* including subhumid and dry steppe or prairie and shortgrass; (5) *scrub,* or woody, semiarid shrub vegetation; (6) *desert.* Transitions of course are common—for example, *savannah* between forest and prairie.

The major communities are known as formations. They are regarded, with reason, as expressions of major climatic types. Allowance must be made, however, for variations due to physiographic conditions which modify the impact of the general climate, thus producing microclimatic differences, and for soil (edaphic) conditions which modify the availability of water and nutrients or impose unusual chemical limitations.

For such reasons, the actual boundaries between formations are seldom smooth and unbroken. Rather they are lobed and interdigitated, resembling peninsulas and chains of islands. As Asa Gray put it, there must be debatable borders between regions where slight incidents will throw the balance either way. Climates fluctuate in the intensity of their expression from year to year, and consequently in their marginal effects.

Rapid increases in elevation result in a telescoping of climates within comparatively small areas. Thus in ascending a mountain one may pass through plant communities expressing climates which on level terrain might encompass many hundreds of miles.

Any map of world formations must be generalized to a high degree, yet inspection of such a map reveals the transitions from extreme oceanic to extreme continental climates except in circumpolar regions where temperature becomes the limiting factor. The failure of such maps, in temperate and tropical regions, to correlate more exactly with conventional rainfall maps is due to evaporation, a quantity not generally measured by the meteorologist, but one of critical importance to vegetation.

Ecological plant geography is a subject of the highest utility in its bearing upon world resources and industries and in its indication of proper types of land use and management. It is likewise a factor in military strategy.

Plant Sociology.—In its broad sense this term is equivalent to synecology, or the study of vegetation rather than the individual plant, or the physical factors of the environment. It is sometimes employed to indicate particular techniques of statistical study. Whereas flora represents the "sum total of plant species," vegetation refers to the aggregate of plant life in terms of the communities into which it is organized. Beginning with the great formations already referred to, vegetation may be subdivided into communities of descending rank and of distinctive character at each level.

Difficult problems of nomenclature and classification are involved here, including the old Aristotelian problem of the specific thing and the form which it represents. The deciduous forest of eastern North America may be designated as the oak-beech formation, which in turn includes the maple-beech, oak-

hickory, and oak-chestnut associations. These associations again may be divided into faciations (white oak-black oak), consociations (bur oak), and these latter into societies of subordinate species. More formal systems, involving Latinized terms, are also employed. In general the more refined a subdivision, the more homogeneous its character.

The attributes of a plant community are structure (the growth forms present—*e.g.*, trees, shrubs, grasses—and their relative arrangement), composition (the species present), and development (life history or succession). Thus a forest is dominated by trees of one or more species, the individuals exhibiting definite spatial relations to each other. In the environment thus controlled, characteristic undershrubs, seedlings, vines and herbs occupy suitable niches. Equally essential, although less conspicuous, are the fungi and bacteria which utilize the materials formed by the dominant vegetation and by decay return these materials for re-use by green plants. Characteristic parasites and symbionts are also part of the community structure, and so are its animals as well. Such a structure may vary greatly in floristic composition, depending upon the species present in the region. The deserts of Asia and North America are similar in structure, but composed of different plant families.

One of the most fruitful discoveries in connection with plant communities is the fact of succession or development. This can be simply illustrated by the changes which occur on an abandoned field, a bare rock surface, or a sand dune from the first invading pioneers to the final stabilized forest or prairie. Succession involves change in both structure and composition and moves toward a condition of relative equilibrium characterized by little change in either respect, and known as a climax community. The test of a climax community lies in the ability of the species composing it to reproduce themselves under the conditions which they so largely determine. Pioneer and subclimax species do not have this power. In principle a climax community, once established, maintains itself unless disturbed by physiographic, climatic, or biological (biotic) change. Such disturbance for example would result from serious erosion, uplift or depression, shift in available moisture or temperature patterns, evolution or immigration of new species, fire, clearing, drainage, disease, etc.

Succession represents a process of increasing integration between life and environment. It apparently tends to follow the principle of Le Chatelier as developed by Bancroft; *i.e.*, heterogeneous systems tend progressively toward a condition of minimum disturbance by external forces and internal stresses. So far as the somewhat limited evidence goes, succession also tends toward a progressively more efficient use of energy. The climax community is a close-knit and delicately balanced system which stores and uses solar energy. So intimately adjusted are the nutrient and reproductive cycles of its constituent organisms that the minimum of useful energy is wasted in the chain of metabolic relationships. Thus the climax community represents the maximum in organic economy, as contrasted with the extreme of energy waste in a bare area which receives solar energy only to dissipate it into space without benefit to living organisms.

Representing thus the maximum capacity of a landscape for sustained production, the climax community affords a scientific norm of great value to man in the planning of land use and management and, by analogy at least, in the organization of his own communities. For this reason, quite as much as for sentimental and aesthetic considerations, it is important that in civilized and heavily populated areas substantial remnants of natural vegetation should be set aside, preserved and permanently protected from disturbance. Such reserves or nature sanctuaries are to be distinguished from parks set aside for recreation, and from public forests managed for economic yield.

There is, unfortunately, some difficulty among ecologists in arriving at an agreement regarding the exact meaning of the word "climax." For practical purposes the climax plant community might be regarded as the limit toward which the vegetation of a given climatic area and a given evolutionary composition tends. This definition is chiefly convenient because the changes in climate and evolution are slow in terms of human experience. Against them as a background, succession involves the operation of three other dynamic processes: (1) physiographic change, (2) soil development and (3) biological interaction.

Physiographic Change.—The youthful landscape is typically marked by strong contrasts of elevation, which for a time are increased by the rapid downcutting of narrow stream valleys. This tends to diversify the effect of climatic conditions, producing extremes of shelter in ravines and depressions, of exposure on uplands, and marked differences in available soil moisture throughout. As topography matures, valleys widen, depressions fill and uplands are lowered, thus lessening the initial contrasts. The limit of this process is represented by the peneplain, a generally uniform physiographic system over which local modifications of climate are at a minimum. Until this mature stage of topography is reached, the stability of any community within the landscape is provisional, and its climax character is relative, subject to completion of the erosion cycle.

Actually the peneplain condition is not often attained. Tilting, warping and uplift often interrupt the orderly progress of the erosion cycle, rejuvenating the landscape and interrupting the course of plant succession. Moreover, the rate of erosion and deposition is significantly modified by the presence of vegetation. This can be observed by comparing the sharp and rugged topography of a thinly clad desert or semiarid terrain with the gently rounded hills of a heavily vegetated humid region. By removing natural vegetation and substituting clean-tilled fields, man has become a prime agent of geological change, inducing as much erosion in a few decades as might occur in a millennium under natural conditions.

Soil Development.—Soil represents not merely the finely divided rock of the earth's surface, but the underground extension of community action and influence. This activity results in a physical, chemical and biological organization of the soil of which the structural expression is the soil profile. The soil profile is studied by means of trenches, or along road and stream cuts, and accurately records the character of the particular climate and vegetation. Thus a forest soil profile is characterized by a thin, very rich and acid surface layer of black humus formed by the fungous decay of fallen leaves and other organic debris. Beneath is a light layer from which the acids have leached soluble mineral material, and below that the layer occupied by tree roots, from which they draw mineral nutrients that are subsequently dropped on the surface by falling leaves, branches, fruits, etc. By comparison, a grassland soil profile exhibits a dark humus layer often 36 in. or more in thickness, measuring the depth of penetration of the abundant fibrous roots and the accompanying microorganisms and fauna. In consequence of these differences cleared woodland soil quickly loses its shallow, rich surface layer with careless handling, while prairie soil can endure longer periods of exploitation. The latter, on every continent, is particularly suited to cereal production, and from it comes the bulk of such staple foodstuffs.

Thus the soil profile is an expression of the energy which activates the living community, and the organization of the profile indicates the capacity of the area to sustain life under current conditions. It should be noted that this organization represents an accumulation of solar energy, manifesting itself in the accumulation and mobilization of materials, and facilitating the work of living organisms. The accumulated energy in soil is analogous not so much to the power which runs a factory, as to the energy used in its construction and equipment. Soil development is clearly a most important phase of community succession. And in the same way that physiographic processes tend to minimize the initial differences of a given climatic area, soil development tends toward uniformity throughout such an area.

Biological Interaction.—The influences of vegetation and habitat are mutual and continuous. Yet it may be said that the influence of the physical environment is at a maximum under pioneer conditions, while that of vegetation is greatest at climax. The pioneers in a new or "raw" habitat usually encounter extremes of physical and chemical conditions, and frequently violent fluctuations in those conditions. For example, successful pi-

oneer plants must be adapted to withstand high intensities of light usually characteristic of such habitats. But these plants produce shade, which is unfavourable to their own seedlings, and they are replaced by species more tolerant of shading.

Pioneer habitats likewise often present extremes of moisture or dryness. The growth of pioneer plants, adjusted to such extremes, increases humus and modifies the local water balance, a circumstance which operates in favour of plants which, while less hardy than the pioneers, are much more efficient than their predecessors under the new conditions which those predecessors have brought about.

An exceedingly important aspect of this process is the role played by animals and microorganisms, through competition and through the mutual adjustments between dominant and secondary species belonging to the same stage of succession. Like the processes of physiographic change and soil development, biological interaction is convergent in character, leading from initial heterogeneity to ultimate homogeneity. Thus, in the north central states, such varied habitats as dunes, ponds, bare rock and clay ridges have their distinctive pioneer vegetation. Each passes through a characteristic sequence beyond this stage, approaching in structure and composition the beech-sugar maple forest—a relatively stable and self-perpetuating community. Numerous instances are on record of beech-maple climax forests which have developed on each of these types of initial areas; on the other hand a lag in physiographic change or soil development may arrest the sequence for a long period at some subclimax level. Thus the moist shaded northern face of a steep hill may reach the climax condition while the hot dry southern exposure remains covered with the subclimax oak and hickory.

Problems of technique in the field of plant sociology have been quite as troublesome as those of nomenclature. Mapping, both topographic and two-dimensional, is of course essential. Aerial photography has been an invaluable aid.

Within the community itself the problem of expressing quantitatively the relationships which exist is extremely complicated. In addition to relative abundance of various species, their cubic magnitude, both above and below ground, may be significant. Typical concepts used are frequency, coverage, constancy, presence. Since the end of quantitative study is always a qualitative judgment, the choice of particular techniques of counting and measuring varies widely with workers and with the nature of the communities studied. Thus in grassland and herbaceous communities the use of standard quadrats, or squares of uniform size for sampling and comparison, has been extensively developed. In forest regions quadrats of larger size are necessary to give adequate sampling.

Since plant succession is at best a slow process, it must ordinarily be demonstrated by a combination of more or less indirect and inferential methods. Prevalence of vigorous juveniles of species different from the existing dominants is strong evidence of the direction of succession. The zonal distribution of plants, as, for example, about a senescent lake, often indicates the sequence of advance of land vegetation into the lake bed. Comparison of numerous related communities in different stages of development is also a fruitful method. Records, whether palaeobotanical, archaeological, or historical, often afford valuable clues. Direct proof is increasingly afforded by the growing length of scientific records.

Ecological Measurement, or Habitat Analysis.—These terms are employed in the absence of better ones to designate evaluation of the nonliving factors of the environment. The ecologist here depends upon techniques borrowed from sciences which deal with earth and atmosphere. Not infrequently he contributes to these sciences in return, as is evidenced by the recently growing attention given to evaporation by meteorologists.

It is an axiom that the living community is the most perfect expression or integration of the physical environment. This has led to considerable use of plant communities as indicators of conditions which cannot conveniently be measured otherwise, as for instance, depth of water table. Individual species are also used as indicators.

It is essential, however, that the physical environment be understood as accurately and completely as possible. This is well exemplified by the problem of the North American prairie. For a century able scientific men had propounded explanations as to the absence of trees on the prairie. More than a score of theories were advanced, including such suggestions as fire and soil. It was not until after 1910, and then as a result of patient instrumental studies, that proof was obtained that the lack of available moisture is the limiting factor for tree growth in the main body of the grassland. This had been frequently surmised, but never before established.

For the greatest value, ecological measurements should be continuous and inclusive. Light, humidity, precipitation, temperature, evaporation, wind movement and direction are the atmospheric factors most important. Moisture, temperature, texture and chemical composition are the corresponding soil properties. Automatic recording instruments, such as the hygrothermograph, must be employed, supplemented by frequent determinations for such factors as are not adapted to automatic measurements.

The earlier ecological methods of studying light only measured the intensity of actinic rays. Improved means are now available which measure both intensity and quality for a wide range of the effective spectrum. Also important is the photoperiod, or relative length of day and night. Measurements for evaporation have until recently given only relative figures, which could not be integrated with rainfall data. Improvements under way (1944) promise to give means for direct and absolute determination of the evaporating power of the air.

In the study of environment the "principle of limiting factors" must constantly be borne in mind. It is empirically expressed in the proverb "a chain is no stronger than its weakest link," and was recognized by Baron Justus von Liebig in his study of soil fertility by his "law of the minimum." In 1905 it was placed upon precise experimental basis for plant metabolism by F. F. Blackman, who stated that the rate of photosynthesis was conditional upon the least favourable of the several factors necessary. Depending upon local conditions, moisture, acidity, nutrients, temperature, light, etc., may be the controlling or limiting factor in a given habitat for given plants. The object of much ecological measurement is to determine limiting factors.

Ecological measurement has been sufficiently perfected to give material aid in predicting the hazards to be encountered in critical areas under various types of land use and management. This technique can be of the greatest economic importance in semiarid regions, such as the high plains of North America.

Applied Plant Ecology.—Illustrations of the economic uses of ecology have been given in the preceding sections. With few exceptions, however, such applications have been sporadic. At the first Imperial Botanical conference, held in London in 1924, systematic plans were laid for the employment of ecology in developing new parts of the empire. With the encouragement of General Jan Smuts, this conference has borne fruit in Africa. The Russians have made intelligent use of ecology, although there is reason to believe that parts of the steppe area have suffered unduly from exploitation. The United States department of agriculture, including the soil conservation service organized in 1935, is making increasing use of ecology.

Yet it is probably fair to say that among public men, and among the general population, there is yet little realization of the basic importance of this subject in establishing permanent and healthful relations between landscape and population.

In the problems of land use and management, ecology occupies a role analogous to that of physics and chemistry in modern industry. Such problems must increasingly be solved by the rigorous application of the principles of ecological science.

Man is the beneficiary not only of a prolonged process of organic evolution which has provided him a great variety of useful plants and animals, but of prolonged and continuous activity by plant and animal communities. This has resulted in the development of fertile soil, as well as in forests and grasslands whose products are no less essential to man than those of his

cultivated fields. Moreover, natural vegetation maintains a cover which stabilizes the earth beneath him and retards the violent action of erosion.

Natural communities are characterized by a positive or favourable energy budget. Many, perhaps most, areas controlled by man are exploited, resulting in a negative energy budget, the final mark of which is unproductiveness and abandonment. The fundamental problem of applied ecology therefore is to assay various landscapes occupied by man and determine whether they are registering a net loss or gain in efficiency. The simple criterion of cash returns cannot be applied here. The next problem of the ecologist is to assist in devising methods of land use suited to the character of the locality so that a favourable energy budget may be maintained or restored.

Due to the character of our political system and our long habit of using science chiefly where immediate problems of health or profit are involved, the fundamental application of ecology cannot be hastily achieved. In practice, however, growing numbers of civil servants—foresters, county agents, agricultural engineers, entomologists, etc.—are acquiring some understanding of ecology. The same thing is true to a lesser extent of farmers and farm owners. As this knowledge becomes more general, it will materially affect practice and planning, and has in fact already done so in favoured localities.

In the field of land management, or actual operation, ecology also has important functions, some of which have been suggested in preceding sections.

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(P. B. S.)

PATHOLOGY OF PLANTS

Plant pathology (or Phytopathology) is that branch of biological science which treats of the diseases of plants. While there can be no doubt that diseases of plants, and in particular of cultivated plants, have manifested themselves from time immemorial, it is only within comparatively recent years that their study has been taken up in an organized and scientific manner. The application of the scientific method generally to the study of practical agricultural problems is a development scarcely older than the 19th century.

Historical.—In view of the devastating effects of plant disease, especially when the particular plant attacked is of primary importance as food for mankind or his domestic animals, it is not surprising to find that references to epidemics of disease are not uncommon in historical writings, even of remote times. The earliest records are to be found in the Old Testament (*e.g.*, Deut. xxviii, 22, 1 Kings viii, 37) under such terms as "blasting" and "mildew." The precise nature of the diseases referred to cannot now be determined but there is little doubt that some of the epidemic diseases of cereals, such as rust or mildew, are indicated. The ravages of insects are frequently noted, such as for instance plagues of locusts, caterpillars and canker-worms.

In Greek literature we find references to plant diseases in the writings of Aristotle, and more particularly in those of his pupil Theophrastus, the father of botany. The latter describes diseases of a number of cultivated crops, such as various legumes, cereals, fig, olive, etc., and observes that varieties of the same crop may show different degrees of resistance to disease. This is probably the first mention of the idea of "resistant varieties" which figures so largely in present day writings on the subject. Among Roman writers the younger Pliny, who flourished in the 1st century of our era, devotes some attention to the subject and makes a number of well-founded observations regarding the incidence of certain plant diseases.

The middle ages were for plant pathology, as for all other sciences, dark ages and we have to come down to the Renaissance, with its general quickening of interest in all intellectual pursuits, to find evidence of further progress. The 17th and 18th centuries witnessed considerable activity in the study of plant diseases. The new studies proceeded in the main from two different directions. The practical gardener or agriculturalist was chiefly concerned in describing the various diseases to which his crops were subject and in attempting to evolve methods of treatment. On the other hand, the student of human pathology was interested in the diseases of plants from the possible analogies to his own problems which such a study might offer. The whole science of botany had in the old days a distinct medical bias. It is not surprising, therefore, that the study of plant diseases has been to a large extent modelled upon the older science of human pathology, the terminology of which has been freely borrowed.

The elucidation of the real nature of plant disease, from the point of view of the causal agent, is mainly dependent upon the perfection of the microscope. But even the extended powers of observation which the use of that instrument brought to bear on the subject did not at once lead to a correct appreciation of the true nature of plant disease. Various structures were observed and accurately figured in detail as being associated with the diseased parts, but they were interpreted as portions of the plant which had become changed by the disease and not as belonging to a distinct organism which was responsible for the disease. The first incontestable proof that a specific plant disease was due to the invasion of the tissues of the plant by a definite parasitic organism was furnished by the German scientist, De Bary, whose pioneer researches prepared the way for a host of other workers, at first chiefly in Germany, and later in all civilized countries. The 20th century has witnessed an extraordinary activity in the study of problems of plant disease, most strikingly, perhaps, in the U.S.A. The economic importance of the subject, as a branch of scientific agriculture, has become increasingly recognized and the prosecution of plant disease researches is being more and more taken up by government departments in all countries possessing a progressive agriculture.

Definition and Scope.—While it is true that the distinction between a healthy and a diseased plant is often perfectly obvious, it is not easy to frame a definition of the diseased condition which will meet all cases. The border line between health and disease is not always sharply marked. It will be shown below that the majority of plant diseases result from the invasion of the plant tissues by a definite organism, the *parasite*. Nevertheless, the presence of a parasite does not always necessarily mean disease in the common acceptation of the term. For example, the root-nodules of leguminous plants (pea, bean, clover, etc.) are produced by the attack of an organism—a bacterium—and far from producing damage, the presence of the bacterium is essential to the proper development of the plant. The important part played by certain fungi in the germination and subsequent growth of many plants, such as orchids and heaths, is a further illustration. The living together of two organisms does not necessarily produce injury to either partner, in which case one speaks of a *symbiotic* relationship. Every gradation may be traced from the purely symbiotic type, in which the two partners are benefited or not obviously injured, to the distinctly parasitic type in which one partner thrives at the expense and to the detriment of the other. In fact both types of relationship may be shown between the same two partners—that is, a symbiotic or harmonious relationship is at first set up, but by and by one of the partners suppresses the other and the relationship becomes one of parasitism. There is thus a gradual transition from a condition of health to one of disease.

So far reference has only been made to the diseases of parasitic nature. Over and above these there is a class of diseases in

FROM (A, B, C, D) DUGGAR, "FUNGOUS DISEASES OF PLANTS" (GINN & CO.), (E) SALMON & WARE IN "JOURNAL OF MINISTRY OF AGRICULTURE" (H. M. STATIONERY OFFICE), (F) WILTSHIRE IN "STUDIES ON THE APPLE CANKER"

FIG. 15.—TYPES OF PLANT DISEASES

A. Abnormal development of buds on branch of cherry giving rise to "witches' broom." B. Ergot of rye, showing replacement of grain by a fungal structure (Sclerotium). C. Finger-and-toe or club root disease of cabbage. D. Canker of apple tree. E. Spike disease of hop (Central branch diseased, lateral climbing branches healthy). F. Spotting of fruit disease "Anthracnose" of bean

which no parasite is present at all, viz., the so-called *physiological diseases*. The existence of the latter increases the difficulty of defining disease in terms of the causal agent.

Perhaps the most adequate definition is obtainable by considering the normal development of a plant. Over a certain range of conditions, which one reckons as normal, a particular species of plant develops in a certain way—*e.g.*, has a certain appearance, reaches a certain size, and so on—all of which are the reflection of a normal physiology or functioning of the plant. If now a particular individual diverges from the normal and if the abnormality impairs the functioning and more especially imperils the life of the plant, that plant may be considered as being diseased.

From the purely practical or economic point of view, a satisfactory definition of disease presents no great difficulties. Any given crop is grown in the expectation of a certain yield, both as regards quality and quantity. Disease in its economic aspects may therefore be defined as a condition of the crop in consequence of which it fails to give a satisfactory yield.

General Classification.—Diseases, whether of plants or animals, may be classified on the basis of the symptoms produced or of the causal agent concerned. For reasons given more fully below, the latter system of classification is more generally adopted in connection with plant diseases, and it is convenient to give at this point a general classification along such lines in order to limit the scope of the present article.

Classified on the basis of the causal agency, plant diseases are as follows:—

(1) Non-parasitic diseases due to nonliving features of the environment.

(2) Virus diseases due to an infectious principle, a so-called virus.

(3) Parasitic diseases due to other living organisms.

The first group includes those troubles in which the disease symptoms can be related to certain physical or chemical features of the environment. The second group includes those troubles caused by an infectious principle, a "virus," which may be transmitted in various ways from diseased to healthy plants. The third group, in its broadest sense, includes all disturbances due to the attacks of other organisms, either animal or plant.

The depredations of most animal organisms, *e.g.*, mammals, birds and snails, are considered by economic zoology, while the injuries from insects and mites to plants is within the field of economic entomology. (*See* ENTOMOLOGY: *Economic.*)

The field of plant pathology as now generally recognized includes all of the non-parasitic diseases, the virus diseases and all troubles due to plant parasites and in addition those due either to eelworms (nematodes) or to protozoa.

Plant parasites may be bacteria, algae, fungi (including slime moulds) or higher plants. Plant diseases of bacterial origin were at one time believed not to exist, on account of the supposed fact that the acidity of plant juices is inimical to bacterial growth. Many bacterial diseases of plants are now known, some of great economic importance. The recorded cases of parasitism due to algae are few and unimportant.

Diseases caused by higher plants, some of which will be cited later, are on the whole of greater scientific interest than of economic importance. The fungi (*q.v.*) are by far the most important group of disease-producing organisms, so far as plants are concerned.

Broadly speaking, therefore, the plant pathologist is by training either an entomologist or a mycologist. As far as diseases of parasitic type are concerned, only those caused by plants, and therefore chiefly of fungal origin, will be dealt with in the present article. At the same time it is important to note that the two aspects of the study of plant disease, the entomological and the mycological, cannot in practice always be separated.

Symptoms of Disease.—The study of symptoms is the first step in the examination of a disease problem. By symptoms one means the total of the modifications shown in the plant as the result of disease. In the majority of plant diseases of parasitic type the true symptoms are accompanied at one stage or other of the disease by certain appearances such as the fructifications of

the parasite.

A very important difference between the typical plant disease and the typical animal disease is as regards the definiteness of the symptoms shown. In animals and especially in man disease symptoms are usually very characteristic, so that it is often possible to identify (or *diagnose*) a particular disease from a study of the symptoms alone. With plants this is not generally possible. Disease symptoms in the latter are much more generalized, *i.e.*, the same or approximately the same symptoms can be produced by a great variety of causes. Wilting of the foliage, for example, is a symptom of disease in plants and its cause may be most varied—damage to the roots by fungal or insect attack, damage to the stem, presence of injurious salts in the soil, scarcity of water, and so on. Hence it follows that while a study of the symptoms may give valuable indications of the nature of a particular plant disease, it is in general necessary to discover the cause or *aetiology* of the disease before the latter can be definitely identified. Determination of the causal agent may be difficult and usually involves considerable expense of labour and time.

While the main symptoms of plant disease are of a rather generalized nature, a number of different types may be distinguished. The more important of these are given in the following list:

(*a*) *Change of colour,* such as paleness, silvering, reddening, blackening of leaves. The change of colour may be shown over the leaf or even over the whole plant, or it may be limited to spots, streaks or patterns, such as the well-known "mosaic" appearance.

(*b*) *General wilting* of the shoot, as when the plant suffers from drought, or from "damping off" disease, or from the effects of a parasite which destroys the roots or is present in the water-conducting system.

(*c*) *Premature shedding* of leaves, blossoms, fruits, etc.

(*d*) *Abnormal retention* of leaves, which is especially well shown in certain diseases of deciduous trees. The autumnal shedding of leaves is a vital or physiological process, due to the action of a definite *absciss* or cutting-off layer at the base of the leaf. If this layer is prevented from functioning, as for example by the killing action of a parasite which has invaded it, the leaves cannot be shed in the normal way.

(*e*) *Dwarfing or stunting,* which may be general to the whole plant or may only be shown in particular organs.

(*f*) *Abnormal enlargement or multiplication* of parts (*hypertrophy*) resulting in the formation of such structures as galls, tumours, knots, warts, etc. (fig. 15). Hypertrophy is generally accompanied by distortion or malformation as in the rolling or puckering of leaves and the twisting of shoots. Frequently it takes the form of an abnormal development of buds, the majority of which would normally have remained dormant. The structures called "witches' brooms" (fig. 15) which are common on certain trees (*e.g.*, willow, birch) are produced in this way.

(*g*) *Replacement* of one organ by another, as for example the change of petals into foliage leaves. Some changes of this type, though properly speaking malformations, may be economically desirable and are therefore not considered as diseases. An example is the "doubleness" of some flowers.

(*h*) *Change of habit of growth, e.g.,* from the prostrate to the erect, from the climbing to the non-climbing type of growth (fig. 15).

(*i*) *Change in the periodicity relationships* of the plant, as for example the premature flowering ("bolting") of a biennial plant in its first year of growth, or the opening of foliage or floral buds at the wrong time of year.

(*j*) *Replacement* of parts of the plant by structures belonging to the parasite, such as the conversion of the rye grain into the resting organ (*sclerotium*) of the Ergot fungus (fig. 15). "Mummification" of certain fruits is another example of this type.

(*k*) More or less rapid *killing* (*necrosis*) of the plant or parts of it. Killing is often accompanied by more or less pronounced rotting, as in the decay of fruits, buds, etc. (fig. 15). Localized killing of portions of leaves results in the formation of dead spots. The killed tissue may remain as such or may dry up and fall out, thereby producing a "shot-hole" effect.

(*l*) Formation of *deep-seated wounds* or *cankers* (fig. 15). In a canker, the parasite slowly eats into the plant tissue, the part invaded being killed and to a large extent disappearing. Associated with this type of wound there is usually a certain amount of hypertrophy of the tissue which still remains alive round the margin of the invaded part.

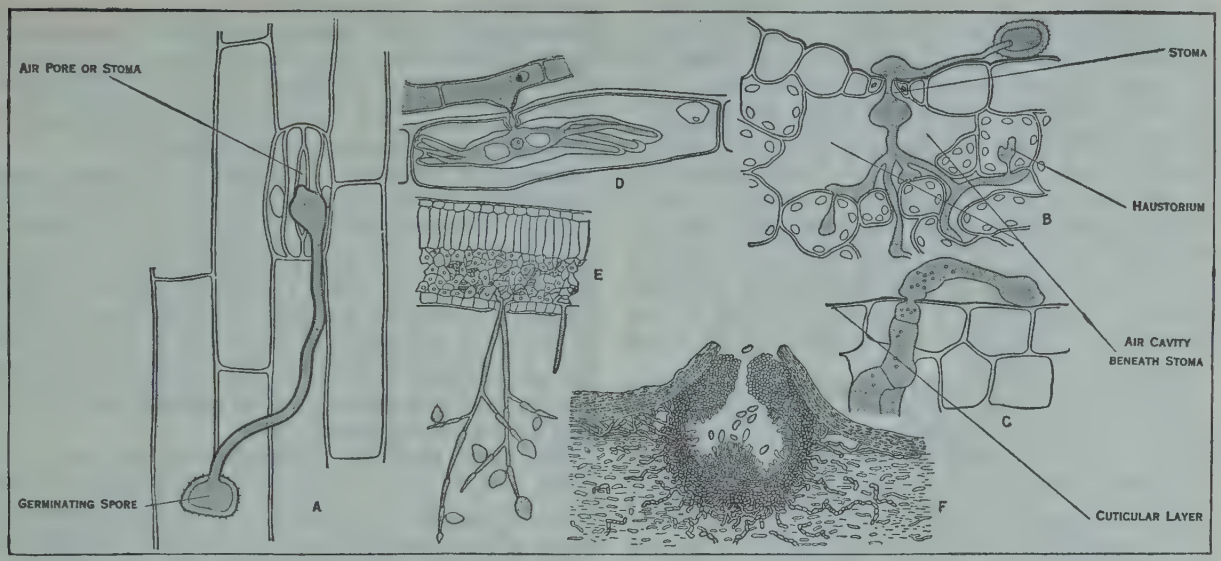
(*m*) Various kinds of *exudations,* as in the gumming of plum trees or the abnormal flow of resin in certain conifers.

METHOD OF STUDYING PLANT DISEASE

Though the investigation of a plant disease is a matter for the specialist, a short account of the methods adopted will serve to indicate the type of problems encountered. The parasitic type of disease is in practice the one most frequently met with, and therefore in actual study it is usually assumed in the first instance that the disease under investigation is of parasitic origin.

Identification of the Parasite.—The first problem which arises is the determination of the nature of the parasite (assuming that such is actually present). The tissues of the plant which show the symptoms of disease are examined, after suitable preparation, under the microscope and if the disease is actually due to a parasite it is usually not difficult to demonstrate its presence. Definite indications of its nature and identity may also be obtained at this stage. In a number of cases, the parts of the plant which show the symptoms of disease may appear to contain no parasite, even though further study may confirm that the particular disease is of truly parasitic nature. Thus the parasite may be so small as to be beyond the range of microscopic vision (see *Plant Diseases Due to Viruses,* below), or, as occasionally happens, the parasite is located elsewhere but is able to produce symptoms in parts of the plant remote from it. The mere presence of a fungus or bacterium within the diseased part (or *lesion*) is not, however, a certain indication that the disease is caused in that way. Direct proof can only be obtained by inoculating healthy plants of the species showing the disease with the organism in question and observing whether the disease is thereby produced. The details of the procedure involved in the carrying out of such artificial inoculations will vary much in different cases. In general it is necessary, as a first step, to prepare "pure cultures" of the organism, that is, to grow the latter in such a way that no other organism is present. These pure or unmixed cultures of the organism are then tested separately by inoculations on the host plant, and by this means evidence is obtained as to which is the active parasite concerned. The active parasite being isolated and its pathogenicity (or capacity to produce disease) proved, one is now able to identify the particular disease in terms of the parasite which is responsible for it.

Identification of the disease is of value inasmuch as it enables the investigator to correlate his work with similar work done elsewhere, and of which a record is obtainable in the scientific literature. But mere identification is not the most important part of the study. It is essential to work out the *life-history* of the fungus—*i.e.*, to know where and in what form it occurs throughout the year. The same fungus may exist in a variety of forms in different situations or at different times of the year, and it is essential to connect up the various stages. In particular it is very important to establish the manner in which the fungus passes the winter (or equivalent) season. In temperate climates, for example, a summer growing season alternates with a period of dormancy during the winter. Often it is only on the actively growing crop in summer that the disease is observable. It reappears each spring, spreads during the summer, and becomes more or less latent during winter. The considerations which arise in this connection vary much in the different cases. A few examples will illustrate this. Annual crops pass the winter season in the form of seed. Is the disease therefore carried over the winter by means of the seed, and if so is it present within the seed, or is it carried on the surface? Or does it persist in the soil, or is the new crop infected afresh from dead remains (stubble, trash, etc.) of the preceding year's crop? Or again, do various perennial plants, such as certain weeds, serve to carry the disease through the winter? With perennial crop plants such as fruit trees, there is the further possibility that the disease may over-



FROM (A) "PHILOSOPHICAL TRANSACTIONS," BY COURTESY OF THE ROYAL SOCIETY, (B, C) "ANNALS OF BOTANY," (D) "BOTANICAL GAZETTE" (UNIVERSITY OF CHICAGO PRESS), (E, F) DUGGAR, "FUNGOUS DISEASES OF PLANTS" (GINN & CO.)

FIG. 16.—THE FINER STRUCTURE OF SOME PARASITIC FUNGI (MAGNIFIED)

A. Surface view of plant leaf, showing rust spore germinating, B. Section of leaf showing entrance of rust fungus through a stoma, C. Penetration of cuticular layer of plant by fungus, D. Haustorium or absorptive process of mildew within plant cell, E. Fructification of potato blight fungus with egg-shaped spores, F. Fructification of Black Rot fungus embedded in the tissue of an apple, rupturing outer skin of the fruit

winter in a resting form on or in the plant itself. The determination of the exact method of overwintering which obtains in any particular case is obviously of the greatest practical importance.

The further examination of a disease problem from the point of view of the parasite would take into consideration the geographical range of the latter. Plants showing the particular symptoms would be obtained from different localities and the parasites isolated and compared. Thus a general idea would be obtained of the geographical distribution of the parasite and of the range of host plants which it could parasitize.

The complete elucidation of a plant disease involves much more, however, than the determination of the existence and habits of a parasite as outlined above. The presence of the parasite is only one of the conditions essential for the appearance of a specific parasitic disease. The more important factors and the manner in which they operate will now be indicated.

Temperature.—This factor determines in large measure the rate of growth and general vigour both of parasite and host. There is a certain temperature (*minimum*) below which an organism will not grow, a *maximum* above which it will not grow, and an *optimum* at which it grows best. These three temperatures constitute the so-called *cardinal points* for the particular organism. The cardinal points for the parasite are not in general the same as for the host plant, and the cardinal points for the disease itself are not the same as those of either host or parasite. Usually the range of temperature over which disease takes place is distinctly narrower than that over which either of the two organisms concerned will grow. The optimum temperature is well known in many cases to be different for host and parasite, and thus it is clear that the possibility exists of finding a temperature at which the host plant grows well but which is unfavourable for the development of the disease. The precise relationships are somewhat complex and have been fully worked out for a limited number of diseases only, but it is possible in general terms to classify diseases into the two main types, high temperature and low temperature diseases. An example of each will show the difference. The root-rot disease of tobacco is one of the low temperature type. Susceptible varieties of tobacco when grown in infected soil are badly diseased if the temperature rules low, whereas in the same soil the disease would not occur at a higher temperature. The wilt disease of cabbage is of the high temperature type, and only occurs in seasons when the general ground temperature is high.

Water.—The water-relationships of the crop are of equal importance with those of temperature and are to be studied in terms of the amount and distribution of rainfall, the water-retaining capacity of the soil, drainage, etc. Two factors which are of great importance in the initiation of parasitic attack are the relative humidity of the air surrounding the plant and the percentage of moisture present in the soil. The parasite requires the presence of a certain amount of moisture to start its growth processes. So it will often be possible for the plant pathologist to explain the occurrence of disease at one time or place and not at another in terms of these factors. The percentage of moisture in the soil affects not only the capacity of the parasite to grow but also the growth of the roots of the plant. It may therefore also influence the capacity of the roots to resist the attacks of the parasite.

Light.—Light is also a factor which influences the susceptibility of a plant to disease. The quantity of light received by the plant determines in large measure its vigour of growth, not merely as regards the amount of new tissue formed, but also as regards the mechanical strength and to a certain extent the chemical composition of the tissues of the plant. These qualitative differences influence the degree of resistance which the plant can offer to the attack of a parasite. For example the weak, pale, rather juicy, "forced" type of growth which results when plants are grown under conditions of feeble illumination—as when plants are grown in glasshouses during winter or when they shade each other by standing too closely together—predisposes them to attack by a variety of fungi ("damping-off" diseases). On the other hand, certain fungi (*e.g.*, some of the rusts) attack their hosts with vigour only when the latter are growing under conditions of good illumination. Again, the symptoms of certain diseases (*e.g.*, some mosaics) will only appear when the plant is exposed to light of a certain range of intensity.

The three fundamental factors, temperature, humidity and light are, in the open field, to a large extent beyond control. Nevertheless, it is often possible, in agricultural practice, materially to modify their action. By suitable methods of cultivation—draining, subsoiling, ridging, manuring—the amount of soil water can be regulated. By the provision of shade trees—as is usual in many tropical cultivations—or by suitable spacing of the crop itself or by pruning, the intensity of light or humidity of the air can be adjusted so as to approximate to the needs of the plant.

Soil Factors.—Reference has been made to soil moisture as

a factor of importance in connection with plant diseases. This is merely one of the many soil factors which influence plant growth and which therefore require to be considered in dealing with the liability of plants to disease. The physical texture of the soil and the presence or absence of certain chemicals are of importance mainly inasmuch as they influence soil humidity. But there are in addition a number of soil factors which act otherwise. Thus the amount of certain constituents present in the soil (*e.g.*, nitrogen, potash, phosphate) influences not only the quantity of plant growth but also, to an appreciable degree, its quality—and in particular its susceptibility to disease. The presence or absence of lime, by controlling the reaction of the soil, is in some cases the factor which determines whether a particular disease will develop or not. Soil aeration is a factor in itself, though in practice it is often difficult to separate its effects from those due to soil humidity.

Internal Factors.—So far the discussion of the factors which influence plant disease has been limited to the environment. The latter, however, merely modifies the result which is in the main conditioned by the structure and physiology of the host plant itself. These "internal" factors are more elusive than those already discussed and in their fundamental aspects are practically unmapped. A few examples of internal factors and of their manner of functioning will be given in the following section. Nevertheless, though very little is known of the underlying factors which determine immunity or susceptibility, certain phases of the problem are open to direct observation and experiment.

From the foregoing sketch it is clear that the complete investigation of a plant disease may ramify into various branches of agricultural science. The plant pathologist is thus much more than a mycologist, or student of fungi, though in practice the two names are often used as equivalent. Plant disease investigations may call for the joint work of the mycologist (or entomologist), the soil chemist, the physicist and the practical agriculturalist, and lastly—as will be shown more clearly later—the co-operation is required of the geneticist for the breeding of resistant varieties, and of the pure chemist for the preparation of chemical means of combating the disease.

NATURE OF DISEASE; PHYSIOLOGY OF PARASITISM

The discussion under this heading will be confined almost wholly to diseases of parasitic nature. The problems presented in parasitic disease are simpler inasmuch as the interactions of parasite and host plant can be studied under the microscope, and to a certain extent at least are amenable to chemical and physical analysis. For simplicity, the description will be confined to a disease of fungal origin.

The earliest phase of such a disease is the entrance of a fungal thread or *hypha* (*see* FUNGI for account of fungal structure). The fungus, usually in the form of a spore, germinates on the surface of the plant, or otherwise comes in contact with the latter. It then enters, either by naturally occurring openings (stomata, water pores) (fig. 16, B) on the surface or by boring directly through the skin or cuticle of the plant (fig. 16, C). Certain parasites, known as *wound parasites*, are only able to enter through openings or wounds which have been made by other agencies; *e.g.*, insect bites, bruises due to processes of cultivation, frost cracks, wind damage, pruning wounds, etc. Then again dispute exists as to whether the actual process of penetration is effected by purely mechanical means or by the agency of some chemical substance which softens or dissolves the cuticular layer of the plant. Once inside the plant, the fungus progresses by sending hyphae through the tissue, either between the cells (*intercellular*) or into the cells (*intracellular*). The particular relationship shown—*i.e.*, whether the hyphae are *between* or actually *in* the host cells —is more or less characteristic of individual diseases. In many cases the hyphae of the fungus ramify between the cells of the host and here and there send characteristic outgrowths (*haustoria*) into the cells themselves (fig. 16, D). These outgrowths are clearly the organs which enable the parasite to abstract its nutriment from the host cells.

While the fungus is progressing through the plant, the cells of the latter in the neighbourhood of the parasite, or even at some distance from it, show a number of more or less characteristic changes. The total sum of these changes, it should be noted, constitute the symptoms of the disease. The details of the changes shown vary much from one disease to another, but broadly speaking one can distinguish two main types of disease, each with a characteristic set of host changes associated with it.

Generalized Parasites.—In the first type, the fungus secretes certain chemical substances into the surrounding host cells, with markedly destructive effects to the latter. The living contents (*protoplasts*) of the cells are killed and the walls which separate the individual cells (and which form the mechanical skeleton of the living plant) are softened or partially dissolved. The destructive principle exuded by the fungus is able to diffuse out into the host tissue and thus bring about killing of the latter well ahead of the growth of the fungus. Fungi of this type are therefore not parasites in the strict sense of the term, inasmuch as they are growing all the time, not on the living plant, but on parts of it they have previously killed.

This type of parasitism is relatively simple and crude. The fungus, so to speak, is in the nature of an assassin who kills and then plunders his victim. The essential part is the killing and this merely entails that the fungus must possess the necessary battery of substances for carrying out this process. In these respects such fungi and the diseases to which they give rise stand in marked contrast to the type which will now be described.

Specialized Parasites.—In the second type of disease, there is no rapid killing or rotting effect produced by the parasite on the host cells in the neighbourhood. The cells of host plant and parasite live side by side for a considerable time with no apparent damage to the former. Indeed it frequently happens that the presence of the parasite stimulates the host cells to unusual growth and activity. Thus the cells in the neighbourhood of the parasite, some of which are actually penetrated by the food-absorbing processes of the latter, are often found on examination to be more richly supplied with food reserves than are the normal cells removed from the zone of influence. If the part of the plant affected is a leaf or other green part, the stimulating effect produced by the parasite may often be seen in the more intense green round the margin of the invaded spot than elsewhere. The stimulating action in many cases takes the form of renewed growth on the part of cells which normally would not have grown further. In this way are produced the tumours, galls, warts, witches' brooms, etc., frequently associated with diseases of this type. Such parasitism illustrates the *symbiotic* relationship to which reference has already been made. The symbiotic relationship may persist for a considerable time, but by and by injurious effects supervene, leading to more or less extensive destruction of the host tissue.

The second type of parasitism is much more subtle in nature than the first. The method of attack adopted has no resemblance to that of the assassin but savours rather of the blackmailer whose interests would not be well served by the premature death of his victim. Up to a point the interests of blackmailer and victim are identical, and if the association leads to unusual industry on the part of the latter the final harvest is all the richer. In diseases of the second type an analogous behaviour is shown. The analogy can in fact be pressed more closely still. Fungi which produce the first type of disease are, like the assassin, not selective in their action. In diseases of the second type, on the other hand, a high degree of selectivity is typically shown.

Fungi which produce this specialized type of disease show specialization in other respects. Their food requirements are of a very particular nature, and on this account it is generally impossible to cultivate them on any medium other than the living plant to which they are specialized. The symbiotic relationship is apparently necessary, and if this is not developed, no effective parasitism ensues.

As fungal attack progresses, one usually finds that the parasite makes provision for its further distribution by the development of a fruiting or sporing stage. The spores may be formed within the tissue of the parasitized plant and are disseminated only when the latter is decomposed, as for example by rotting on the surface

of the soil. More generally the fructifications of the fungus are developed on or towards the outside of the plant, either emerging from the stomata or bursting through the outer skin (fig. 16, F). Many fungal parasites develop two kinds of spores. One of these is produced in profusion during the growing period and serves to spread the disease rapidly to new plants. This is the so-called summer spore, which is usually short-lived and germinates with great readiness when the environmental conditions are suitable. The second type of spore is usually produced later in the season. This is a resting form which typically will not germinate until after a certain interval has elapsed, and which in some cases requires exposure to winter cold before it is capable of germination. The resting spore is usually provided with a thick protective wall, and is capable of enduring long exposure to atmospheric conditions. Its function is to carry the fungus over the winter.

Immunity.—The preceding sketch of the progress of a successful parasitic attack would be incomplete without some reference to those features of the plant which confer resistance or immunity to disease. These are the "internal" (as apart from environmental) factors to which reference was made above. It was also pointed out that immunity to certain highly specialized fungi was really due to over-susceptibility.

It may be noted in the first instance that a plant may be immune in the practical sense for the reason that it merely *escapes* disease. Internally it may be just as susceptible as other plants which become badly diseased. The presence of water-drops on the surface, which enable germination of the fungal spores, is a necessary antecedent to attack. Many plants are enabled to escape attack on account of a property of their outer surface which prevents the adherence of water.

With fungi which penetrate the cuticle, the strength of the latter is obviously of importance, at least if the mechanical view of penetration is accepted. In many cases there is definite evidence that this factor comes into play. Thus certain fungi are only able to attack the young leaves in which a mature, fully thickened cuticle is not yet present.

When the fungus has actually entered the tissues of the plant, it must, if parasitism is to be effected, be able to live in the sap with which it comes into contact. Attempts have therefore been made to explain the susceptibility or resistance of a tissue in terms of the properties of the plant juices. Certain difficulties of a technical nature are met with in such investigations; *e.g.*, it is not certain how far an extract which is pressed out from a plant is a true representation of the cell-sap originally present in the cells. Up to the present it has been possible only in a few cases to correlate the resistance of the host tissue to fungal attack with the anti-fungal properties of the plant juice.

The **method** by which the "killing" type of fungus breaks down the resistance of the host tissue is by excreting certain enzymes which partially dissolve the cell walls and kill the protoplast. These ferments are highly specific in action; *i.e.*, they are active on some tissues and not on others. The main factor in this connection seems to be the chemical composition of the cell walls.

So far we have dealt with possible chemical measures of defense. Many plants adopt a mechanical means of defense by laying down a protective layer of cork in advance of the parasite. The corking-over of an exposed or wounded surface is a common reaction of plants, and the same often takes place in response to the wound caused by a parasite. One or more layers of corky cells are formed somewhere along the line of separation between diseased and healthy tissue, and these act as a mechanical barrier to further progress. Any condition of the invaded plant which tends to accelerate this formation of cork increases the resistance to attack, and conversely. Similarly it has been shown in one case (the "silver leaf" disease of plum trees) that resistance depends on the formation, as a wound response, of a layer of hard gum which mechanically shuts off the parasite.

No reliable evidence exists as yet of any formation of antibodies such as play a fundamental part in the arrest of certain animal diseases. Here we meet with another illustration of the essential difference between plant and animal diseases.

ECONOMIC IMPORTANCE OF PLANT DISEASES

The number of known plant diseases is very great, and even if those occurring on non-economic plants are ignored, there is still a large residue. A glance at the disease lists of economic crops, such as are published from time to time by departments of agriculture and other bodies, will show as many as 20 or more diseases occurring on particular species of cultivated plants. The majority of these appear, for the present at any rate, to be of little economic importance, but one may say generally that more or less all cultivated plants are subject to two or three diseases of major importance, which at various times or places interfere seriously with their profitable cultivation. Thus in the case of the potato, one may cite four important diseases, blight, wart, common scab and virus disease, all of which afford serious problems to the grower. Of the many diseases reported on the apple, one may mention mildew, scab, canker, brown rot, bitter pit and scald as of the greatest economic importance; and so on, for other crop plants. In any one year and in a given locality, certain of these diseases may do little damage or may even appear to be absent, but over a wide area and over a period of years the aggregate loss is very great. One might forecast that the seriousness of the losses due to plant disease will tend to become greater as the gradual increase in the world's population makes it less possible for the supply of any product to outstrip the demand.

Though the farming class as a whole may in certain cases reap an advantage from the prevalence of plant disease, to the individual farmer the occurrence of disease in his crops can only bring loss. He therefore adopts certain measures with a view to protecting his crops and submits to various legislative restrictions, the object of which is to prevent or limit the spread of plant diseases. All these measures have as their ultimate result an increased cost of production of the article concerned, and this in the long run represents a loss to the community.

Epidemics.—It is, however, when plant disease comes on in epidemic form that the most striking damage is produced. The general public which is unaware of the widespread and ever-continuous frittering away of plant products as a result of disease, sees then the disease in its most concentrated form. Such epidemics have at one time or other produced enormous losses. They have profoundly influenced the economic development of certain countries, and have led frequently to acute distress and famine. The following examples will serve to illustrate these statements.

The rust diseases of cereals are present in all cereal-producing countries and the annual loss in many of them runs into millions of dollars. The estimated loss from the stem-rust disease of wheat in 13 of the northern United States for the ten-year period 1915–24 is given as about $550,000,000, half of which loss was incurred in a single "rust" year, 1916. The rust epidemic of 1891 cost Prussia about three-quarters of the whole cereal crop. Similar disasters have occurred in India, Australia, South Africa and other wheat-growing countries. It is partly owing to the fact that wheat is cultivated in so many widely separated countries—in all of which a rust epidemic is not liable to occur in any one year—which acts as a safeguard against a serious bread famine.

The coffee disease, also caused by a rust, is a striking example of the effect which a disease may have on the economic history of a country. In the earlier part of the second half of the 19th century, the coffee industry was the mainstay of the prosperity of Ceylon. About 1870 a hitherto unrecorded leaf disease appeared on the coffee bushes. As with many important plant parasites, the seriousness of this disease was not recognized at first. Within a few years the fungus had spread over the whole island and the coffee industry soon disappeared from Ceylon.

Perhaps the most outstanding instance of distress caused by a fungal disease is afforded by the great Irish potato famine in 1845 and 1846. The potato disease ("blight") had only appeared in Europe a few years previously, the causal fungus being, like the potato itself, a native of South America. The disease spread like wildfire over western Europe and in the seasons 1845 and 1846 almost completely destroyed the potato crop in Ireland. As the potato at that time constituted the staple food of the

peasant population, the result of the epidemic was a famine of unprecedented severity.

The story of the coffee leaf disease in Ceylon has in recent years found a very close parallel in that of the chestnut blight in the United States. This disease first appeared in 1904 on a few trees in the neighbourhood of New York. Subsequent investigation showed that the causal fungus was a native of Eastern Asia where it occurs on certain native species of chestnut, but without causing appreciable damage. It had apparently been introduced into the United States on a consignment of chestnuts from the east, and there is every probability that if its importance had been recognized, the disease could have been stamped out in the early stages. As it was, the disease began to spread over the New England states and it soon became apparent that the fungus was much more destructive to the American sweet chestnut (*Castanea dentata*) than to the Asiatic forms. Control methods of the most elaborate nature were put in operation, but too late to be effective. At the present time, this disease has destroyed practically all the native chestnuts in the United States. (*See* CHESTNUT.)

Records of the complete extermination of an industry by fungal disease are fortunately not numerous. On the other hand it would be possible to multiply examples in which fungal diseases are an ever-present menace to particular cultivations. The most important single factor in the cultivation of many economic plants is the liability to certain fungal diseases.

METHODS OF CONTROLLING PLANT DISEASE

The checking of a plant disease, so that if not actually eliminated it is reduced to manageable proportions, is spoken of as its "control." This may be complete or partial. The methods of control may be divided into two main groups, first those which are put into practice by the grower himself, and second those which are enforced upon him by legislation. In the following discussion these will be considered separately.

Voluntary Control.—The adoption of control measures by the grower is subject to a number of severe restrictions. It is only with a certain number of crops that individual treatment of plants is possible, and in all but exceptional cases the economic consideration of cost is all-important. It is idle for the plant pathologist to suggest measures of control if the requirements of time and labour involved in the treatment are such as cannot be satisfied or if the ultimate gain to the grower is not obviously greater than the cost of the measures adopted. The control methods adopted may be directed to increasing the resistance of the plant to disease, or in the case of a parasitic disease may also be directed against the parasite. The former will be dealt with first.

Resistance.—For every plant there is a certain range of environmental conditions within which it grows best. If the conditions vary widely in any important respect from those which are ideal, the plant grows badly. A weakly growing plant is in general more susceptible to parasitic attack than is a strongly growing one, and the abnormal condition of the plant resulting from the unfavourable environment may in itself be so pronounced as to be called diseased. Good cultivation, therefore, which aims at giving the plant the optimal conditions for its growth, is the first line of treatment to be adopted with a view to lessening the incidence of disease.

The most approved methods of husbandry will not however guarantee freedom from plant diseases, nor are they always practicable. More special methods must therefore be adopted. In recent years it has become increasingly recognized that the main line of defense against many important diseases consists in the development of *immune* or *resistant* varieties of the host plant.

To obtain varieties of a crop plant which are resistant to a particular disease is in many cases not difficult. These may in fact exist among the varieties already in cultivation. If the resistant forms possess high merits in other respects—*e.g.*, in yielding power, in quality of product, etc.—then the problem of the particular disease is in large measure solved. Often, however, the resistant varieties which are already known to occur show certain disadvantageous features, and these may be so great as to outweigh the benefits conferred by the high disease resistance shown.

One method of obtaining a resistant *strain* from a commercial variety consists in growing the plants under conditions in which they are exposed to infection and selecting out for propagation those individuals which stand up successfully against the disease. This method has been adopted with great success in the development of strains resistant to some of the important wilt diseases (cotton, cabbage, etc.).

A more elaborate method consists in the artificial crossing of parents of known characteristics, followed by the sorting out of the different types which occur among the progeny. (*See* PLANT BREEDING.) This is the application to problems of disease of the principles of Mendelism (*q.v.*). Resistance to disease behaves as a single or multiple Mendelian factor, and is usually dominant in the immediate offspring.

Destruction of the Parasite.—The control of plant diseases by the adoption of measures against the fungus is best considered with reference to the life-history of the fungus and in particular to the manner in which it reinfects the growing crop after each period of winter dormancy.

If the fungus is a *soil parasite,* it may be possible to starve it out by ensuring that it does not come in contact with the particular crops on which it grows and multiplies. This involves a system of *rotation* of crops. The practice of crop rotation is justified for other agricultural reasons and is of great value in that it tends to check the multiplication of specific soil (and other) parasites. Some soil parasites, however, are able to live indefinitely on the humus material of the soil so that they cannot be starved out (*e.g.*, some wilt diseases), others may persist so long in the dormant form that the interval required between successive susceptible crops is too long to be economically practicable (*e.g.*, wart disease of potato).

The elimination of a parasite from the soil by any process of sterilization is generally impracticable on account of the expense involved. In greenhouse cultivation or in those cases where the main source of infection is the seed-bed, soil sterilization may be attempted. For this purpose, heat (*e.g.*, steam-heat as obtained from a boiler) or a fungicidal chemical such as formalin is generally used.

Preventive Measures.—If the disease is carried by the seed, the practical method of control consists either in the selection of seed known to be free from contamination or in some process of seed treatment devised to destroy the parasite without appreciably affecting the germinating capacity of the seed. If the fungus is present merely on the surface of the seed, treatment is generally simple. This consists in steeping the contaminated seed in solutions of various chemicals—formalin, copper sulphate, mercuric chloride, organic salts of mercury, etc.—for a suitable time. The fungus is killed by this treatment whereas the seed is little damaged on account of the protection afforded by its seed coat. Dusting the seed with various chemical powders is similarly effective.

A general palliative measure in the treatment of plant disease is to reduce the amount of infective material available. If the fungus overwinters on the dead remains of the previous year's crop, the latter should be disposed of, either by burning or by digging into the ground. Crop rotation, by segregating to some extent the current year's crop from last year's, is likewise useful.

One of the most important methods of protecting plants against the attack of air-borne parasites is by the use of fungicidal chemicals which are sprayed or dusted over the plants. The object aimed at here is to coat the surface of the plant with a thin but more or less continuous film of the fungicidal substance so that, when the air-borne spores of the parasite arrive, they are unable to initiate attack. Spraying or dusting, if properly carried out, prevents attack but is ineffective if the disease has already established itself. Thus an intimate knowledge of the life-history of the fungus with special reference to the date at which it emerges from its winter resting stage is of the greatest importance for

success in spraying operations. The leaves and young shoots of the plant are readily injured by the action of poisonous chemicals, so that great care is necessary in the preparation and use of fungicides, otherwise greater damage may be done than that which it is intended to prevent. The spray, which consists of a very fine suspension in water of the fungicidal substance, is discharged under pressure in the form of a mist so that as far as possible the whole plant surface is covered. In practice various inert substances ("spreaders") are added in order to facilitate wetting of the leaves and adhesion of the spray. The basis of most sprays in commercial use is either copper or sulphur. To the former class belong the well known Bordeaux and Burgundy mixtures, prepared by adding solutions of copper sulphate to lime and soda respectively. To the latter belong such preparations as "liver of sulphur," "lime sulphur" and "colloidal sulphur."

Legislative Control.—The legislative enforcement of certain measures for the control of plant diseases actually dates back for several hundred years. Witness for example the Rouen act of 1660 for the control of wheat rust by the eradication of barberry bushes (*see* later). The full development of these measures, however, has only come about within the last twenty years. The Destructive Insects and Pests act was passed by the British parliament in 1907 and a similar law, the National Plant Quarantine act came into force in the United States in 1912. Practically all civilized countries adopted the same type of regulations and at much the same time.

Restriction of Imports.—As between one country and another, the effect of these enactments is to limit free trading in such plants or plant products as are considered likely to bring dangerous parasites into the importing country. The restrictions may amount to a complete embargo, as applies for instance to the import of English potatoes into the United States (on account of the wart disease) or of American gooseberry bushes into England (on account of mildew). In other cases import is allowed provided the material has been inspected by a responsible authority in the exporting country and warranted free from certain diseases. Such material is subjected to further inspection at the port of entry and if found contaminated may be destroyed. From the port it may be liberated directly to the trade or may be sent to a quarantine station, where it is grown in an isolated situation for such time as enables its freedom from disease to be fully established. These restrictive regulations may also be in force between different parts of the same country, as for instance, between the different states of the United States.

Domestic Control Measures.—Within the limits of any one country, legislative control may take the form of compulsory notification of certain diseases. The latter will then be inspected, and the appropriate measures—such as destruction of the infected material—enforced. A further measure is the placing of restrictions on the kind of crop which may be grown within certain infected areas. The legislation against wart disease of potato in England is an illustration of this type of control measure. Within an infected area (called a "scheduled" area) only immune varieties of potatoes may be grown. The enforcement of this kind of measure is very difficult unless suitable immune varieties or other substitute crops are available.

Legislative control of the type outlined above has naturally led to the creation of an inspection service, and further to a wide extension of facilities for advisory work and for the carrying out of research. This increased interest in problems of plant disease, arising from government intervention, is perhaps the most striking development in plant pathology which the 20th century has produced.

CLASSIFICATION OF PLANT DISEASES AND SPECIAL ACCOUNT

In the present section a brief account will be given of some of the more important plant diseases and under the following headings—

(*a*) Physiological Plant Diseases.
(*b*) Plant Diseases due to Bacteria.
(*c*) Plant Diseases due to Viruses.
(*d*) Plant Diseases due to Fungi and Slime Moulds.
(*e*) Plant Diseases due to Higher Plants.

Physiological Plant Diseases.—Plants, like animals, may show deficiency diseases due to the lack of some important chemical constituent in their food supply. Thus a lack of iron salts in the soil produces the condition called "chlorosis," in which the green pigment of the plant, chlorophyll, fails to develop. Lack of potash, such as often occurs in poorly manured soils or in light soils leached by heavy rainfall, produces very characteristic symptoms of disease in certain plants, *e.g.*, potato, tobacco and cereals. Similarly, for other essential food elements such as magnesium, phosphate and nitrogen. Conversely, disease conditions may result from the presence of an excess of certain chemicals in the soil. To this class belong various kinds of chlorosis, due to excess of lime or manganese in the soil. The most important diseases of this type are those associated with the accumulation of soil alkali. These are met with in irrigated regions where they often constitute the chief agricultural problem.

Among diseases due to unsuitable environmental conditions may be cited those caused by too high temperature, such as sunscorch of leaves, heat canker, etc. The effects of too low temperature are familiar as frost injury to leaves, young shoots, fruit, etc., but a more important illustration is seen in the winter killing of trees in those countries which experience severe winter freezing. The development of "winter-hardy" varieties of cultivated plants is of great importance in countries possessing the continental type of climate.

Injuries due to noxious chemicals in the air are well shown by plants growing in industrial areas. The more important chemicals in this connection are gases, such as coal gas and sulphur dioxide, fumes such as sulphuric acid, and dusts such as soot and cement dust. The latter act by choking up the breathing pores of the plants, but this action is often accompanied by the poisonous effects of gases associated with the dust. In this connection should also be mentioned the injuries which arise from the injudicious use of chemical protective agents such as sprays.

Plant Diseases Due to Bacteria.—The most important diseases of this type are the fire blight (*Bacillus amylovorus*) of apples, pears and similar fruits; the angular leaf spot or blackarm disease of cotton (*Pseudomonas malvacearum*); the olive tubercle (*P. Savastanoi*); citrus canker (*P. citri*); various wilt diseases (*Bacillus tracheiphilus* in cucurbits, *B. solanacearum* in tomato, potato, etc.); soft rots of a number of vegetables (*B. carotovorus* and allied species); two leaf spot diseases of tobacco (*Bacterium angulatum* and *B. tabaci*); and crown gall (*P. tumefaciens*) on a large variety of herbaceous and woody plants.

Plant Diseases Due to Viruses.—This important group was formerly placed among the physiological diseases, but it is now known that they are of infectious or contagious nature. Detailed investigation has failed to show the presence of a visible parasite, but in other respects the resemblance to the parasitic type of disease is very close. The disease can in many cases be transmitted by the inoculation of the juice of a diseased plant into a healthy one. Where this simple method of transmission fails, infection of a healthy plant can be obtained by grafting on it a shoot of a diseased plant. In certain cases it has been proved that the juice of a diseased plant is able to convey infection after it has been filtered through a porcelain cup, whence the current view with regard to these diseases is that they are caused by filter-passing organisms. The symptoms of virus disease are confined to the shoot portions of the plant, and take the form typically of mottling ("mosaic") of the leaves, with as a rule a certain amount of puckering, distortion or inrolling. The habit of growth may also be affected, and often there is dwarfing, premature death, and a marked diminution in the yield. The chief agents of transmission are various leaf-biting or leaf-sucking insects, particularly aphides. The number of crop plants which are known to show virus diseases is very large and includes potato, tomato, tobacco, cucumber, clovers, spinach, hop, sugar cane, sugar beet, peach and many others. Certain kinds of ornamental variegation are also infectious and are thus not dis-

tinguishable from virus disease.

Diseases Due to Fungi and Slime Moulds.—These constitute by far the most numerous group of plant diseases. The species of fungi which cause plant disease are to be numbered by thousands and occur in all the main divisions into which fungi are classified (*see* FUNGI). In the majority of text books on plant pathology, these diseases are classified according to the systematic relationship of the causal fungus, but in some cases a grouping according to the crop plant affected or according to the type of symptom produced may offer certain advantages. In the present article, any systematic review of even the more important diseases is impossible. All that can be attempted is to indicate some of the more important groups or types.

The slime moulds (*Myxomycetes*) live mainly on decaying vegetable matter and are responsible for but few diseases of economic importance. A few species have been recorded as causing injury to growing crops, but a definite parasitic relation is doubtful. The group of the Lower Fungi (*Phycomycetes*) includes two subclasses, the *Oömycetes* and the *Zygomycetes*. The former includes the chytrids, the water moulds and the pythiaceous fungi, white rusts and downy mildews; the latter the black moulds and related forms. The best-known example of the chytrids is the finger-and-toe or club root of crucifers (turnips, swede, cabbage, etc.) due to the organism *Plasmodiophora brassicae*. This disease is remarkable for large size of the hypertrophies produced on the roots of affected plants. Another important member of the chytrids is *Synchytrium endobioticum*, the cause of black scab or wart disease of the potato. The downy mildews cause important diseases of a great number of crops including grape, hops, lettuce, several grasses and many others. The late blight and rot (*Phytophthora infestans*) of the potato is perhaps the most important disease of all.

Within the group of the *Ascomycetes* there are numerous important parasites. Species of *Sclerotinia* produce the brown-rot or "mummy" diseases of apple, plum and similar fruits, being among the most destructive orchard parasites. The family of the *Erysiphaceae* comprises the powdery mildews. These fungi cause the abundant formation on the plant of a powdery mass of summer spores, whence the name of the group. Crops of economic importance which are attacked by powdery mildews include cereals, clover, vine, hop, gooseberry, strawberry, apple, rose and oak. Species of *Exoascus* produce the leaf-curl disease of peaches and almonds and a number of interesting if economically unimportant diseases such as witches' brooms on cherry and birch. To the group of *Ascomycetes* also belong such important diseases as ergot of grasses (*Claviceps purpurea*), apple canker (*Nectria galligena*), wheat scab (*Gibberella saubinetii*), black knot of plum (*Plowrightia morbosa*), chestnut blight (*Endothia parasitica*), and apple scab (*Venturia inaequalis*).

The group *Basidiomycetes* includes three orders of parasites of great economic importance: smuts, rusts and bracket fungi.

The smuts (*Ustilaginales*) are a peculiar group of parasites which live almost wholly within the host plant and usually attack the developing flower and fruit. The latter in the typical case becomes a black powdery mass of spores which constitute the "smutted" head characteristic of this type of disease. The most important examples are found among the grasses—viz., the loose and covered smuts of barley, wheat, oats, rye, rice, maize, etc.

The rusts (*Uredineales*) include perhaps the most important of all plant parasites. The cereal rusts (*Puccinia graminis* and allied forms) are the best known and economically the most serious, but important parasites occur on apple, plum, coffee, Weymouth pine, and many others, especially herbaceous plants. A striking feature in the life history of some of these rusts is that they pass from one host species to another. Thus some forms of the wheat rust parasite have a stage on the barberry; the Weymouth pine blister rust passes to various species of currant. The elimination of the so-called "alternate host" offers a means of control for certain of these rusts. Hence the "barberry eradication campaign" which is being actively prosecuted in certain wheat-growing countries.

The bracket fungi (*Polyporales*) are a group which attack living trees and timber. These are generally wound parasites which gain entrance through broken branches or other injuries, destroy the wood of the tree, and from time to time produce the well-known bracket-like fructifications on the surface. Species of *Polyporus* and *Fomes* attack a large variety of growing trees.

Diseases due to Imperfect Fungi make up an enormous and miscellaneous list, including such as the following: many fruit rots (*Botrytis, Penicillium*), wilts (*Fusarium*), stripe disease of cereals (*Helminthosporium*), and an almost infinite number of leaf, stem and fruit spots (*Phoma, Septoria, Gloeosporium*, etc.).

Diseases Due to Higher Plants.—Parasites of this type are of great botanical interest, but as a rule of little economic importance. Well known examples are the mistletoe (which is a semi-parasite only, being able to manufacture its carbonaceous food from the air by means of its green leaves) and the dodders or love vines. These attach themselves to and parasitize the stems of other plants.

BIBLIOGRAPHY.—F. D. Heald, *Manual of Plant Diseases* (New York and London, 1926), gives a full bibliography (pp. 20–24) of general and specialized text-books. Current literature: *Phytopathology* (American Phytopathological Society, 1911 onwards); *Journal of Agricultural Research* (Washington, D.C., 1913 onwards); *Annals of Applied Biology* (London, 1914 onwards); *Zeitschrift für Pflanzenkrankheiten* (Stuttgart, 1891 onwards); *Review of Applied Mycology* (Kew, England, 1922 onwards). The journal last mentioned gives full abstracts of all the current plant pathological literature. (W. BRO.; X.)

PLANUDES, MAXIMUS (*c.* 1260–1330), Byzantine grammarian and theologian who flourished during the reigns of Michael VIII and Andronicus II Palaeologi, spent the greater part of his life as a monk in Constantinople. On entering the monastery he changed his original name Manuel to Maximus. Possessing a knowledge of Latin remarkable for his time he was sent by Andronicus II in 1327 ôn an embassy to remonstrate with the Venetians for their attack upon the Genoese settlement in Pera. Planudes, especially by his translations, paved the way for the introduction of the Greek language and literature into the west.

He is the author of a Greek grammar, a biography of Aesop and a prose version of his fables, certain scholia, various original poems. His numerous translations from the Latin included Cicero's *Somnium Scipionis* with the commentary of Macrobius: Caesar's *Gallic War;* Ovid's *Heroides* and *Metamorphoses;* Boetius, *De consolatione philosophiae;* Augustine, *De trinitate*. He also edited a supplement to the Anthology known as *Appendix Planudea*.

See Fabricius, *Bibliotheca graeca*, ed. Harles, xi, 682; theological writings in Migne, *Patrologia graeca*, cxlvii; correspondence, ed. M. Treu (1890), with a valuable commentary; K. Krumbacher, *Geschichte der byzantinischen Literatur* (1897); J. E. Sandys, *Hist. of Class. Schol.* (1906), vol. i.

PLAQUE, a small flat plate or tablet, applied particularly to rectangular or circular ornamental plates or tablets of bronze, silver, lead or other metal, or of porcelain or ivory. Small plaques, called plaquettes, in low relief in bronze or lead, were produced in great perfection in Italy at the end of the 15th and beginning of the 16th centuries, and were usually copies of ancient engraved gems, earlier goldsmith work and the like.

PLAQUEMINE, a city of southeastern Louisiana, U.S., located on the Mississippi river 14 mi. S.W. of Baton Rouge. It is the parish seat of Iberville parish. Pop. (1950) 5,747; (1940) 5,049 by federal census. Plaquemine is served by the Texas and Pacific and Missouri Pacific railways and by state highways 30 and 168. Its principal industries include sugar, lumber, cattle and oil. The town's chief importance, however, derives from the fact that it is the site of the Plaquemine locks, constructed in 1909. The locks are located in a channel which connects the Mississippi river with the Intracoastal canal which extends south and then east and west to Pensacola, Fla., and to Brownsville, Tex.

Plaquemine took its name from the bayou which flows out of the Mississippi river through the Plaquemine locks. The word is said to be a derivation of the Indian word for persimmon, a fruit which thrives in the vicinity.

Plaquemine was incorporated in 1838 and became the parish seat four years later.

PLASKETT, JOHN STANLEY (1865–1941), Canadian astronomer, was born Nov. 17, 1865, near Woodstock, Ont. He

was educated at the University of Toronto, from which he graduated in 1899, and afterwards taught there as an assistant in physics until 1903, when he became associated with the astronomical branch of the Canadian department of the interior. Two years later he was made astronomer of the Dominion observatory at Ottawa, and remained in that position until 1917, when he was placed in charge of the Dominion Astrophysical observatory in Victoria, B.C. After his retirement in 1935, he supervised the grinding and polishing of the 82-in. mirror for the telescope of the MacDonald observatory in Texas.

Plaskett was one of the most noted astronomers of his time. Of his many important discoveries, one of the first came in 1922 when he found that what had for years been considered a large single star was actually two stars. The stars, although clearly visible to the naked eye, could not be identified as twins until Plaskett studied them through the Dominion observatory's 72-in. telescope, which he had been instrumental in persuading the government to install. The stars were subsequently given his name and are known as "Plaskett's twins." He also made valuable studies on the motions of stars, on the Milky Way and its movements and on the rotation of the galaxy.

Of his numerous papers, the most important include *Star Image in Spectroscopic Work; Design of Spectroscopes; The Rotation of the Galaxy; Diffuse Matter in Interstellar Space;* and several on the O-type stars. He was the recipient of a number of honorary degrees and awards for his distinguished services to astronomy. He died at Esquimault, B.C., Oct. 17, 1941.

PLASSEY, or PALASI, a village of Bengal, scene of Robert Clive's victory on June 23, 1757, over the forces of the nawab Suraj-ud-Dowlah. Clive, with a force of about 3,000 men and 8 fieldpieces, took the field against the nawab, who had about 60,000 men, 53 heavy guns and some French artillery under St. Frais. Only the river Bhagirathi separated Clive's force from the entrenched camp of the enemy, when the English leader, for once undecided, called a council of war. Clive and the majority were against fighting, Maj. Eyre Coote, of the 39th foot, and a few others for action. Coote's soldierly advice powerfully impressed Clive, and after deep consideration he altered his mind and issued orders to cross the river. After a fatiguing march, the force bivouacked in a grove near Plassey early on June 23. The nawab's host came out of its lines and was drawn up in a huge semicircle almost enclosing the little force in the grove; and St. Frais's gunners on the right wing opened fire. Clive replied and was soon subjected to the converging fire of 50 heavy guns. For hours the unequal fight was maintained, until a rainstorm stopped it. The English covered up their guns, but the enemy took no such precaution.

Mir Mudin, the only loyal general of the nawab's army, thinking that Clive's guns were as useless as his own, made a disastrous cavalry charge upon them; he lost his own life, and his colleagues then had the game in their hands. Mir Jafar persuaded the nawab to retire into the entrenchments. St. Frais stood fast until one of Clive's officers, Maj. John Kilpatrick, successfully drove him in. Clive followed up this success by cannonading the camp at close range.

But the rank and file of the native army, ignorant of the treachery of their leaders, made a furious sortie. For a time Clive was hard pressed, but his cool generalship held its own against the undisciplined valour of the enemy, and, noticing that Mir Jafar's division in his rear made no move against him, he led his troops straight against the works.

After a short resistance, made chiefly by St. Frais, the whole camp fell into Clive's hands. At a cost of 22 killed and 50 wounded this day's work decided the fate of Bengal. Although the historic grove has disappeared, a monument has been erected to commemorate the victory.

PLASTER OF PARIS or GYPSUM PLASTER, $2CaSO_4.H_2O$, a hemihydrate of calcium sulphate made by heating gypsum, $CaSO_4.2H_2O$. When mixed with water it quickly sets to a mass of gypsum crystals with an increase in volume. It is used in making moulds, casts and finishing plaster. (*See* CEMENT.)

(J. B. Ps.)

PLASTER-WORK. Plastering is one of the most ancient of handicrafts employed in connection with building operations, the earliest evidence showing that the dwellings of primitive man were erected in a simple fashion with sticks and plastered with mud. Soon a more lasting and sightly material was employed to take the place of mud or slime, and that perfection in the compounding of plastering materials was approached at a very remote period is proved by the fact that some of the earliest plastering which has remained undisturbed excels in its scientific composition that which is used at the present day. The pyramids in Egypt contain plaster-work executed at least 4,000 years ago (probably much earlier) and yet existing, hard and durable. Indeed the principal tools of the plasterer of that time were practically identical in design, shape and purpose with those used to-day. For their finest work the Egyptians used a plaster made from calcined gypsum just like the plaster of paris of the present time, and their methods of plastering on reeds resemble in every way our "lath, plaster, float and set" work. Hair was introduced to strengthen the "stuff," and the whole finished somewhat under an inch thick.

Very early in the history of Greek architecture we find (*e.g.*, at Mycenae) the use of plaster of a fine white lime stucco. The art had reached perfection in Greece more than five centuries before Christ, and plaster was frequently used to cover temples externally and internally, in some cases even where the building was of marble. It formed a splendid ground for decorative painting, which at this period of Grecian history had reached a very high degree of beauty. The temple of Apollo at Bassae, built of yellow sandstone about 470 B.C., is an excellent example. Pavements of thick, hard plaster, stained with various pigments, were commonly laid in Greek temples. In England the walls of large houses were formerly plastered above the wainscoting and coloured, while the ornamented plaster ceilings of the time of Henry VIII, Elizabeth and James I, are still the admiration of lovers of the art. Still earlier specimens of the plasterer's skill are extant in the pargeted and ornamented fronts of half-timbered houses. With regard to the smaller buildings, comprising small dwelling houses and cottages, the general application of plaster is of comparatively late date; for wainscoted walls and boarded ceilings or naked joists alone are frequently found in houses of not more than a century old both in England and on the continent.

Wood and Metal Lathing.—Wood laths are narrow strips of some straight-grained wood, generally Baltic or American fir, in lengths of from two to four or five feet to suit the distances at which the timbers of a floor or partition are set. Laths are about an inch wide, and are made in three thicknesses; "single" ($\frac{1}{8}$ to $\frac{3}{16}$ in. thick), "lath and a half" ($\frac{1}{4}$ in. thick), and "double" ($\frac{3}{8}$ to $\frac{1}{2}$ in. thick). The thicker laths should be used in ceilings, to stand the extra strain, and the thinner variety in vertical work such as partitions, except where the latter will be subjected to rough usage. Laths are nailed with a space of about $\frac{3}{8}$ in. between them to form a key for the plaster, and they must be nailed so as to break joint in bays three or four feet wide with ends butted one against the other. By breaking the joints of the lathing in this way, the tendency for the plaster to crack along the line of joints is diminished and a better key is obtained. Every lath should be nailed at each end and wherever it crosses a joist or stud. All timbers over three inches wide should be counterlathed, that is, have a fillet or double lath nailed along the centre upon which the laths are then nailed. This is done to preserve a good key for the plaster. Walls liable to damp are sometimes battened and lathed in order to form an air cavity between the damp wall and the plastering.

Lathing of metal, either of wire or in the form of perforated sheets, is extensively used on account of its fireproof and lasting quality. There are very many kinds of this material made in different designs under various patents. A lathing has been introduced formed of thin wooden rods wired together at $\frac{1}{4}$-in. intervals. This can be fixed around curves, and economizes plaster.

Lathing nails are usually of iron, cut, wrought or cast—and in the better class of work they are galvanized to prevent rusting. Zinc nails are sometimes used, but are costly.

Materials for Plaster.—The lime principally used for internal plastering is that calcined from chalk or other nearly pure lime-

stone, and is known as fat, pure, chalk or rich lime. Hydraulic limes (*see* MORTAR IN BUILDING) are also used by the plasterer, chiefly for external work. Perfect slaking of the calcined lime before use is very important as, if used in a partially slaked condition, it will "blow" when in position and blister the work. Lime should therefore be run as soon as the building is begun, and at least three weeks should elapse between the operation of running the lime and its use.

Hair is used in plaster as a binding medium, and gives tenacity to the material. Ox hair, which is sold in three qualities, is the kind usually specified; but horsehair, which is shorter, is sometimes substituted in its stead or mixed with the ox hair in the lower qualities. Good hair should be long, strong and free from grease and dirt, and before use must be well beaten to separate the lumps. In the U.S. goats' hair is frequently used, though it is not so strong as ox hair. The quantity used in good work is one pound of hair to two or three cubic feet of coarse stuff.

Manila hemp fibre has been used as a substitute for hair. As a result of experiments to ascertain its strength as compared with that of other materials, it was found that plaster slabs made with Manila hemp fibre broke at 195 lb., plaster mixed with sisal hemp at 150 lb., jute at 145 lb. and goats' hair at 144½ lb. Another test was made in the following manner. Two barrels of mortar were made up of equal proportions of lime and sand, one containing the usual quantity of goats' hair, and the other Manila fibre. After remaining in a dry cellar for nine months the barrels were opened. It was found that the hair had been almost entirely eaten away by the action of the lime, and the mortar consequently broke up and crumbled quite easily. The mortar containing the Manila hemp, on the other hand, showed great cohesion, and required some effort to pull it apart, the hemp fibre being apparently quite uninjured.

Sawdust has been used as a substitute for hair and also instead of sand as an aggregate. It will enable mortar to stand the effects of frost and rough weather. It is useful sometimes for heavy cornices and similar work, as it renders the material light and strong. The sawdust should be used dry.

Some remarks are made on the ordinary sands for building in the article MORTAR IN BUILDING. For fine plasterer's work special sands, not hitherto referred to, are used, such as silver sand, which is used when a light colour and fine texture are required. In England this fine white sand is procured chiefly from Leighton Buzzard.

External Work.—For external work portland cement is undoubtedly the best material on account of its strength, durability and weather resisting properties. The first coat or rendering is from ½ to ¾ in. thick, and is mixed in the proportions of from one part of cement to two of sand to one part to five of sand. The finishing or setting coat is about $\frac{3}{16}$ in. thick, and is worked with a hand float on the surface of the rendering, which must first be well wetted.

Stucco is a term loosely applied to nearly all kinds of external plastering, whether composed of lime or of cement. The principal varieties of stucco are common, rough, trowelled and bastard. Common stucco for external work is usually composed of one part hydraulic lime and three parts sand. The wall should be sufficiently rough to form a key and well wetted to prevent the moisture being absorbed from the plaster. Portland cement is used for all but the commonest external work. White portland cement, made in the United States and France, is very successfully used with white sand to give an excellent stucco closely resembling stone and very durable.

Rough stucco is used to imitate stonework. It is worked with a hand float covered with rough felt, which forms a sand surface on the plaster. Lines are ruled before the stuff is set to represent the joints of stonework. *Trowelled stucco*, the finishing coat of this work, consists of three parts sand to two parts fine stuff. A very fine smooth surface is produced by means of the hand float. *Bastard stucco* is of similar composition, but less labour is expended on it. It is laid on in two coats with a skimming float, scoured off at once and then trowelled. Stucco may be executed in colours, the desired tints being obtained by mixing with the lime various oxides. Black and grays are obtained by using forge ashes in varying proportions, greens by green enamel, reds by using litharge or red lead and blues by mixing oxide or carbonate of copper with the other materials.

Roughcast or *pebble-dash* plastering is a rough form of external plastering in much use for country houses. In Scotland it is termed "harling." It is one of the oldest forms of external plastering. In Tudor times it was employed to fill in between the woodwork of half-timbered framing. When well executed with good material this kind of plastering is very durable. Roughcasting is performed by first covering the wall or laths with a coat of well-haired coarse stuff composed either of good hydraulic lime or of portland cement. This layer is well scratched to give a key for the next coat, which is also composed of coarse stuff knocked up to a smooth and uniform consistency. While this coat is still soft, gravel, shingle or other small stones are evenly thrown on with a small scoop and then brushed over with thin lime mortar to give a uniform surface. The shingle is often dipped in hot lime paste, well stirred up and used as required.

Sgraffito (Italian for "scratched") is scratched ornament in plaster. Scratched ornament is the oldest form of surface decoration and is much used on the continent, especially in Germany and Italy, in both external and internal situations. Properly treated, the work is durable, beautiful and inexpensive. The process is carried out by applying a first coat or rendering of portland cement and sand, in the proportion of one to three, laid on about ½ in. thick; then following with the colour coat, which is sometimes put on in patches of different tints as required for the finished design. When this coat is nearly dry, it is finished with a smooth-skimming, $\frac{1}{12}$ to $\frac{1}{8}$ in. thick, of Parian, selenitic or other fine cement or lime, only as much as can be finished in one day being laid on. Then by pouncing through the pricked cartoon, the design is transferred to the plastered surface. Broad spaces of background are now exposed by removing the finishing coat, thus revealing the coloured plaster beneath, and following this the outlines of the rest of the design are scratched with an iron knife through the outer skimming to the underlying tinted surface. Sometimes the coats are in three different colours, such as brown for the first, red for the second and white or gray for the final coat. The pigments used for this work include Indian red, Turkey red, Antwerp blue, German blue, umber, ochre, purple brown, bone black or oxide of manganese for black. Combinations of these colours are made to produce any desired tone.

Internal Plastering.—Lime plastering is composed of lime, sand, hair and water in proportions varying according to the nature of the work to be done. In all cases good materials, well mixed and skilfully applied, are essential to a perfect result. When brickwork is to receive plaster, it is all-important that its surface should be rough enough to form a key or, alternatively, that the joints should be well raked out. Plaster is applied in successive coats or layers on walls or lathing, and gains its name from the number of these coats. One coat work is the coarsest and cheapest class of plastering, and is limited to inferior buildings, such as outhouses, where merely a rough coating is required to keep out the weather and draughts. This is described as "render" on brickwork, and "lath and lay" or "lath and plaster one coat" on studding. Two coat work is often used for factories or warehouses and the less important rooms of residences. The first coat is of coarse stuff finished fair with the darby float and scoured. A thin coat of setting stuff is then laid on, and trowelled and brushed smooth. Two coat work is described as "render and set" on walls, and "lath, plaster and set," or "lath, lay and set" on laths. Three coat work is usually specified for all good work. It consists, as its name implies, of three layers of material, and is described as "render, float and set" on walls and "lath, plaster, float and set," or "lath, lay, float and set," on lathwork. This makes a strong, straight, sanitary coating for walls and ceilings. The process for three coat work is as follows: For the first coat a layer of well-haired coarse stuff, about ½ in. thick, is put on with the laying trowel. This is termed "pricking up" in London, and in the U.S. "scratch coating." It should be laid on diagonally, each trowelful overlapping the previous one. When on

laths the stuff should be plastic enough to be worked through the spaces between the laths to form a key, yet so firm as not to drop off. The surface while still soft is scratched to give a key for the next coat, which is known as the second or "floating coat," and is ¼ to ⅜ in. thick. In Scotland this part of the process is termed "straightening" and in America "browning," and is performed when the first coat is dry, so as to form a straight surface to receive the finishing coat. Four operations are involved in laying the second coat, namely, forming the screeds; filling in the spaces between the screeds; scouring the surface; keying the face for finishing. Wall and ceiling screeds are plumbed and levelled. Screeds are narrow strips of plastering, carefully plumbed and levelled, so as to form a guide upon which the floating rule is run, thus securing a perfectly horizontal or vertical surface, or, in the case of circular work, a uniform curve. The "filling in," or "flanking," consists of laying the spaces between the screeds with coarse stuff, which is brought flush with the level of the screeds with the floating rule.

The "scouring" of the floating coat is of great importance, for it consolidates the material, and, besides hardening it, prevents it from cracking. It is done by the plasterer with a hand float which he applies vigorously with a rapid circular motion, at the same time sprinkling the work with water from a stock brush in the other hand. Any small holes or inequalities are filled up as he proceeds. The whole surface should be uniformly scoured two or three times, with an interval between each operation of from six to twenty-four hours. This process leaves the plaster with a close-grained and fairly smooth surface, offering little or no key to the coat which is to follow. To obtain proper cohesion, however, a roughened face is necessary, and this is obtained by "keying" the surface with a wire brush or nail float, that is, a hand float with the point of a nail sticking through and projecting about ⅛ in.; sometimes a point is put at each corner of the float. After the floating is finished to the walls and ceiling, the next part of internal plastering is the running of the cornice, followed by the finishing of the ceiling and walls.

The third and final coat is the "setting coat," which should be about ⅛ in. thick. In Scotland it is termed the "finishing," and in America the "hard finish" or "putty coat." Considerable skill is required at this juncture to bring the work to a perfectly true finish, uniform in colour and texture. Setting stuff should not be applied until the floating is quite firm and nearly dry, but it must not be too dry or the moisture will be drawn from the setting stuff.

The coarse stuff applied as the first coat is composed of sand and lime, usually in proportions approximating two to one, with hair mixed into it in quantities of about a pound to two or three cubic feet of mortar. It should be mixed with clean water to such a consistency that a quantity picked up on the point of a trowel holds well together and does not drop. Floating stuff is of finer texture than that used for "pricking up," and is used in a softer state, enabling it to be worked well into the keying of the first coat. A smaller proportion of hair is also used. Fine stuff mixed with sand is used for the setting coat. Fine stuff, or lime putty, is pure lime which has been slaked and then mixed with water to a semifluid consistency, and allowed to stand until it has developed into a soft paste. For use in setting it is mixed with fine washed sand in the ratio of one to three.

For cornices and for setting when the second coat is not allowed time to dry properly, a special compound must be used. This is often "gauged" stuff, composed of three or four parts of lime putty and one part of plaster of paris, mixed up in small quantities immediately before use. The plaster in the material causes it to set rapidly, but if it is present in too large a proportion the work will crack in setting.

The hard cements used for plastering, such as Parian, Keene's and Sirapite, are laid generally in two coats, the first of cement and sand ½ to ¾ in. in thickness, the second or setting coat of neat cement about ⅛ in. thick. These and similar cements have gypsum as a base, to which a certain proportion of another substance, such as alum, borax or carbonate of soda, is added, and the whole baked or calcined at a low temperature. The plaster they contain causes them to set quickly with a very hard smooth surface, which may be painted or papered within a few hours of its being finished.

Mouldings.—Plain, or unenriched, mouldings are formed with a running mould of zinc cut to the required profile. Enrichments to suit a scheme may be added after the main outline moulding is set, being cast in moulds of gelatine or plaster of paris. For a cornice moulding two running rules are usual, one on the wall, the other on the ceiling, upon which the mould is worked to and fro by one workman, while another man roughly lays on the plaster to the shape of the moulding. The mitres at the angles are finished off with joint rules made of sheet steel of various lengths, three or four inches wide, and about ⅛ in. thick, with one end cut to an angle of about 30°. In some cases the steel plate is let into a "stock" or handle of hardwood.

Cracks in plastering may be caused by settlement of the building, and by the use of inferior materials or by bad workmanship, but apart from these causes, and taking the materials and labour as being of the best, cracks may yet ensue by the too fast drying of the work, caused through the laying of plaster on dry walls which suck from the composition the moisture required to enable it to set, by the application of external heat or the heat of the sun, by the laying of a coat upon one which has not properly set, the cracking in this case being caused by unequal contraction, or by the use of too small a proportion of sand.

For partitions and ceilings, plaster slabs (often of fibrous plaster) are in very general use when work has to be finished quickly. For ceilings they require simply to be nailed to the joists, the joints being made with plaster, and the whole finished with a thin setting coat. In some cases, with fireproof floors, for instance, the slabs are hung up with wire hangers so as to allow a space of several inches between the soffit of the concrete floor and the ceiling. For partitions the slabs frequently have the edges tongued and grooved to form a better connection; often, too, they are holed through vertically, so that, when grouted in with semifluid plaster, the whole partition is bound together, as it were, with plaster dowels. Where very great strength is required the work may be reinforced by small iron rods through the slabs. This forms a very strong and rigid partition which is at the same time fire-resisting and of light weight, and when finished measures only from two to four inches thick. The slabs may be obtained either with a keyed surface, which requires finishing with a setting coat when the partition or ceiling is in position, or a smooth finished face, which may be papered or painted immediately the joints have been carefully made. Partitions are formed with one or other of the forms of metal lathing referred to, fixed to iron uprights and plastered on both sides.

Fibrous Plaster.—Fibrous plaster is given by plasterers the suggestive name "stick and rag," and this is a rough description of the material, for it is composed of plaster laid upon a backing of canvas stretched on wood. It is much used for ceilings, partitions, mouldings, circular and enriched casings to columns and girders, and ornamental work, which, being worked in the shop and then nailed or otherwise fixed in position, saves the delay often attendant upon the working of ornament in position.

Desachy, a French modeller, took out in 1856 a patent for "producing architectural mouldings, ornaments and other works of art, with surfaces of plaster," with the aid of plaster, glue, wood, wire and canvas or other woven fabric. The modern use of this material may be said to have started then, but the use of fibrous plaster was known and practised by the Egyptians long before the Christian era; for ancient coffins and mummies still preserved prove that linen stiffened with plaster was used for decorating coffins and making masks. Cennino Cennini, writing in 1437, says that fine linen soaked in glue and plaster and laid on wood was used for forming grounds for painting. Canvas and mortar were in general use in Great Britain up to about 1850. This work is also much used for temporary buildings.

It is a notable fact that after World War I the rise of plasterers' wages in Great Britain and the United States, combined with the great scarcity of skilled workmen and other considerations, led to a considerable increase in the use of substitutes for plasterwork.

Various "boards," made of woodpulp and other materials, ply-

wood and asbestos-cement sheets, have come largely into use for the finishing of walls and ceilings.

A later addition to the group of plasters is acoustical plaster. This material, which is heavily sound absorbent when properly worked onto the wall, will reduce objectionable echo. Either acoustical plaster or acoustical wallboard is needed to reduce echo for rooms over 50 ft. in length. Acoustical wallboard is usually considered to be somewhat more effective than acoustical plaster.

(L. C. M.; X.)

PLASTICS. The term "plastic," derived from the Greek πλαστικός, appears to have been used first as a suffix implying growing, developing and forming. Later it was used as an adjective meaning capable of being formed. The manufacture of pottery and earthenware depends on the plastic qualities of the clay; the making of glass and plastics and the use of putty, asphalt and cement are all dependent upon the plasticity of the product. Properly speaking, all these products should be considered in any description of plastics and the plastics industry, but the term "plastics" is much more highly restricted, although no unchallenged definition can be made of the word. It is used to describe a product of synthetic origin which is capable of being shaped by flow in some stage of manufacture and which is not rubber, wood, leather or metal.

Before the introduction of manufactured plastics, almost any material was pressed into service, especially those materials which could be cut easily and which would take on a high lustre on polishing. Among the products found useful were ivory, coral, tortoise shell, mother-of-pearl, amber, bone and horn. Out of ivory, numerous intricate carvings were made during all periods of history. Ivory lends itself readily to the manufacture of handles for cutlery, for brushes, combs, balls, toys and models. Amber was used in the form of beads and turned into ornaments and holders of various types. Buttons and handles were made out of bone; and combs, handles, drinking cups, powder horns and musical instruments were fabricated out of horn. Although these natural products do not require plasticity in their fabrication, they are consciously or otherwise classed with plastics. The reason that they are so considered may reside in the fact that these natural products may possess a type of residual plasticity or thermoplasticity which enables them to flow slightly from the heat generated during the polishing operation.

While the designation "plastic" is broader generically than the word "resin" (*q.v.*), both terms are used indiscriminately with respect to synthetic products. It is worthy of note, however, that general usage refers to cellulose derivatives as plastics and not as resins; and conversely, the synthetic resinous products, particularly those entering into the surface-coating field, are referred to as resins and not plastics. Doubtlessly, this distinction is again based on usage, since products of the resin class were primarily employed in the surface-coating field and the plastic characteristics were achieved by solution rather than by heat. The articles called plastics generally require shaping by heat during their fabrication by moulding or extrusion. Since the newer synthetic products can frequently be used interchangeably as coatings or as mouldings, the distinction between resins and plastics becomes less pronounced. Moreover, modern technology shows that the materials which are designated as rubber, fibres, resins and plastics are of a similar molecular structure, and by appropriate chemical and physical treatment it is possible to interconvert any one of these materials. It follows that certain structural features are common to all these products, and, being common, they relate to similarity in physical properties between materials which are not necessarily chemically related.

It might be argued that rubber is a plastic, since it can be fabricated by procedures similar to those employed in moulding plastics, but rubber is not generally considered to be a part of the plastics industry. Moreover, synthetic rubber is in a similar category, even though the preparation of the polymeric rubber molecule employs many of the processes developed for the preparation of resinous polymers. Similarly, the fibre industry is considered to be independent of the plastics industry, and here again the same raw materials, polyamides (nylon), cellulose and cellulose acetate are used by both industries. Plastics are also divorced from the self-supporting type of film production such as the manufacture of photographic film and cellophane. The term plastic, therefore, is essentially a commercial classification to which no strictly scientific definition can be applied.

HISTORY OF DEVELOPMENT

The modern plastics industry is an integration of many different and unrelated bodies of knowledge. One part of the development is derived from the fundamental investigations which were made into the chemistry, physics and biology of such high-molecular-weight natural products as natural resins, rubber, guttapercha, cotton, cellulose, ramie, pectins, chitin, starch, glycogen, wool, silk and hair. Initially, optical methods were used in order to investigate the nature of these products, and later ultramicroscopy was brought into play. Somewhat later colloidal chemical methods were developed and used in the study of the gross morphology of these substances. X-rays indicated that some of these natural products, such as cellulose, gutta percha and silk, were crystalline; other materials were amorphous; and still others were both crystalline and amorphous depending on the state of the product. Natural rubber (hevea) in the unstretched state was amorphous when examined by X-ray diffraction methods but it became crystalline when in the stretched state. As new technological tools were developed, they were also brought into use, and among the more powerful of these methods were the measurements of viscosity and the sedimentation of the products when they were subjected to extremely high centrifugal forces such as those developd by the ultracentrifuge. The idea grew that the natural products must of necessity be of a very high molecular weight.

Causes of Resinification.—In the preparation and synthesis of new compounds, materials would often resinify through unknown and uncontrollable reactions either during the course of the preparation or spontaneously after the product was formed and isolated. Other compounds were made where the transformation to the resinous and polymeric state could be followed and the various stages studied.

J. J. Berzelius in an article in the *Jahresbericht* of 1833 introduced the term "polymer." Naturally the definition which Berzelius presented underwent some later change. Initially, a polymer indicated the presence of the same atoms in the same proportion in compounds having different molecular weight. These conditions satisfy many compounds which are no longer considered polymers. The term "high polymer" is now restricted to high-molecular-weight compounds which are composed of simple molecules while the term "polymerization" (*q.v.*) relates to the process by which large molecules are synthesized from smaller ones.

In the same year (1833), nitrocellulose was prepared; H. Regnault in 1838 noted that vinyl chloride polymerized in sunlight and in the following year E. Simon polymerized styrene; J. Redtenbacher prepared acrylic acid in 1843; W. Caspary and B. Tollens in 1873 synthesized the methyl, ethyl and allyl esters, whereas G. W. A. Kahlbaum prepared the polymer of methyl acrylate in 1880. It is known that isoprene was prepared by G. Williams in 1860, and that it was polymerized by G. Bouchardat in 1879. R. Anshutz prepared polymers of itaconic-acid esters in 1881, and E. Frankland and B. F. Duppa discovered a method of making ethyl methacrylate from hydroxyisobutyric esters in 1865. Many condensation-type resins were also discovered during this interval, and many polyesters were also prepared, particularly those derived from glycerol and dibasic acids (*see* RESINS). The transformation of ethylene oxide from monomer to polymer was studied by M. A. von Lourenço, who showed that the boiling point and the viscosity increased progressively with molecular weight of the polymer. I. Ostromislensky maintained that there was a stepwise synthesis of rubberlike substances. Similarly it was observed that when glycine was condensed, there was obtained a series of products in which there was a regular change in the physical properties. The classical work of Emil Fischer in synthesizing numerous polypeptides out of simple amino acids is well known. Although Fischer showed that his synthetic product

possessed many of the properties of the hydrolytic products of naturally occurring proteins, it was generally considered that the natural products such as proteins, cellulose and rubber possessed unique properties of their own and one that was not shared by the products of the laboratory. The so-called "association theory" was advanced to account for the behaviour of the natural products.

Part of the dilemma of the different behaviour shown by natural and synthetic products was resolved by Hermann Staudinger in 1926. He demonstrated the inter-relationship existing between the structure as determined physically by X-rays and the size and structure of the polymer as determined chemically from analysis, as well as the size of the molecule determined by the nature and number of end groups existing in the high-molecular-weight compound. These various ideas were consolidated by Staudinger in his book which has now become a classic, *Die hochmolekularen organischen Verbindungen-Kautschuk und Cellulose*. In this treatise he shows the similarities which exist between polystyrene, a synthetic substance, and rubber (*Kautschuk*) and between the polyoxymethylenes and naturally occurring cellulose. He demonstrated that the products of the laboratory have many properties in common with the natural products and that the synthetic materials can be used as prototypes in evaluating the natural materials.

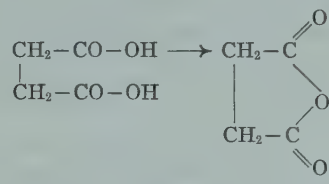
The causes of resinification of organic compounds remained obscure for a long time. The chemical reactions which led to resinification were unknown and the development was empirical. It was recognized very early that unsaturated compounds yielded resins and when the phenol-formaldehyde resins were first introduced, the same unsaturation hypothesis was advanced. The resin formation of phenol-formaldehyde resins was attributed to the polymerization of methylene quinones. Somewhat later the concept of "resinophoric" groupings (*e.g.*, azomethine $-C=N-$, carbodiimide $-N=C=N-$, conjugate unsaturation $-CH=CH-CH=CH-$, $-CH=CH-CHO$) was introduced by W. Herzog and I. Kreidl, and although the theory was shown to be untenable, it focused attention on the relationship of structure and it led to studies which revealed that there were essentially two chemical reactions responsible for resinification: one involving a condensation reaction, where the polymer differs from the starting material by the elements eliminated in the condensation; and a second involving a polymerization reaction, where the polymer and starting material have the same chemical composition. (*See* POLYMERIZATION.)

About the same time that Staudinger was conducting his investigations in Europe, studies were being made in the United States on various condensation-type resins, and the foundation was laid for the so-called functionality concepts which enabled a clear distinction to be made between the chemistry of the thermoplastic resins and the behaviour of the thermosetting type of product. Synthetic products made by W. H. Carothers using condensation reactions yielded fibrelike materials which possessed many of the crystalline properties which had been associated only with natural products.

In order that a chemical compound can be made to condense to a material of high molecular weight, it is necessary that each molecule of that compound contain two or more functional groups which can react with one another. When a compound contains molecules possessing only one functional group, these molecules on interaction will yield a product which can be, at best, twice as large as the molecules of the starting material. When a compound possesses molecules containing more than two functional groups, then each molecule can be joined to two other molecules. Preferably these functional groups should be at the ends of the molecule or at least so situated sterically that cyclization or intramolecular reaction cannot occur. These important steric or spatial configuration factors were first thoroughly evaluated by Carothers. When all of these requirements are met, it is possible for the functional groups to react with one another intermolecularly, leading to a reaction product containing long chains. These long chains are molecules of high molecular weight. When the product contains molecules having more than two functional groups, the reaction product which is formed by condensation leads to the formation of complex structures. It is such complex molecules which are responsible for the industrially valuable physical properties found in plastics.

The functional groups referred to above are simply any chemical groups which can react with others. For example, two organic acid molecules can react to form an anhydride (1, below). If the original starting molecule contains two acid groups and these groups are so situated sterically that ring formation can occur, then ring formation takes place without the formation of a high-molecular-weight compound; for example, succinic acid dehydrates to an anhydride (2). If, on the other hand, the acid groups are situated sufficiently far apart to preclude cyclization, such as are found in sebacic acid, polymeric, high-molecular-weight, linear anhydrides are formed (3).

$$2R-COOH \longrightarrow R-CO-O-CO-R + H_2O \qquad (1)$$



(2)

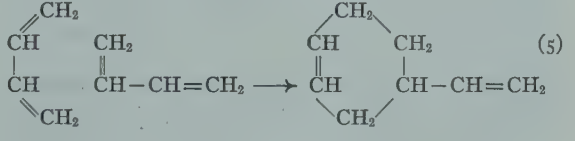
$$HOOC-(CH_2)_8-COOH \longrightarrow HO-CO-(CH_2)_8-CO-O-CO-(CH_2)_8-COOH \qquad (3)$$

Likewise, an alcohol and acid can react to form an ester. If a simple organic molecule contains an acidic group on one end and an alcoholic group on another, the initial condensation product that is formed still possesses a hydroxyl group and a carboxyl group which can react similarly to the starting materials (4).

$$HO-R-COOH + HO-R-COOH \longrightarrow HO-R-CO-O-R-COOH \qquad (4)$$

Such a condensation can proceed to yield a high-molecular-weight polymer. The unreacted end groups left over at the ends of such large molecules are referred to as "end groups."

A similar situation exists with respect to polymerization products. Under these conditions, cyclization to a low-molecular-weight compound can occur (5); or if the conditions are properly selected, a polymer of high molecular weight may result (6).



(5)

$$CH_2=CH-CH=CH_2 \longrightarrow (-CH_2-CH=CH-CH_2-) \qquad (6)$$

Later studies gave some insight into the molecular size and structure of the large molecules that are found in plastic materials. Minor changes during the preparation, and the addition of small amounts of other chemicals, may markedly change both the proportion and the distribution of the molecular species with the result that a new product of differing physical properties may be formed. Moreover, the same materials may under different chemical processing yield resins and polymers of widely different physical characteristics. By means of these two procedures innumerable types of resinous compositions can be produced. Since most of the plastic products depend on the chemical industry as their source of raw materials, it follows that as soon as a new chemical is developed it is immediately tested by plastic manufacturers to determine whether this new material may serve as a partial or a total replacement for the material now employed. The new materials are quickly introduced into the plastics industry, allowing the preparation of new products with different structures and different handling characteristics.

FABRICATING TECHNOLOGY

The development of moulding technology parallels the study of resinification, since it was only by fabricating the synthetic laboratory products that these materials could be turned into articles of commerce. The art of moulding developed following Charles Goodyear's discovery of the vulcanization of rubber about 1839; this involved the use of a simple hand type hydraulic press. This type of press came into use for all types of moulding operations where the mould is sufficiently light to warrant manual handling. With the development of phenolic resins, larger objects could be moulded, and this necessitated the improvement of compression moulding in order to increase the output of any individual mould. Automatic presses were developed and pins were incorporated into the mould itself to permit automatic ejection of the pieces from the mould. Where metallic inserts had to be introduced into the specimen during moulding, semiautomatic presses were constructed, enabling the introduction of inserts in an efficient manner. To eliminate error further and to speed production, automatic presses were fashioned which can measure the charge, preheat the charge, load it into the cavity, close the mould, mould the object, open the mould and eject the final piece. Still greater mould efficiencies are achieved by electronic preheating of the plastic prior to its introduction into the mould.

The conventional type of compression moulding is both awkward and expensive when applied to thermoplastic materials. Where compression moulding is used on thermosetting materials the mould can be kept at a uniform and constant temperature. During the moulding and curing operations chemical reaction occurs, causing the plasticity to decrease, with the result that the product is sufficiently rigid while hot to be ejected from the mould. Thermoplastic resins, on the other hand, do not undergo any chemical change, and after fabrication of the piece it is necessary to cool the mould in order to decrease the plasticity to the point where the object can be taken out as a single entity. The idea arose that if it were possible to inject the hot plastic into a cool mould, utilizing the procedure used in the die-casting of metals, it would obviate the periodic heating and cooling of the mould. It is of interest to note that the first experiments directed toward injection moulding were made by John and Isaiah Hyatt, who were also instrumental in first commercializing nitrocellulose (*see* below); but they abandoned the work. Later the technique of injection moulding was again revived, this time in Germany. The first presses had an injection capacity of from about 0.5 oz. to 1.5 oz. per cycle and were useful only for the manufacture of small objects such as buttons, combs and costume jewellery. Once the value of these presses was demonstrated and a suitable plastic composition developed, larger and larger presses were designed until it became possible to inject 32 oz. of plastic into a mould in a single cycle.

The advent of the injection type of equipment speeded up the production of thermoplastic resins, and in order to increase the mould capacity of the thermosetting resins a type of injection moulding was developed for the thermosetting type of material. This is known as transfer moulding. Since thermosetting resins remain plastic for only a very short time, they cannot be preheated in the manner employed for thermoplastic resins; the heating chamber must be loaded afresh for each cycle and the heated charge forced into a hot mould. Not only does transfer moulding decrease the time of moulding of certain objects, but it allows the introduction of inserts which sometimes cannot be introduced into conventional compression mouldings. The plastic enters the mould in a highly fluid state and will not displace or break such fragile inserts as glass and fine metal parts. Moreover, the separation of resin and filler are minimized by this type of moulding, and the resulting moulded objects are stronger, of more uniform density and freer of gas pockets.

A third type of moulding is the so-called extrusion type, which was used for many years in the rubber industry before it was applied to thermoplastic resins. The resin is fed from a hopper, thence to a screw conveyor where the resin is heated, whereupon it emerges from a die in a continuous strip in the form of the die opening. In order to minimize distortion, the heated plastic is frequently caught on a belt which travels at the same rate as the extruded object. By this means rods and tubing of various sizes and shapes can be produced efficiently.

Still another type of plastic fabrication is the process known as "pulp-preforming." By means of this procedure, resin and filler are deposited on suitable forms prior to moulding.

CELLULOSE PLASTICS

Nitrocellulose.—In 1833 Henri Braconnot, a professor of chemistry at Nancy, described the preparation of a "xyloidine," which he considered similar to lignin, by treating starch, sawdust and cotton with nitric acid. He found that this material was soluble in wood vinegar and attempted to make coatings, films and shaped articles of it. For those who are concerned with origins, it is in these early experiments that one can see the beginnings of both the plastics and the lacquer-coating industry. Somewhat later, in 1846, C. F. Schoenbein nitrated cotton, using for this purpose a mixture of nitric and sulphuric acids. He also found that he could dissolve the nitrocellulose in a mixture of ether and ethyl alcohol and this solution came to be called "ether glue." At the time, Schoenbein made the prediction that this nitrated cotton or explosive cotton wool would make a substitute for gunpowder. The explosive nature of this product attracted the attention of militarists all over Europe, and many governments and private individuals started extensive tests to adapt this smokeless powder to explosive use since, unlike ordinary gunpowder, it left no black smudge after firing. Because crude preparatory methods were employed, disastrous explosions occurred in many countries, with the result that the manufacture of the product began to be looked upon with disfavour.

These explosions had a salutary effect, however, in that the pressure and stimulus were removed from production and allowed leisurely scientific research into processes and means of stabilizing the product.

Investigations into various methods of conducting nitration indicated that several types of nitrated cotton might be made. The nitrocellulose possessing the highest degree of nitration, where the nitrogen content was more than 13%, was referred to as guncotton or explosive cotton; where the nitrogen content was from 12.6% to 12.8%, the material was referred to as pyrocollodion and where the nitrogen content was from 11.5% to 12% the materials were known as pyroxylin, collodion or photocotton. The nitration reaction is a very complicated one, involving a heterogeneous system of cellulose, nitric and sulphuric acids and water. Each constituent may play several roles which are both physical and chemical in nature, the reagents swelling as well as reacting with the cellulose.

While some attempts had been made to prepare coating compositions out of collodion, the first successful plastic was made by a young U.S. printer, John W. Hyatt. So great was the demand for ivory that the great elephant herds were being slaughtered in an attempt to supply the market. It was in 1863 that Phelan and Collander, manufacturers of ivory billiard balls, offered a $10,000 reward to anyone who might develop an adequate substitute for natural ivory. Working with his brother, Isaiah, John Hyatt prepared satisfactory billiard balls. Somewhat later the Hyatt brothers were granted a patent which described the process of dissolving nitrocellulose under pressure. Since very volatile liquids were employed as solvents, a great economy of materials resulted. Procedures for mixing the pyroxylin and camphor were disclosed in patents issued to the Hyatts between 1870 and 1872. Subsequently, 75 patents were taken out on various procedures for plasticizing nitrocellulose in order to produce the plastic. In 1870 the Albany Dental Plate company was organized by Hyatt and in 1871 the Celluloid Manufacturing company was formed. The immediate use of this material was for dental plate blanks; later the plastic was used in sheet form for automobile side curtains as well as the well-known celluloid collars. Toughness, flexibility and good appearance were the properties which enabled the material to be used for a wide variety of items such as combs, brush handles, spectacle frames and various novelty and decorative items.

In 1884 Count Hilaire de Chardonnet, a pupil of Louis Pasteur, deposited with the French Academy of Sciences a document entitled, "Artificial Textile Material Resembling Silk." The paper, which was opened in 1887, described the method of transforming guncotton into fibrous, silklike material. At the Paris exposition in 1899 he was awarded the grand prize for his discovery. The fibre left much to be desired inasmuch as it was highly inflammable, but it focused attention on the possibility of manufacturing synthetic filaments from a vegetable source.

As noted above, it was possible to dissolve nitrocellulose in ether and alcohol, and such collodion solutions could be cast into films. In the early days of photography, it was necessary to prepare the plate prior to exposure. Many descriptions have been given of the methods employed by the early photographers using their so-called "wet" collodion plates. The solvent combination was extremely volatile, making it difficult to secure uniform films free from "blushing." After the development of the dry-process plate, the next logical step was the elimination of the glass support for the nitrocellulose. Such a nitrocellulose film was demonstrated at a photographic exhibition held in Paris in 1881.

The discovery by John H. Stevens that amyl acetate could be used as a solvent for nitrocellulose was made in 1882. This solvent proved to be far superior to anything used previously and enabled uniform films to be formed without haze. The first successful attempt to secure transparent flexible film for photographic purposes was made by H. Goodwin of Newark, N.J., during the years 1887–98. A somewhat similar process was developed independently by H. Reichenbach in 1889. Further work resulted in processes which allowed the nitrocellulose to be fabricated in continuous fashion, enabling the production of suitable base for both still and motion-picture photography. Another important use for nitrocellulose in sheet form was in safety glass. Sheet nitrocellulose was laminated between glass sheets forming a glass-plastic sandwich. The nitrocellulose film discoloured rapidly, however, and was eventually superseded by other, more light-stable plastics; but it served as an invaluable guide and established the importance of safety glass in the automotive industry.

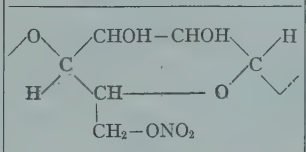
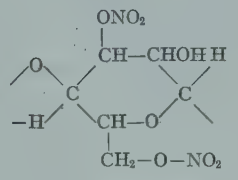
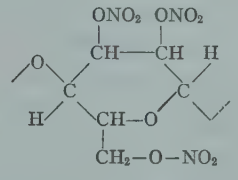
Prior to World War I, Russia supplied the largest volume of fusel oil. This oil, remaining after the distillation of grain alcohol, was the raw material used in the synthesis of amyl acetate. Following the loss of this source of supply during the Russian Revolution, and with the loss of additional supplies caused by the enactment of the U.S. prohibition laws, the amount of this potential lacquer solvent became vanishingly small. New solvents for nitrocellulose were being developed rapidly, however. During 1920–23 the butyl-alcohol process was perfected by Chaim Weizmann, and about the same time anhydrous ethyl acetate made its appearance. Moreover, other plasticizers than camphor were being developed. Tricresyl phosphate was prepared in 1920 and triacetin in 1921, and both materials weakened the grip of the camphor monopoly which had been notorious in manipulating the price of the product.

Since the theoretical nitrogen content for mono-, di- and trinitrated forms of cellulose are 6.77%, 11.3% and 14.16%, respectively (*see* Table I), it can readily be seen from the nature of the manufactured products that the most valuable nitrocellulose plastic compositions contain from two to three nitrate groups per glucose residue in the cellulose molecule. Explosives are made from those materials having from 12.2% to 13.8% of nitrogen; lacquers and films from 11.5% to 12.2% and plastics from 10.5% to 11.5%. The properties of the nitrocellulose thus secured are dependent not only upon the degree of nitration but also on the uniformity of nitration of the cellulose molecule. Moreover, the length of the chain of the nitrocellulose molecule is very important since the longer the chain—that is, the larger the x in the equation below—the more viscous the solution of nitrocellulose in organic liquids. The reaction leading to cellulose trinitrate may be expressed by the equation:

$$[C_6H_7O_2(OH)_3]_x + 3x\,HNO_3 \longrightarrow [C_6H_7O_2(ONO_2)_3]_x + 3x\,H_2O. \qquad (7)$$

For coating applications high-viscosity lacquers are a disadvantage since only thin films can be deposited, and large and excessive amounts of solvent are required. The viscosity of the nitrocellulose can be controlled to some extent by selecting the source of the cellulose and by modifying the nature of the nitration. The most important means of controlling the viscosity of the nitrocotton, however, is by chemical treatment; and while it had been observed that certain materials such as ammonia and metallic salts had the property of decreasing the viscosity of nitrocellulose, it was found that the most certain method for securing a low-viscosity nitrocellulose was by treating the product with water under pressure.

TABLE I.—*Relation between Nitrogen Content and Degree of Nitration of Cellulose*

Ester	Formula	% Nitrogen
	$C_6H_7O_2(OH)_2ONO_2$	6.77
	$C_6H_7O_2(OH)(ONO_2)_2$	11.30
	$C_6H_7O_2(ONO_2)_3$	14.16

Several factors contributed to the greatly expanded use of nitrocellulose immediately following World War I. Some idea of the expansion can be seen from the fact that the consumption of these materials jumped from 1,000,000 lb. in 1922 to more than 20,000,000 lb. in 1929. These developments could be traced to: (1) the availability of desirable solvents at relatively low cost; (2) to the large quantities of nitrocellulose on hand following termination of the war; (3) the development of a method for preparing lacquers possessing a high solids content with relatively low viscosity; and (4) the tremendous demand for rapid-drying finishes by the rapidly expanding automotive industry. Through the use of a combination of nitrocellulose with alkyd resins, it was possible to decrease the time of finishing of an automobile body from weeks to a matter of hours.

For plastic manufacture, the nitrocellulose or pyroxylin is admixed with alcohol together with camphor, either natural or artificial, and kneaded into a doughlike mass. Colouring matter is added, either in the form of dyes for transparent colours, or as pigments for opaque colours. The coloured masses are rolled to discharge some of the volatile solvent, sheeted and pressed into blocks. After seasoning, the blocks are sliced; then they are either further fabricated, or the process is repeated for various mottled and variegated effects. The sheets may be moulded and when sufficiently soft may be fashioned by "blow moulding" into hollow objects. Rods and tubes are fabricated by extrusion. Artificial leather is made by painting fabrics with nitrocellulose solutions and then stamping or embossing the surface after discharge of the solvent.

Despite its obvious disadvantages of inflammability, discoloration on aging and limited tolerance to heat and to strong organic solvents such as alcohols, ketones and esters, the nitrocellulose plastic is colourful, tough, flexible, of good appearance and resistant to wear, water and humidity. It is easy to fabricate into

many diverse forms and finds wide acceptance for billiard balls, piano keys, mirror and spectacle frames, combs, brush handles, machine keys, radio dials and various novelty and decorative items.

The various developments of nitrocellulose in fibres, films, coatings and plastics paved the way for further advances for newer materials which did not possess the disadvantages enumerated above, and the technology used in nitrocellulose was a useful guide in the processing of new products. Most important, the success of nitrocellulose indicated that a market existed for plastic products.

Cellulose Acetate.—The deficiency inherent in nitrocellulose for plastic use brought up the possibility of adapting other esters of cellulose, particularly the esters of organic acids. Paul Schützenberger acetylated cellulose in 1865 and A. Franchimont in 1879 found that the esterification reaction could be catalyzed by sulphuric acid. In 1894 C. F. Cross and E. J. Bevan, working in England, patented a process for preparing a chloroform-soluble type of cellulose acetate. The most important commercial development was made by G. W. Miles in 1903–05 with the discovery that if the highly acetylated cellulose was subjected to hydrolysis, it became transformed to a less highly acetylated compound which was soluble in cheap organic solvents such as acetone. In 1911 Henry Dreyfus perfected a manufacturing process for the preparation of the acetylated compound and its hydrolysis. The same basic process is employed in the manufacture of the cellulose acetate as that employed in the manufacture of a nitrate with the exception that the anhydride is used as the esterification reagent with the net result that acetic acid is the by-product rather than water.

$$[C_6H_7O_2(OH)_3]_x + 3x\ (CH_3CO)_2O \longrightarrow [C_6H_7O_2(OCOCH_3)_3]_x + 3x\ CH_3COOH. \qquad (8)$$

The cellulose acetate with an acetate content of about 62.5% is then hydrolyzed, precipitated, washed and dried. This process of hydrolysis can be conducted on the acetate in the fibrous form or in solution. In order to bring out the full toughness of the product, the fibrous acetate is colloidized with plasticizers. These are high-boiling liquids possessing a low vapour pressure and having solvent or gelling action on the plastic. Among the more useful plasticizers are such materials as dimethylphthalate, diethylphthalate and dimethoxyethylphthalate. Depending on its ultimate use as a film, moulding powder or safety glass, different quantities, amounts and types of plasticizers are employed, allowing one type of polymer to fill many diverse applications.

The first use for this material was in the so-called "safety film" for photographic use. The acetone-soluble cellulose acetate found extensive use in World War I as the "dope" for coating aircraft wings because it was much less inflammable than nitrocellulose. After the war the excess plant capacity found a ready market for cellulose acetate as an acetate rayon. However, another very important development, the new procedure for moulding thermoplastic resins mentioned above, was occurring simultaneously. It was found that the acetate was particularly amenable to being moulded by injection, and the cellulose-acetate plastic was given a new impetus by this rapid and efficient means of fabrication. The acetate was preferred since the nitrate could not be subjected to the same temperature conditions required in injection moulding. Cellulose acetate became widely used in the automotive industry because of its mechanical strength, toughness, wear-resistance, transparency and ease of mouldability. The high resistance to impact made it a desirable material for protective goggles, tool handles, oil gauges and the like.

Since the cellulose acetate did not discolour as did the nitrate on exposure to light, it was far more suitable for safety-glass manufacture; and, while its resistance to water was not all that could be desired, the laminated safety glass found favour, especially when precautions were taken to edge-seal the assembly in order to prevent access to moisture. Such safety glass became accepted and in time definitely made the public safety conscious.

Cellulose Acetobutyrate and Other Esters.—Since one of the more serious limitations of cellulose acetate lies in its poor resistance to moisture and weathering, attempts were made to use longer, less water-soluble organic acids for esterification purposes. The use of mixed acids was not overlooked, with the result that it was found that a mixture of butyric and acetic acids (as anhydrides) yielded mixed esters which were very similar in properties to the acetate but possessed much better moisture resistance, better weathering and superior adhesion. When moulded by injection, cellulose acetobutyrate required somewhat less pressure than acetate and yielded better welded joints.

Other cellulose esters were prepared commercially. During World War II processes for the manufacture of propionic acid (and anhydride) were developed, and cellulose esters made from this acid appeared on the market. Since propionic acid contains three carbon atoms, it is intermediate between acetic and butyric acids. It follows that the cellulose propionate possesses many excellent properties similar to those exhibited by the acetobutyrate as well as many characteristics of its own, particularly a shorter moulding cycle and easier machining qualities. Cellulose benzoate was manufactured in Germany but the material did not find a market in the U.S.

Cellulose Ethers.—Since cellulose is a polyhydric alcohol, it can be made to undergo etherification reactions as well as the esterification reactions mentioned above. Ether linkages cannot be saponified; so it is not surprising to find that the cellulose ethers are among the more stable of the cellulose derivatives. The idea of ethylating cellulose was first conceived by W. von Suida in 1905 with the primary object of changing the affinity of cellulose for dyestuffs. The cellulose ethers were studied simultaneously by Leon Lilienfeld in Austria, Otto Leuchs in Germany and Henry Dreyfus in France. It was found that the cellulose ethers and in particular ethyl cellulose were soluble in organic liquids and possessed potentialities in plastic as well as in lacquer and in rayon applications.

Ethyl cellulose was first produced commercially in Germany and it was not until 1935 that large-scale production was undertaken in the U.S. The alkali cellulose—a mixture of cellulose and caustic soda—is reacted with either ethyl chloride or with ethyl sulphate until the desired ethoxy content is secured. While it is possible to introduce three ethoxy groups into each glucose segment in the cellulose molecule, it has been found that only those products which contain from 43.5% to 49.5% ethoxy content are of commercial interest. This degree of ethylation amounts to from 2.15 to 2.58 ethoxy groups per glucose residue. Those ethylcellulose derivatives possessing from 47.5% to 50% ethoxy content exhibit the greatest solubility in organic liquids as well as the best compatibility with other film-forming materials. However, ethyl cellulose possessing somewhat lower ethoxy content (from 45.0% to 47.5%) yields harder films and plastics which have less tendency to flow at elevated temperatures. The chief uses of ethyl cellulose are in coating, in adhesives and as plastics possessing a high degree of toughness over a wide temperature range.

Many other cellulose ethers are known. The methyl cellulose, glycol cellulose and cellulose glycolic acid prepared respectively from methyl sulphate (or chloride), from ethylene oxide (or chlorohydrin) and from sodium monochloroacetate are dispersible in water and have found use as sizing and finishing agents in the textile industry.

OTHER NATURAL PRODUCTS AS PLASTIC MATERIALS

Casein Plastics.—Casein (the protein derived from milk) was condensed with formaldehyde by A. Spitteler and W. Krische to form a tough, insoluble mass which could be fabricated readily. Production of this plastic was begun shortly after 1900 in Germany and France and in 1914 in England under the name of Galalith (milk stone). When the monopoly was broken during World War I, manufacture was undertaken in the U.S. in 1919. At the time the casein plastic came into prominence it possessed an immediate advantage over the competitive products inasmuch as it was much less inflammable than nitrocellulose and could be fabricated into objects of lighter colour than was possible with the phenolic resins. When an attempt was made to introduce the

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COMMON SMALLER ARTICLES OF PLASTICS

From left to right, top to bottom: kitchen clock (acetate), fabric (saran), trays (acetate), electric shaver (phenol and urea), small juice extractor (styrene), date stamp (phenol), measuring cup (urea), egg holders (acetate), salad spoon and fork (acetate), strainer (acetate and urea), salt and pepper shaker (acetate), doorknob (styrene), keyhole flashlight (below salad fork) (urea), fishing tacklebox (to right of salad spoon and fork) (acetate), card box (acetate), strips of extruded moulding (acetate and butyrate), cigarette holder (acrylic), transparent funnel (polystyrene)

casein plastic into the United States, the limitations of the material became apparent, especially under the extremes of humidity encountered. The result was that the product was wholly unsuited for electrical fixtures and other applications requiring some degree of dimensional tolerance. The limitation of the composition, and the advent of synthetic resins which could be handled more rapidly and did not possess the limitations inherent in the protein plastic, gradually restricted the use of casein plastic until the only large outlet for the product was in the manufacture of buttons from alum-hardened casein.

Shellac.—This natural resin finds use in the manufacture of moulding compositions, particularly phonograph recordings. In many respects shellac is an ideal plastic binder for certain types of electrical equipment and communication instruments. The resin is often used by itself as well as in combination with such fillers as flaked mica and asbestos.

SYNTHETIC RESIN PLASTICS

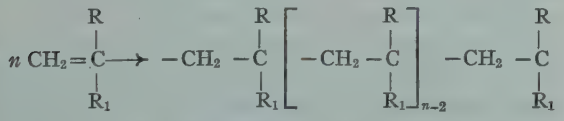
Synthetic resins can be grouped into many different arrangements but one generally accepted classification involves the designation "thermoplastic" and "thermosetting" types of resins. The thermoplastic resins are characterized by their ability to remain plastic after numerous heating treatments, while the thermosetting or thermocuring resins are not susceptible to repeated heating cycles and, once heated, are converted to a cured or infusible form which cannot be fused again without serious chemical degradation. From the molecular structural standpoint, the thermoplastic resins are characterized by molecules which are essentially linear or threadlike in form, while the thermocuring resins consist of molecules which are considered to be linked three-dimensionally into a network arrangement. Resins may also be classified by the chemical means employed to effect reaction. Certain resins formed without the elimination of volatile components are generally referred to as the polymerization type. Where volatile ingredients such as water and alcohol are formed during the resin preparation, this type of product can be considered a condensation resin. When the chemical and physical types are superimposed, it is possible to have the grouping:

1. Thermoplastic condensation resins
2. Thermoplastic polymerization resins
3. Thermocuring condensation resins
4. Thermocuring polymerization resins

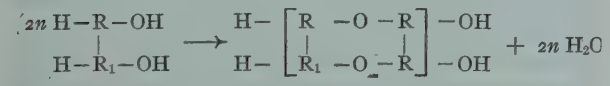
The equations leading to the formation of these various types may be written schematically as follows:

$$2n\ H-R-OH \longrightarrow H-[R-O-R]_n-OH + n\ H_2O$$

Linear polymer formed by condensation reaction



Linear polymer formed by loss of unsaturation



Network polymer formed by condensation reaction

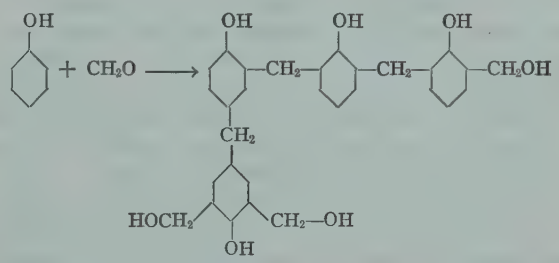
Network polymer formed by loss of unsaturation

Generally the thermocuring resins will tolerate substantial quantities of inert fillers such as cellulose flock, wood flour, asbestos and the like, whereas the thermoplastic resins are fabricated clear or when fillers or opacifiers are used, the quantity employed is much less than with the thermosetting type of resin. Different methods of fabrication are utilized with thermoplastic and thermosetting resins since chemical changes occur during the moulding of thermocuring resins, whereas physical changes predominate in the moulding and extruding of thermoplastic resins.

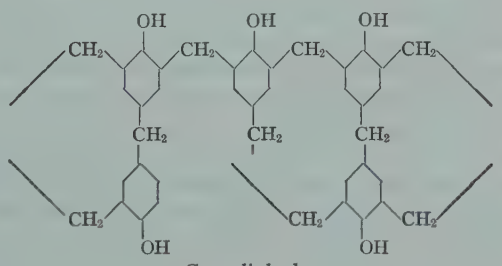
Thermosetting Resins.—*Phenol-Formaldehyde Resins.*—When Leo H. Baekeland offered the phenol-formaldehyde resins in 1909, the value of nitrocellulose plastics sold annually in the U.S. was more than $5,500,000. Irrespective of the fact that the pyroxylin plastic was well established, this new material found a ready market because, unlike the nitrocellulose product, the phenol-formaldehyde resin could be made insoluble and infusible. Moreover, unlike the thermoplastic material, the thermosetting phenolic condensation product would tolerate considerable amounts of inert ingredients or fillers and, in much the same manner that the thermoplastic materials could be changed by the incorporation of various plasticizers, the thermosetting resins could be modified through the incorporation of various fillers.

In some respects, this resin-filler combination was being exploited prior to Baekeland's entrance into the plastic moulding field. Various coal-tar residues were mixed with asbestos and silica and these resins were moulded under pressure and subsequently heated outside the mould to further the reaction. Since a great deal of curing does not occur, the strength of such cold-moulding compositions was not very high. When the phenolic binder became available, however, and when it was substituted for the bituminous binder, the moulded piece took on a much better finish and possessed increased strength.

In making phenolic moulding powders, phenol and formaldehyde are heated in the presence of suitable catalysts, generally acids, and the condensation is conducted to the stage where the water separates. The viscous phenolic condensation product on cooling to room temperature becomes hard and brittle. The resin at this stage is soluble and can be dissolved in various organic liquids; such solutions are employed for laminating and impregnating purposes. The structure can be represented schematically as follows:



Intermediate condensation product



Cross-linked

In order to make the moulding compound, the resin is ground and mixed with appropriate filler, lubricants and dyes. To render the combination as homogeneous as possible, the mixture is milled and then ground. For general use, wood flour is the preferred filler, but where heat resistance, impact strength or electrical characteristics are involved, other fillers such as cotton flock, asbestos and chopped fabric are used. The resin, because of its excellent insulating characteristics, enters into the manufacture of radio parts such as sockets, binding parts, knobs and dials, and into the electrical system of the automobile in the form of distributor

heads, coil parts, switches, magnetos, instrument-housing panels and the like.

Where the resin is to be cast, the initial condensation of the phenol and formaldehyde is heated with alkaline catalysts in such a way as to hold the water which is formed in the condensation as a suspension in the resin. The reaction mixture is subjected to reduced pressure whereby the water of condensation is removed without phase separation. Where opaque castings are desired, the viscous resin is poured directly into moulds made of either rubber or lead. Hardening is allowed to take place from one to two days at moderately elevated temperatures. During curing of the resin, the water which is evolved forms droplets which are large enough to interfere with the transmission of light. Where clear castings are required, suitable modifiers are added to the resin prior to the introduction into the mould. These modifiers cause the water which is formed in the final cure to assume a size smaller than the wave length of light and, being of such dimensions, the particles do not interfere with the transmission of light. Such castings are clear. Mottled effects can be secured by appropriate mixing of coloured viscous resins prior to the introduction into the mould. The castings are machined and polished to objects possessing a high degree of lustre and brilliance.

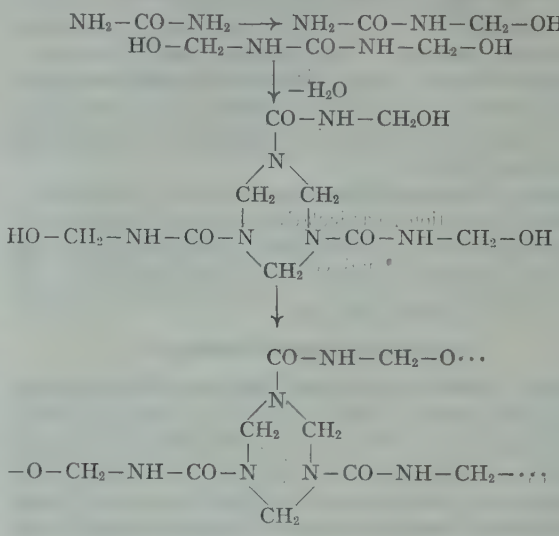
For laminated structures, the resin in alcoholic solution is used to impregnate either paper or fabric. After impregnation the sheets are dried, consolidated and subsequently heated under pressure to form a rigid, tough assembly of high strength and good electrical properties which can be machined and fabricated. Power transformers, timing gears, cams, clutches, fan belts and many other materials can be made from such structures. When fabric is substituted for the paper, similar laminated compositions are made which can be machined to form gears and bearings.

Lignin, which is the bonding agent of wood and other cellulosic derivatives, has been isolated from certain intermediates from paper manufacturing. The lignin resins have been used as extenders for phenolic resins, particularly those entering into varnishes, moulding resins and adhesives.

Phenol-Furfural Resins.—Furfural is an aldehyde which is derived from waste farm products such as the hulls of oats, rice and cottonseed and corn husks. This aldehyde will condense with phenol to produce a resin similar to that secured from phenol and formaldehyde. The plastic properties of the two compositions differ, however, in that the furfural product possesses a long period of flow at low temperatures; this property enables it to be used in certain types of intricate mouldings.

Urea-Formaldehyde Resins.—The resins derived from urea and formaldehyde have been considered truly synthetic materials inasmuch as all the basic materials are derived from gases. These gases are ammonia, carbon dioxide, carbon monoxide and hydrogen. Reaction of ammonia and carbon dioxide under pressure yields urea, whereas the reduction of carbon monoxide results in the formation of formaldehyde. Condensation of urea with commercial formalin (aqueous solution of formaldehyde) yields the water-soluble intermediate condensation products known as mono- and dimethylolurea, which on further reaction form water-soluble, resinous condensation products.

The intermediate water-soluble resins are starting materials for the production of resin, adhesives, surface coatings and moulding powders. Initially, glass-clear products were produced and extensively investigated as substitutes for glass and were often referred to as "organic glass." While the initial products were clear and brilliant, they quickly deteriorated on aging. Part of the difficulty resided in the ability of the plastic to absorb water from a humid atmosphere and then to release the water when the moisture content of the atmosphere decreased. This "breathing" of the plastic resulted in some loss of transparency and glasslike clarity. Furthermore, on prolonged standing, cracks and fissures developed in the surface of the resin, probably arising from liberation of water and formaldehyde through further condensation occurring in the colloidal mass; these fissures further decreased the transparency and limited the strength of the product since, on impact, the surface fracture acted as a focal point for the transmission of energy into the interior of the specimen. The glasslike product was extensively investigated by Hanns John and by Heiner Ramstetter and by Fritz Pollak and Kurt Ripper during



the decade following World War I, but attempts to commercialize the product were unsuccessful.

The combination of the urea-formaldehyde resin with various fillers was investigated by many chemists, but the combination of cellulose and resin has been generally associated with the development work of Carleton Ellis in the U.S. A parallel development occurred in England, however, where because of lack of timber, Norwegian pulp was imported and used. The introduction of fillers destroyed the transparency of the product but the resin-filler combination, when suitably compounded with flow promoters, plasticizers, lubricants, accelerators and catalysts, could then be moulded in steel dies under heat and pressure to insoluble and infusible products possessing a wide utility. Manufacture of one of these materials began in the U.S. in 1929. The plastic can be produced in any colour, from translucent and colourless to ivory and pure white, through pastels and brilliant hues to jet black. In thin sections the natural uncoloured combination of urea and cellulose transmits light in a highly diffused state, and by altering the thickness and pigmentation, the reflection and transmission can be modified at will. Among the widespread uses of the moulded product, aside from its value in luminaries, are in the manufacture of closures, buttons, wall plates, instrument dials, display boxes, dress accessories and housings of all types.

The resin in solution form possesses many other applications aside from impregnating filler to make moulding compositions. The resin solutions are used in the preparation of cements which can be hardened hot or, through the proper addition of catalysts, may be set cold. When the water-soluble resin is suitably dispersed in organic solvents, it forms the basis of a very important class of resin finishes and enamels for metal coating. As an impregnant for wood veneer, the water-soluble condensation products serve both as a binder and a protective coating. Since the resin is colourless, the cured resin materially enhances the beauty of the wood. The solutions are also used to treat textiles in order to control their shrinkage and render them crease or crush resistant.

In the manufacture of laminated stock, sheets of absorbent paper are impregnated, dried and assembled to appropriate thickness and then heated between platens to yield a sheet stock which has found utility in lighting reflectors, signs, wall panels, table tops and decorative murals.

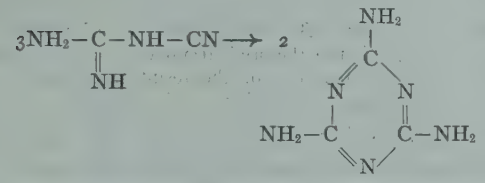
Melamine-Formaldehyde Resins.—Prior to 1939 melamine was practically an unobtainable rare chemical compound which could be secured only in limited amounts at $40 a pound. Although the compound was rare, it was not new and unknown. It had been known and characterized for more than 100 years and had been first prepared in 1834 by the famous chemist Justus von Liebig.

After 1939, melamine became a commercial article made in ton quantities, and like urea it is secured from the air. Combination of the nitrogen in the air with calcium carbide yields calcium cyanamide, which can be hydrolyzed to cyanamide and dimerized to dicyandiamide. Under high temperature and pressure dicyandiamide is transformed to melamine, an extremely stable substance containing only carbon, hydrogen and nitrogen in its chemical structure. These reactions can be represented by the following chemical equations:

$$CaC_2 + N_2 \longrightarrow CaCN_2 + C$$

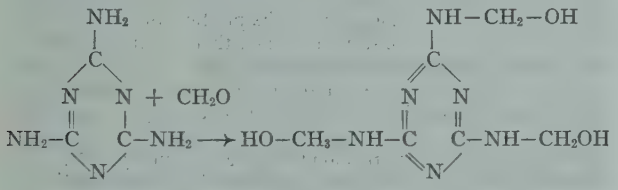
$$CaCN_2 + 2H_2O \longrightarrow Ca(OH)_2 + NH_2-CN$$

$$2NH_2-CN \longrightarrow NH_2-C(=NH)-NH-CN$$

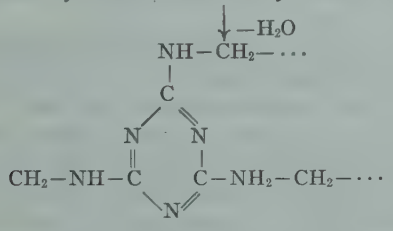


Preparation of melamine from calcium cyanamide

Condensed with formaldehyde, melamine forms products which in superficial respects resemble the condensation products of urea but, where only mono- and dimethylolureas have been prepared, a much wider number of the initial melamine-formaldehyde condensation products are known. Di-, tri- and hexamethylol melamines have been prepared.



Melamine formaldehyde Trimethylol melamine



Network condensation of melamine with formaldehyde

The melamine resin is not so sensitive to alkalies and can tolerate fillers which cannot be used with the urea condensation product. One of these fillers is the mineral asbestos. Because of their excellent heat and arc resistance, good dielectric strength and low water pickup, mineral-filled melamines suitably modified with other resins were used in ignition systems, particularly in the large distributor heads in military aircraft where, under the reduced pressures at high altitude, flash-over and tracking are especially troublesome. The mineral-filled materials may also be used where other unusual performance characteristics are required such as in the automotive ignition parts of trucks, tractors and automobiles.

Cellulose-filled melamine plastics have been used in many of the applications already discussed for the urea resins, but since the melamine resin is more resistant to high temperatures, to boiling water and to more alkaline solutions, and since it does not retain food odours, it is particularly useful in tableware. The melamine resin possesses extreme hardness and this, together with its good colour and abrasion resistance, makes it an invaluable material for surfacing of laminated assemblies. Translucent mouldings may be made and are applied to button manufacture.

Anhydrous Thermosetting Resins.—The thermosetting resins used for laminating and moulding depend on the loss of water to effect insolubilization. In order that this water content be as small as possible, the resin is carried to an advanced stage of condensation where considerable heat and pressure must be utilized to cause the resin to flow sufficiently to fill the mould. During World War II, new types of products appeared which did not involve the loss of water to bring about insolubility and infusibility of the resin. These compositions have been referred to as anhydrous thermosetting resins and solventless varnishes, while the process has been called low-pressure or contact moulding. They belong to the class of thermocuring polymerization type of resins. Irrespective of the name, all of these resins have one characteristic in common: the polymerizable molecules possess a plurality of unsaturated groups and undergo reaction to insolubility quickly and exothermically without the evolution of low-molecular-condensation residues. The unsaturation can be introduced into the initial molecule by the incorporation of either unsaturated acid residue or unsaturated alcohol residues or both. The polymerization is generally catalyzed by peroxides. The physical state of the anhydrous thermosetting resins can be varied within wide limits; some are thin fluids, other viscous liquids, whereas still others are solid or greaselike in consistency. Since only low pressure is required in fabrication, comparatively inexpensive moulds can be utilized. In many instances, the fluid-moulding technique may be employed for making complex shapes; this procedure depends on delivering pressure uniformly over a large area through the use of rubber bags, and by such means large structural parts of aeroplanes and boats have been built. When such rigid sheets of plastics are laminated into a cellular or honeycomb core, highly rigid and lightweight combinations can be produced which possess good strength and insulating characteristics.

Thermoplastic Resins.—*Vinyl Resins.*—As noted above, acetic anhydride is required in the manufacture of cellulose acetate. Following World War I various methods were investigated for processes which might be used to convert the acid to the anhydride since it was anticipated that large quantities of this cellulose plastic would be required in the manufacture of fibre, film and safety glass. Among the methods investigated for the manufacture of acetic anhydride was the reaction of acetic acid with acetylene to form ethylidene diacetate, which in turn could be decomposed to acetic anhydride. In conducting the reaction between acetylene and acetic acid, investigators obtained substantial quantities of an organic liquid which was too low boiling to be the desired product. This liquid was monomeric vinyl acetate. Although the investigation was directed primarily to the preparation of an acetylating agent, vinyl acetate was in time destined to be the basis of the manufacture of most of the plastic for use in safety glass.

Polyvinyl Acetate Resins.—The transformation of vinyl acetate ($CH_2=CH-O-CO-CH_3$) to a safety glass interlayer did not occur all at once, however. Manufacture of the early product was difficult because little was known concerning the chemistry of transformation of a vinyl monomer to its polymer. Moreover, the early development was hazardous from a commercial standpoint since there were no uses for such a resinous product. It was first investigated as a shellac substitute, but its remarkable adhesive properties, when hot, made it invaluable for uniting many diverse materials such as cloth, paper, leather, wood and glass. Compounded with fillers, glycerine, sugar and flavouring, polyvinyl acetate makes an acceptable chicle substitute in the manufacture of chewing gum. Hydrolysis of the polyvinyl acetate causes cleavage of the ester grouping resulting in the formation of polyvinyl alcohol,

$$-(CH_2-\underset{\displaystyle O-CO-CH_3}{\underset{|}{CH}}-)_x \longrightarrow (-CH_2-\underset{\displaystyle OH}{\underset{|}{CH}}-)_x$$

a resinous polymeric alcohol that forms viscous solutions in water and finds some utility as a thickening agent for emulsions and in the preparation of plastics which, although sensitive to water, are highly resistant to oils. Polyvinyl alcohol can be spun into a fibre, and although the fibre is soluble in water, special uses can be made of this solubility in the weaving of sheer laces; fibres of

polyvinyl alcohol and any other fibre can be woven and the synthetic water-soluble fibre dissolved, leaving a sheer fabric which would be difficult to approach by mechanical means alone.

Many chemical transformations of polyvinyl alcohol are possible. It can be condensed with other low-molecular compounds, particularly aldehydes, to form new resinous materials. Condensation with formaldehyde, acetaldehyde and butyraldehyde results, respectively, in polyvinyl formal, polyvinyl acetal and polyvinyl butyral. The polyvinyl formal finds use as a coating resin for electrical insulation; the acetal possesses potentialities as a photographic film base and as an injection-moulding material; but it is the butyral which possesses the most outstanding utility, and as much as 100,000,000 sq.ft. has been produced annually for safety-glass manufacture. The resin when suitably plasticized yields a tough, high-impact film which maintains its properties at low temperature, and when laminated between glass yields a composite assembly which possesses little tendency to yield flying splinters on impact.

Polyvinyl Chloride Resins.—Vinyl chloride is a gas at room temperature and can readily be prepared from either ethylene or acetylene. Addition of hydrogen chloride directly to acetylene yields the monomer, or ethylene can be chlorinated and dehydrohalogenated to vinyl chloride. The polymerization was extensively studied by Ostromislensky, who sought to dehalogenate the polymer to a rubberlike substance. Polyvinyl chloride was transformed to a rubber substitute about 20 years after these basic investigations but by an entirely different procedure.

Polymeric vinyl chloride, $-(CH_2-CHCl)_x-$, is practically infusible and for a long time proved to be a rather intractable substance. In efforts to plasticize the product it was milled and compounded with polyvinyl acetate, mentioned above, but with no great degree of success until it was found that by mixing the ingredients prior to polymerization and then chemically combining the two materials into a polymeric structure, it was possible to achieve in this conjoint polymer or copolymer a new type of product which was easier to handle and one which could be further flexibilized through the addition of high boiling liquids and plasticizers. By varying the ratio of acetate to chloride, resins of varying plasticity and stiffness can be secured.

Intensive investigations were made into the nature of plasticization methods and techniques of direct plasticization of vinyl chloride without the necessity of copolymerization. It was generally conceded, however, that the copolymer is amenable to plasticization by a larger number of widely diverse liquids than is the unmodified polymer. Both types, however, have found extensive use as sheet stock and as wire insulating compounds and as substitutes and replacements for rubber. Since these polymers possess considerable amounts of chlorine, they will not support combustion and they therefore possess distinct advantages in wiring where noninflammability is of importance. The halogen, however, is labile and when the resin is exposed to heat or to ultra-violet light, loss of hydrogen halide occurs, resulting in discoloration.

By the dry spinning of the vinyl chloride-acetate copolymer, it is possible to produce filaments which can be woven into chemically resistant fabric. In Germany fibres were fabricated directly from polyvinyl chloride and were known as PC-fibres.

Polyvinylidene Chloride Resins.—By doubling the amount of chlorine in vinyl chloride, a new chemical entity, vinylidene chloride, is obtained. Because of the symmetrical arrangement of the chlorine atoms in polyvinylidene chloride, $-(CH_2-CCl_2)_x-$, the polymer is crystalline, and advantage can be taken of this crystalline characteristic to form oriented filaments and tubing. Such oriented forms have the molecules arranged in an ordered manner with the result that in the direction of orientation the product is very strong. Extruded, quenched and drawn, the polyvinylidene chloride makes an excellent substitute for reed and rattan and a corrosion-resistant substitute for insect screening; in the form of tubing, the resin can be used to pipe many corrosive chemicals.

Acrylic Resins.—The term acrylic resin covers not only the acrylic esters but also the polymerizable derivatives of both acrylic and methacrylic acids as well as the acid chlorides, nitriles, amides and substituted amides. Acrylic derivatives generally involve cyanide in their synthesis, but investigations indicate that, at least in the case of the acrylic acid derivative, there may be an alternative procedure involving carbon monoxide (in the form of a metallic carbonyl) and acetylene. Considerable investigation was also undertaken in an attempt to prepare acrylic esters from natural lactic acid derived from milk, but it remained to be demonstrated whether the natural lactic acid could compete with the synthetic product. The names of Otto Röhm and Rowland Hill were associated with the preparation and polymerization of acrylic and methacrylic esters, respectively.

From the standpoint of plastic use the methacrylic esters are preferred, since they are harder and more rigid than the corresponding acrylic esters. By changing the type of alcohol which is used in esterification of the original monomeric ester, it is possible to modify the hardness of the resulting polymer. Polymethyl acrylate is tough and rubbery; polyethyl acrylate is softer and more rubbery; polybutyl acrylate is sticky. If one continues up the homologous series of alcohol esters, the polymers become softer and more plastic until at polyoctyl acrylate, it is found that the polymer is almost liquid in consistency.

Polymethyl methacrylate, $(-CH_2-\underset{\displaystyle COOCH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}-)_x$, is the hardest ester in the methacrylate series and, as in the case of the acrylates, the introduction of alcohols possessing longer chains into the ester lowers the softening point of the plastic. Some idea of the relative hardness can be seen in the fact that polyamyl methacrylate is about as hard as polymethyl acrylate. While polymethyl methacrylate is the preferred resin for injection moulding and plastic applications, it was found that cyclohexyl methacrylate was superior for lens casting, since this liquid undergoes less shrinkage during polymerization than does the methyl ester. Cyclohexyl methacrylate polymer, together with styrene resin, was used in combination in the preparation of plastic achromatic lenses.

Without doubt the largest single outlet for the methyl methacrylate resin has been in sheet form for windows in aircraft, particularly in military aircraft. The resin was cast in moulds made of glass and the finished sheet could then be "post-formed" to a wide variety of shapes necessary for blisters, noses, cockpits, windshields and canopies of aircraft. The high clarity of these plastics, as well as the ability to transmit or "pipe" light, also favoured their use in surgical instruments, highway reflectors and edge-lighted advertising displays.

Whereas styrene was copolymerized with butadiene to form a general-purpose rubber, acrylonitrile, the nitrile of acrylic acid ($CH_2 = CH - CN$) was copolymerized with butadiene to yield a special oil-resistant rubber extensively used where rubber of necessity had to be in contact with gasoline and other hydrocarbon liquids. Acrylonitrile forms conjoint polymers with many other vinyl compounds such as acrylic esters and styrene, but from all indications it promised to play its most important role as a polymer in the form of a synthetic fibre.

Polyamides.—By the condensation of diamines and dibasic acid, linear condensation products may be formed and by varying the nature of the acid and the amine, it is possible to produce products which are hard and tough or soft and rubbery. These linear condensation products are referred to as polyamides $[-NH-(R)-NH-CO-R'-CO-]_n$. Polyamides are most generally known in the form of fine and coarse filaments in such articles as hosiery, parachutes, bristles and brushes. As has been pointed out, however, high-molecular-weight organic resinous compounds of certain types can be converted into fibres. The polyamides were first offered commercially in the form of filaments but were later directed to the moulding trade, particularly toward the injection-moulding field where their toughness and ability to flow around complicated inserts are prime considerations. Polyamides, particularly those derived from primary amines, are characterized by a high degree of crystallinity whether in the form of filaments or as mouldings. Under stress, orientation of molecules begins to occur and this orientation continues until the specimen is drawn to about four times its initial size; although this property is of outstanding importance in filaments, it is of more limited utility in moulded articles. The resin exhibits a sharp melting point, and on melting is more liquid and plastic than conventional resinous materials. The fluidity is both an advantage and a disadvantage: the high fluidity

necessitates the use of specialized equipment but on moulding there is no need of using excessive pressure in injection moulding, since the liquid resin transmits its pressure on the moulded specimen hydrostatically.

A product somewhat similar to the polyamides, manufactured in Germany during World War II, utilized isocyanates, particularly the diisocyanates. Reaction of these unsaturated compounds with glycols yielded polyurethanes $[-NH-R-NH-CO-O-R'-O-]_x$ which could be fabricated into bristles.

Polystyrene Resins.—That styrene or vinyl benzene would polymerize has been known for a long time. The designation "vinyl benzene" ($CH_2=CH-C_6H_5$) immediately relates it to the other polymerizable vinyl compounds, such as vinyl chloride, fluoride and acetate. The designation "styrene" arose from the fact that this liquid was first prepared by heating the natural resin storax. The first patents on the possible uses of styrene were taken out by F. E. Matthews in 1911. Monomeric styrene is present in the light oils of coal-tar manufacture and in the drip oils condensed during the preparation of illuminating gas, and although extensive investigations were undertaken to remove styrene from this source, the processes proved too costly and could not compete economically with the synthetic methods. In order to secure a satisfactory plastic out of styrene, it is necessary that a highly purified product be subject to polymerization. Where the monomeric styrene is of inferior quality, the resulting resin is too brittle and on aging the surface of the plastic becomes covered with fine hair lines similar in appearance to those appearing in an unfilled urea-formaldehyde resin. By using a reaction discovered by M. Berthelot in 1869, it was found that by dehydrogenating ethyl benzene catalytically at elevated temperatures and fractionating the resulting mixture, it is possible to secure a product which on polymerization under appropriate conditions yields a polymer possessing valuable chemical and physical properties. Chemically, the resin is highly resistant to both weak and strong acids, although oxidizing types of acids may lead to some discoloration. Alkalies and the lower alcohols do not attack the polymer, and the water absorption of the resin is extremely small. The resin can be dissolved in coal tar and in chlorinated solvents. In electrical characteristics, the plastic possesses an extremely low power (or loss) factor and, when the resin is properly prepared, this power factor remains substantially unchanged over a wide range of frequency. The low power factor combined with the low water absorption makes polystyrene an ideal material for various electrical and electronic applications. The presence of a multiplicity of aromatic rings in the polymer renders the product responsive to temperature, with the result that the resin can be handled expediently by the injection-moulding technique. Among the noteworthy applications of this plastic is the fabrication of battery boxes, ranging in size from those employed in a small automobile to the type that is ordinarily used in portable radio sets. It has found utility in manufacture of condensers, tube sockets, coil forms and switch plates. Since styrene was one of the components entering into the synthetic rubber GR-S, large facilities exist for the manufacture of the monomer. Some idea of the expansion that took place can be seen from the fact that the amount of polystyrene used rose from about 750,000 lb. per month in 1937 to more than 20,000,000 lb. per month in 1951. During this period progress was made on the commercial casting of styrene in several forms. As a copolymer with divinyl benzene, the resin was employed for certain radar applications which involved operating temperatures higher than could be tolerated with polystyrene. The monomer was also cast directly for certain optical parts such as prisms and lenses. Since polystyrene possesses a high dispersion value, it could be combined with polycyclohexylmethacrylate to make corrected plastic achromatic lenses.

One of the limitations of polystyrene for many applications is its inability to tolerate excessive heat; and although the modification with divinyl benzene increases its resistance to heat distortion, it does so at the expense of mouldability. In order to increase the heat resistance of polystyrene and maintain mouldability, the monomer has been copolymerized with various nitrogen-containing compounds such as acrylonitrile, fumaric nitrile and vinyl carbazole. The increase in softening point is attained at the sacrifice of colour. Consequently, extensive investigation was carried out in the direction of introducing various groups into the styrene nucleus in an attempt to improve the heat distortion directly. One of the methods that proved successful involves the introduction of multiple halogens into the aromatic nucleus.

Polyvinyl Carbazole Resins.—Reaction of acetylene with carbazole yields vinyl carbazole $\left[\begin{array}{c} CH_2=CH \\ | \\ N-C_{12}H_8 \end{array}\right]$, which can be converted to a plastic possessing high heat resistance and excellent electrical properties; but the brittleness of the product limits its uses to specialized industrial applications.

Polyethylene Resins.—Although ethylene is the simplest unsaturated compound, it proved to be one of the most difficult to convert into a high-molecular-weight polymer. The polymerization requires extremely high pressures and moderately high temperatures to effect conversion. As might be predicted from its structure, polyethylene, $-(CH_2-CH_2)_x-$, is completely nonpolar and possesses a low power factor and a low dielectric constant. Being highly symmetrical, it is also crystalline; and in common with other crystalline polymers, thin sheets of the resin exhibit high resistance to penetration by water vapour.

At ordinary temperatures the resin is highly resistant to attack by organic and inorganic reagents. At moderate temperatures, the resin can be dissolved in certain organic liquids and such solutions can be applied as a coating, but satisfactory results are obtained only by keeping the object coated in a heated condition until the solvent has evaporated. Polyethylene, however, can be applied more easily directly by extrusion of the molten plastic. It proved suitable for insulating high-frequency and high-voltage circuits. Because of its low water permeability, extensive tests were carried out with a view of using the resin in submarine cables.

Polyisobutylene Resins.—Isobutylene is a hydrocarbon boiling at about −5° C., and when dimerized it can be converted by reduction to iso-octane. By conducting the polymerization at very low temperatures, using boron fluoride as a catalyst, a high-molecular-weight product is formed $\left[\begin{array}{c} CH_3 \\ | \\ -CH_2-C- \\ | \\ CH_3 \end{array}\right]_x$. This polymer is rubberlike but inasmuch as the material is saturated, it cannot be vulcanized. By conducting the polymerization of isobutylene along with a diene such as butadiene, isoprene or dimethyl butadiene, unsaturated residues are introduced into the polymer. These residues can act as nuclei for vulcanization with sulphur.

Perhalogenated Plastics.—Several references can be found in the patent literature to the preparation of polymeric materials which possess only carbon and halogen in their molecular structure. One of the perhalogenated products, polytrifluorochloroethylene, $-(CF_2-CFCl)_x-$, is described in a patent issued to F. Schloffer and O. Scherer (1934), while another patent, that of R. J. Plunkett in 1941, refers to tetrafluoroethylene polymer $-(CF_2-CF)_x-$. The latter product was produced commercially in limited quantities and found its chief utility in the preparation of corrosion-resistant gaskets. Polymeric tetrafluoroethylene is a remarkably stable substance and is insensitive to all organic and inorganic liquids. As would be expected from its symmetrical structure, the polymer is crystalline and the resin on heating undergoes a phase transition at about 327° C., where the mouldings become transparent and the tensile strength decreases markedly.

Trade Names.—Plastics are known and sold commercially under various trade names. A single resin may be sold under a multiplicity of names arising from the fact that the resin manufacturer sells the resin under his own trade name while the moulder may offer this resin in its moulded form to the public under his own distinctive brand name. Moreover, the same chemical composition may frequently be offered to several different consuming industries under several different individual names. As knowledge gradually accumulates concerning the chemical nature and constitution of resins and plastic materials, the custom is becoming established of associating, directly or indirectly, the trade name along with the chemical constitution.

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PLATA, RÍO DE LA, or RIVER PLATE, a funnel-shaped estuary, on the east side of South America, extending west-northwest from the sea about 200 mi. The discovery of the South sea by Balboa, then governor of Castilla del Oro, of which Darién formed a part, created a lively desire to learn something of its coast line, and the year following (in 1514) the Spanish monarch concluded a navigation contract with Juan Díaz de Solís, then *piloto mayor*, to search for a strait connecting the Atlantic with the newly found ocean. De Solís set sail from the port of Lepe on Oct. 8, 1515, reached the Bay of Rio de Janeiro on Jan. 1, 1516, and continuing southward to lat. 35° entered the great estuary now known as the Plata, which, for a short period of time, was called the De Solís and the Mar Dulce. Ascending it to the vicinity of the island of Martín García, near the mouth of the Paraná river, De Solís was ambushed and killed early in 1516 by Charrúa Indians. In 1520 Magellan explored the Río de la Plata, and discovered and navigated the straits which bear

his name. In 1526 Cabot ascended the Mar Dulce, discovered the Paraná river and reached a point on the Paraquay near the site of the present city of Asunción. Here he obtained silver ornaments by barter from Guarani Indians. The receipt of these silver baubles caused the name of Río de la Plata to be applied to the third greatest river of the western continent.

The extreme breadth of the river at its mouth is 138 mi. It narrows quickly to 57 mi. at Montevideo, and to 25 mi. at its head, where it receives the Paraná and Uruguay rivers. Its northern or Uruguayan shore is somewhat elevated and rocky, while the southern or Buenos Airean one is very low. The whole estuary is very shallow, and in no place above Montevideo exceeds 36 ft. in depth at low water. The bottom generally consists of sand covered with from 10 to 20 ft. of water. A dredged channel of about 31 ft. in depth leads from the port of Buenos Aires 20 mi. east to deep water. Winds and tides considerably affect the depth of the channel. The Plata is simply the estuarine receptacle of two mighty streams, the Uruguay and Paraná which drain the Plata basin. This has an area of 1,198,000 sq.mi., or over two and one-half times that of the Pacific slope of the Andes, and comprises the most fertile and healthful part of Brazil, a large portion of the Argentine republic, the whole of Paraguay and southeastern Bolivia, and most of Uruguay.

The Uruguay and Affluents.—The Uruguay river has a length of about 1,000 mi. Many small streams from the western slope of the Brazilian Serra do Mar unite, in about 27° 45′ S. to form this river, which then flows W.N.W., serving as the boundary between the states of Santa Catarina and Rio Grande do Sul, as far as 54° W., near which it receives a considerable tributary from the north, called the Pepirí Guazú. Between 27° 58′ and 33° 34′ S. three important tributaries join it from the east—the Ijuí, the Ibicuí and the Negro.

The Pepirí Guazú in its lower course is about 250 ft. wide, but higher up it narrows to about 30 ft., and runs with great violence between high wooded banks. It is navigable for canoes for about 70 mi. above its mouth, as far as its first fall. The Río Negro has a delta of several large islands at its confluence with the Uruguay. Its headwaters are in the southern part of Rio Grande do Sul, but the main river belongs entirely to the state of Uruguay. Its lower reaches are navigable for craft of moderate draught.

From its source in the coast range of Brazil the Uruguay runs through open, hilly country, and then enters a forest belt of high lands. At the river Pepirí Guazú it turns suddenly to the southwest, and continues this course to its junction with the Paraná and Plata. Near Fray Bentos, 61 mi. before reaching the Plata, it forms a great lake, about 56 mi. long and from 4 to 6 mi. wide. At Punta Gorda, where it debouches into the Plata, it is about 1 mi. wide, but is 90 ft. deep. From the Pepirí Guazú junction its banks are high and covered with forest as far down as 27° 30′ S., where the river is 2,300 ft. wide and from 10 to 40 ft. deep. The Uruguay is much obstructed by rocky barriers. Four miles below its confluence with the Pepirí Guazú it has a cataract, about 8 mi. long, with a total fall of 26 ft. at low water. The river near the Pepirí Guazú is 1,550 ft. wide, but about 1½ mi. before reaching the cataract its width is reduced to 600 ft. Along the cataract it is closed in between high precipitous walls of black rock only 70 ft. apart. Above Punta Gorda, 212 mi., is the Salto Grande, which has a length of 15 mi. of rapids, the greatest single fall being 12 ft., and the difference of level for the entire length of the reefs 25 ft. Nine miles below the Salto Grande is the Salto Chico, which bars navigation during six months of the year, but in floodtime may be passed in craft drawing 5 ft. of water. The Uruguay can be navigated at all seasons by vessels of 4½ ft. draught as far up as the Salto Chico, and of 14 ft. up to Paysandú for a greater part of the year. Fray Bentos may be reached all the year round by any vessel that can ascend the Paraná. Above the navigable lower river there is launch and canoe navigation for many hundreds of miles upon the main artery and its branches, between the rapids which are met with from time to time. The Uruguay has its annual floods, due to the rains in its upper basin. They begin at the end of July and continue to November, attaining their maximum during September and October. Except in floods, it is a clear-water stream, and even at its highest level carries comparatively little silt.

The Paraná and Its Affluents.—The Paraná (the "Mother of the Sea" in Guarani) drains a vast area of southern Brazil. It is formed by the union of the Rio Grande and Paranaíba, and is about 1,600 mi. long from its source in Goiaz to its junction with the Paraguay, and thence 600 mi. to the Plata estuary. Its average width for the latter length is from 1 to 3 mi. Its Rio Grande branch descends from the slope of the Serra da Mantiqueira, in the region where the orographic system of Brazil culminates near the peak of Itatiayassú, almost in sight of Rio de Janeiro. It is about 680 mi. long, but only navigable in the stretches between the many reefs, falls and rapids which interrupt its regular flow.

Besides these rivers, the Paraná has many long and powerful affluents from the Brazilian states of São Paulo and Paraná. Most of them, although obstructed by rapids, are navigable for launches and canoes. Among the eastern tributaries are the Tieté, the Paranapanema, formerly known as the Anemby, and the Iguassú. The Paranapanema is about 600 mi. long, and rises in an offshoot of the Serra Paranapiacaba which overlooks the Atlantic ocean.

The Iguassú, also called the Rio Grande de Curitiba has its sources on the slopes of the Serra do Mar of Brazil, and flows nearly west, through thick forests, along the line of 26° South. Its navigation is difficult even for small craft, as it is full of reefs, rapids and cataracts. Sixteen miles above its mouth is the magnificent Cataratas del Iguassú, sometimes called the Victoria Fall, round which canoes have to be transported 37 mi. before quiet water is again reached. The width of the falls, measured along their crest or edge, is 2½ mi.; part of the river takes two leaps of about 100 ft. each, but a portion of it plunges down the whole depth in unbroken mass. Its mouth is about 800 ft. wide, and the depth in mid-river 40 ft.

The Paraná has unobstructed navigation for about 400 mi. between the Falls of Urubuponga and the Falls of Guairá in 24° 3′ S., where it forms a lake 4½ mi. long and 2½ mi. wide, preparatory to breaching the Serra de Mbaracayú, which there disputes its right of way. It has torn a deep gorge through the mountains for a length of about 2 mi. where it is divided into several channels, filled with rapids and cataracts. It finally gathers its waters into a single volume, to plunge with frightful velocity through a long canyon only about 200 ft. wide. From these so-called Falls of Guairá or "Sete Quedes," as far as its confluence with the Paraguay river, the Paraná has carved a narrow bed through an immense cap of red sandstone, along which it sometimes flows with great rapidity, occasionally being interrupted by dangerous narrows and rapids, where the banks in some places close in to a width of 450 to 600 ft., although the average is from 1,200 to 1,600 ft. At the southeast angle of Paraguay the Paraná is turned westwards; but before escaping from its great sandstone bed it is obstructed by several reefs, notably at the rapids of the Apipé, which are the last before it joins the placid Paraguay, 130 mi. farther on.

The Paraguay.—The river Paraguay, the main affluent of the Paraná, rises in Mato Grosso, in the vicinity of the town of Diamantino, about 14° 24′ South. It flows southwestwards, as far as São Luiz de Cáceres, along the foot of the high plateau which divides it from the São Lourenço (Cuiabá) river to the east, and then, turning southwards, soon reaches the morass expansion of Xarayes, which it traverses for about 100 mi. A few miles below São Luiz de Cáceres it receives an affluent from the northwest, the Jaurú, which has its source nearly in contact with the headwaters of the Guaporé branch of the river Madeira. From the junction of the São Lourenço with the river Paraguay, the latter, now a great stream, moves sluggishly southwards, spreading its waters, in the rainy season, for hundreds of miles to the right and left, as far south as 20°, turning vast swamps into great lakes—in fact, temporarily restoring the region, for thousands of square miles, to its ancient lacustrine condition.

On the west side of the upper Paraguay, between about 17° 30′ and 19° S., are several large, shallow *lagunas* or lakes which receive the drainage of the southern slopes of the Chiquitos sierras, but represent mainly the southwest overflow of the vast morass of Xarayes. The principal of these lakes, naming them from north

to south, are the Uberaba, the Gaiba, Mandioré and the "Bahia" de Cáceres. The Uberaba is the largest. It is in great part surrounded by high ground and hills, but its southern coast is swampy and flooded during the rainy season. The west shore is historic. Here, in 1543, the *conquistador*, Martínez de Irala, founded the "Puerto de los Reyes," with the idea that it might become the port for Peru; and from Lake Gaiba several expeditions, in Spanish colonial days, penetrated 500 mi. across the Chaco to the frontier of the empire of the Incas. At the Puerto de los Reyes Bolivia laid out a town (Puerto Suárez) in 1900 in the hope that the port would serve as an outlet for that commercially suffocated country, there being no other equally good accessible point for Bolivia on the Paraguay river.

South of the São Lourenço, the important rivers entering the Paraguay from the east are the Taquarí, which rises in the Serras das Furnas, on the southern extension of the Mato Grosso tableland; the Miranda, with many branches, draining a great area of extreme southern Mato Grosso, and the Apa, which forms the boundary between Paraguay and Brazilian Mato Grosso.

The Pilcomayo.—The Pilcomayo rises among the Bolivian Andes north of Potosí and northwest of Sucre, races down the mountains to their base, crosses the Chaco plains, and pours into the river Paraguay near Asunción. It does not receive any branch of importance until it reaches about 21° S., where it is joined from the southwest by the river Pilaya, upon which Tupiza, a city in southern Bolivia, is situated. Just below the junction is the Fall of Guarapetendi, 23 ft. high. From this point to the mouth of the Pilcomayo the distance in a straight line is 480 mi., although by the curves of the river, which is extremely tortuous, it is about double that distance. The river bifurcates at 21° 51′ S., but again becomes a single stream at 23° 43′, the right channel being the greater in volume. It is probable that between 23° and 24° S. it throws three great arms to the river Paraguay, the upper portions of which have yet to be explored, but the lower parts have been examined for 100 to 200 mi. up from the Paraguay. From 180 to 200 mi. above its mouth the Pilcomayo filters through a vast swamp about 100 mi. in diameter, through which there is no principal channel. This swamp, or perhaps shallow lagoon, is probably partly drained by the river Confuso, which reaches the Paraguay between the Pilcomayo and Aguaray-guazú. A northern branch of the Pilcomayo, the Brazo Norte, the junction being at 24° 56′ S., is probably also a drainage outlet of the same great swamp.

For the first 100 mi. below the Fall of Guarapetendi the Pilcomayo is from 600 to 1,000 ft. wide, but it so distributes its waters through its many bifurcations, and loses so much from infiltration and in swamps, and by evaporation from the numerous lagoons it forms on either side of its course, that its channel is greatly contracted before it reaches the Paraguay. From Sucre to the Andean margin of the Chaco, a distance of about 350 mi. by the river, the fall is at least 8,000 ft.—a sufficient indication that its upper course is useless for purposes of navigation. Its lower course is of little value for commercial purposes.

The Bermejo.—The Bermejo river flows parallel to the Pilcomayo, and enters the Paraguay a few miles above the junction of this with the Paraná. Its numerous sources are on the eastern frontage of the inland Andes, between the Bolivian town of Tarija and the Argentine city of Jujuy. In 23° 50′ S. the Bermejo receives its main affluent, the San Francisco, from the southwest. The latter has its source in about 22° 30′ S., and, under the name of Río Grande, runs directly southwards, in a deep mountain valley, as far as Jujuy. It then turns eastwards for 50 mi., and is joined by the Lavayen from the southwest. These two streams form the San Francisco, which, from their junction, runs northeastwards to the Bermejo. From its junction with the latter stream the Bermejo flows southeastwards to the Paraguay with an average width in its main channel of about 650 ft., although narrowing at times to 160 and even 100. In its course, however, it bifurcates and ramifies into many channels, forming enormous islands, and frequently leaves old beds for new ones.

Since the exploration of the Bermejo by Patiño in 1721, it has often been examined from its sources to its mouth, with a view to ascertaining its navigability. Like the Pilcomayo, the Bermejo is of little use owing to swift currents, shoals, quicksands, snags and fallen trees.

The Salado.—The Salado, about 250 mi. southwest of and approximately parallel to the Bermejo, is the only great tributary which the Paraná receives from the west below its confluence with the Paraguay. Its extreme headwaters, the Santa María and Calchaqui, which unite near the town of San Carlos and form the river Guachipas, drain a much broken Andean region lying between 24° and 26° 30′ S. in the Argentine province of Salta. Having received the Arias, the Guachipas runs northeastwards about 50 mi., and then it changes its name to the Juramento, which is retained until the river reaches the Chaco plains at the base of the foothills of the Andes. Here it becomes the Salado. It joins the Paraná near Sante Fé in 31° 39′ S. and 60° 41′ W. Explorers of the Salado, inclusive of Captain Page in 1855, claim that its lower half is navigable, but the many efforts which have been made to utilize it as a commercial route have all resulted in failure.

The Pilcomayo, the Bermejo and the Salado erode quantities of the Pampean material, dissolve it into silt and pour it into the Paraguay and Paraná rivers. The engineer, Pelleschi, estimates that "the soil annually subtracted from the territory of the Chaco by the Bermejo alone equals 6,400,000 cubic yards."

Lower Course of the Paraná.—From 31° 30′ S. to the Plata estuary the western bank of the Paraná is a precipitous bluff of reddish clay, varying from 25 to 75 ft. above mean river level. It is being gradually undermined, and tumbles into the water in great blocks, adding to the immense volume of silt which the river carries. The Paraná is lowest in December; it rises in January, February and March, reaching its greatest height in March. It is steady in April, May and June, but falls and rises irregularly during the next three months. The difference between low and high river is generally about 12 ft., depending upon the varying quantity of rains in Brazil and the melting of the Andean snows. Below its junction with the Paraguay the Paraná has an average current of 2½ mi. an hour, and the river varies in width from 1 to 3 mi., at low water; but in floods it seems almost a continuous lake, broadening to 10 and 30 mi. and burying many of its numerous islands and marginal swamps under a vast sheet of water, and obliterating its many parallel lateral channels and connecting canals.

Islands of Paraná.—In the middle Paraná, from the mouth of the Iguassú to the mouth of the Paraguay river, there are many islands, some of them large, rocky and high above the river. From Paraguay to the city of Rosario, islands are numerous, many of them of great area; and again below Rosario they soon increase in number and size until the Plata estuary is reached. In floodtime the upper portion of the trees being out of water, they have the appearance of floating forests. Then the river often makes wild work with its banks, and builds up or sweeps away entire islands, leaving deep channels instead. The lower delta of the Paraná does not share in these phenomena; its islands and main channels appear more fixed. This probably is due to the less elevation attained by the waters in floodtime, and the numerous branches which distribute them into the Plata estuary. This must have extended, in a very recent geological period, inland from its present head to at least 32° S.; but the enormous quantity of silt which the Paraná receives from its Paraguay affluent, and from the tributaries which reach it from the Andes, has filled this length of about 220 mi. with these muddy islands, which rest upon a sandy bed of great depth.

Paraná Delta.—The frontage of the Paraná delta is 40 mi. across, almost in a straight line from north to south. Through this the river finds its way to the Plata by 11 outlets, large and small, the two principal ones being the Paraná Guazú and the Paraná Bravo. In September (low river) the depth of water in the Paraná Guazú is at least 20 ft.; the least depth of the Paraná Bravo is 36 ft. Because the depth of water in the Paraná is controlled by seasonal variations it is difficult to state categorically the draught of vessels that can ascend to various points along the river. At the port of Rosario, 222 mi. above Buenos Aires, the lowest monthly average of the river level is just under 28 ft. At

Santa Fé, 312 mi. above Buenos Aires, the river level varies between 10 and 27 ft., but a depth of 20 ft. in the entrance channel and port is maintained by constant dredging. The maximum draughts that can use the various channels in the Paraná and Paraguay rivers are published in daily bulletins, available in Buenos Aires and all up-river ports.

Communications.—The expenditure of hundreds of millions of dollars for dredging, port improvements and rail and highway connections greatly increased the commercial importance of scores of towns and cities located on the Plata-Paraná-Paraguay river system. The Compañía Argentina de Navegación Mihanovich Ltda., operating in 1941 a fleet of more than 400 boats, launches and barges, maintains regular passenger and freight services between Buenos Aires, Montevideo and all ports on the Plata, Paraguay, Alto Paraguay, Paraná, Alto Paraná and Uruguay rivers. River boats of Lloyd Brazileiro operate on a regular schedule between Montevideo and Corumbá, Brazil, and the Compañía Uruguaya de Navegación and the Línea Río Uruguay operate steamers between Montevideo, Salto and intermediate ports on the Uruguay river and some of its tributaries. Ocean-going vessels can ascend the Paraná to Santa Fé and Bajada Grande (port of the city of Paraná), and the Uruguay to Concepción del Uruguay, or, when the river permits, to Colón. Coastal vessels have a somewhat greater range and are able to sail varying distances up several of the tributaries, including the Gualeguay, Gualeguaychú, Victoria, Paraná Pavón, Ibicuy and Negro. River boats ascending the Paraná to Asunción may be of somewhat deeper draught than those that can navigate the Alto Paraná. Because of this, Corrientes has become an important transfer point for passengers and cargoes destined for ports along the Alto Paraná. The Guairá falls are circumvented by a railroad between Porto Mendes, Brazil, and a point 38 mi. up river. The journey from Buenos Aires to Asunción, a distance of approximately 900 mi., is made in 3½ days by boat. Northward from Asunción the Alto Paraguay is navigable to small craft for more than 1,000 mi., providing the principal outlet for a vast region that produces large quantities of cattle, lumber and quebracho. In addition to being ports on the Alto Paraguay, Porto Esperança and Corumbá, Brazil, and Puerto Suárez, Bolivia, have direct rail connections with São Paulo. Throughout the Plata region the gradual introduction of modern agricultural implements has led to an increase in production, which is reflected in the growth and development of industries and a significant increase in river traffic.

(G. E. C.; R. W. Rd.)

PLATAEA or **PLATAEAE,** an ancient Greek city of Boeotia, situated close under Mt. Cithaeron, near the passes leading from Peloponnesus and Attica to Thebes, and separated from the latter city's territory by the River Asopus. Though one of the smallest Boeotian towns, it stubbornly resisted the centralizing policy of Thebes. In 519 B.C. it invoked Sparta's help against its powerful neighbour, but was referred by king Cleomenes to Athens (for the date, *see* Grote's *History of Greece,* ed. 1907, p. 82, note 4). The Athenians secured Plataea's independence, and thus secured its enduring friendship. In 490 the Plataeans sent their full levy to the assistance of the Athenians at Marathon, and during the invasion of Xerxes they joined eagerly in the national defense. At Artemisium they volunteered to man several Athenian ships, and subsequently abandoned their town to be burnt by Xerxes. In 479 they fought against the Persians under Mardonius in the decisive battle which bears the name of the city. (For an account of the battle *see* Graeco-Persian Wars.) Their great victory was celebrated by annual sacrifices and a Festival of Liberation (*Eleutheria*) in every fourth year at Plataea, whose territory moreover was declared inviolate.

In spite of this guarantee Plataea was attacked by Thebes at the beginning of the Peloponnesian War (431) and formally besieged by the Peloponnesians (429–27). The garrison after capitulating was put to death, and the city razed by the Thebans. The remaining Plataeans received a qualified franchise in Athens, and in 421 were settled on the territory of Scione. Expelled by Lysander in 404 they returned to Athens, until in 387 Sparta restored them in their native town as a check upon Thebes. The city was again destroyed by Thebes in 373, and the inhabitants once more became citizens of Athens. Plataea was rebuilt by Philip and Alexander of Macedon, and during the rest of antiquity enjoyed a safe but obscure existence. It continued to flourish in Byzantine and Frankish times. The walls of the town, which at various periods occupied different portions of the triangular ledge on which it stood, remain partly visible. Recent excavations have discovered the Heraeum; but the temple of Athena the Warlike, built from the Persian spoils and adorned by the most famous artists, has not been identified.

Authorities.—Strabo p. 411; Pausanias ix. 1–4; Herodotus vi. 108, viii. 1, ix. 25–85; Plutarch, *Aristides,* 11–21; Thucydides ii. 1–16, 71–78, iii. 20–24, 52–68; Isocrates, *Plataicus;* G. B. Grundy, *The Topography of the Battle of Plataea* (London, 1894) and *Great Persian War* (London, 1901), ch. xi.; W. Woodhouse in *Journal of Hellenic Studies* (1898), pp. 33–59; H. B. Wright, *The Campaign of Plataea* (New Haven, 1904); R. W. Macan, *Herodotus,* vii.–ix. (London, 1908), appendix; W. M. Leake, *Travels in Northern Greece,* ch. xvi., pp. 323–367 (London, 1835); *Amer. Journ. of Archaeology,* 1890, pp. 445–475; 1891, pp. 390–405. (M. C.)

PLATE, the common name for the electrode from which the current flows through the vacuous space in a radio vacuum tube.

PLATEAU, JOSEPH ANTOINE FERDINAND (1801–1883), Belgian physicist, was born at Brussels on Oct. 14, 1801, and died on Sept. 15, 1883 at Ghent, where he had been professor of physics from 1835. The more original investigations of Plateau refer chiefly to physiological optics and molecular forces. We owe to him the "stroboscopic" method of studying the motion of a vibrating body, by looking at it through equidistant radial slits in a revolving disk. In 1843 Plateau became permanently blind. He published an analytical catalogue of memoirs from the earliest times to the end of the 18th century on his favourite theme of subjective visual phenomena. This blind man's investigations on molecular forces, embracing hundreds of novel experiments whose results he saw only with others' eyes, are described in his great work *Statique expérimentale et théorique des liquides soumis aux seules forces moléculaires* (2 vols., 1873).

PLATED WARE: *see* Sheffield Plate and Electro-Plating.

PLATE GLASS: *see* Glass Manufacture.

PLATE GLASS INSURANCE: *see* Insurance: Miscellaneous.

PLATEN-HALLERMUND, AUGUST, Graf von (1796–1835), German poet and dramatist, was born on Oct. 24, 1796, at Ansbach, and entered the Bavarian life guards in 1814. He took part in the short campaign in France of 1815; he then obtained a long leave of absence, and after a tour in Switzerland and the Bavarian Alps, entered the University of Würzburg in 1818 as a student of philosophy and philology. In 1819 he removed to Erlangen, where he sat at the feet of F. W. J. von Schelling. As a result of his Oriental studies he published a little volume of poems—*Ghaselen* (1821), each consisting of from ten to twenty verses, in which he imitates the style of Rückert; *Lyrische Blätter* (1821); *Spiegel der Hafis* (1822); *Vermischte Schriften* (1822); and *Neue Ghaselen* (1823).

Though Platen was at first influenced by the school of Romanticism, and particularly by Spanish models, yet the plays written during his university life at Erlangen, *Der gläserne Pantoffel, Der Schatz des Rhampsinit, Berengar, Treue um Treue, Der Turm mit sieben Pforten,* show a clearness of plot and expression foreign to the Romantic style. His antagonism to Romanticism became more and more pronounced, and he attacked its extravagances in the witty "Aristophanic" comedies *Die verhängnisvolle Gabel* (1826) and *Der romantische Oedipus* (1828). In 1826 he visited Italy, which he henceforth made his home, living at Florence, Rome and Naples. *Der romantische Oedipus* earned for him the bitter enmity of Karl Immermann and Heinrich Heine, but he retained many staunch admirers, who delighted in the purity of the subject matter of his productions and their beauty of form and diction. In Naples were written his last drama *Die Liga von Cambrai* (1833) and the delightful epic fairy-tale *Die Abbassiden* (1830; 1834), besides numerous lyrical poems, odes and ballads. He died at Syracuse on Dec. 5, 1835. Platen's odes and sonnets,

to which must be added his *Polenlieder* (1831), expressing his sympathy for the Poles in their rising against the rule of the Tsar, rank among the best classical poems of modern times.

Platen's *Gesammelte Werke* were first published in one volume in 1839, and have been frequently reprinted; a convenient edition is that edited by K. Goedeke in Cotta's *Bibliothek der Weltliteratur* (4 vols., 1882). His *Tagebuch* (1796–1825), was published in its entirety by G. von Laubmann and L. von Scheffler (2 vols., 1896–1900). *See* P. Besson, *Platen, étude biographique et littéraire* (1894); A. Fries, *Platen-Forschungen* (1903); E. Petzet, *Platens Verhältnis zur Romantik in sein italien Zeit* (1911); R. Schlösser, *August Graf von Platen. Ein Bild seines geistigen Entwicklungsganges und seines dichterischen Schaffens* (Munich, 1910–13).

PLATERESQUE, the earliest of the styles of Spanish Renaissance, so called, either because the Renaissance found its first popular Spanish expression in silverware (*platero,* silversmith), or because its rich and delicate ornament resembled silversmith work. It is characterized by the application to forms structurally simple, of extremely rich ornament, distantly based on Italian Renaissance forms, using pilasters, entablatures, carved rectangular panels, shallow niches, much heraldic ornament and rich pierced, scrolled cresting. Its courtyards, usually with two or more openings on the upper floor, above a single opening below, are famous for their decorated columns, sometimes simulating balusters, their bracketed capitals and their graceful delicacy. Owing to Moorish influence, there is a common tendency to carry the decoration around the door over the full height of the wall above. Decorative ironwork, as in the church *rejerías* (*q.v.*), or open metal screens, was highly developed. The style embraces, generally, the first half of the 16th century, but its decorative ideals influenced not only the classic period which followed, but the Baroque as well. Characteristic examples are the hospital of Santa Cruz, Toledo, by de Egaz (1504–16), the college at Alcalá de Henares, by Gumiel (1500–17), the university and Irish college at Salamanca, the Casa de las Conchas at Salamanca and the Infantada at Guadalajara. (*See* Renaissance Architecture.)

(T. F. H.)

PLATERSPIEL, Blaterpfeife, a mediaeval simplified bagpipe, consisting of an insufflation tube, a bladder and a chaunter; the double reed in its socket at the top of the chaunter being concealed within the bladder. In the platerspiel we recognize the early mediaeval chorus (*q.v.*) a word which in mediaeval Latin was frequently used also for the bagpipe, while in its later forms it was practically identical with the cromorne (*q.v.*).

PLATINUM, a very heavy steel-grey metal of great usefulness in the chemical and mechanical arts.

Platinum was probably known in the impure state from very early times, but because of its physical properties and especially its high melting point it was impossible to work it by any of the arts then known and it therefore remained as an unnamed substance. (Symbol Pt, atomic number 78, atomic weight 195·23.) It was probably the metal alluded to in the early part of the 16th century by Scaliger, who refers to a metal incapable of being fused obtained from the mines in Mexico and Darien. About the middle of the 18th century it was introduced into Europe in small quantities and attracted the notice of various chemists. Scheffer, in a paper read before the Stockholm Academy entitled "On white gold or the seventh metal," termed in Spanish platina del Pinto" (1752), showed that it was insoluble in nitric acid but soluble in aqua regia, was precipitated from its solutions by mercury, and was infusible at the highest temperature of the furnace. He also dealt with some of its alloys and discovered that it was fusible when mixed with arsenic. Platinum was melted by Macquer and Baumé in 1758 in the focus of a powerful burning glass. Count von Sickingen in 1772 prepared the metal in the form of foil and wire and showed that it was soluble in nitric acid when alloyed with a large quantity of silver. For the later history of platinum, its occurrence and separation from the other metals, *see* Platinum Metals and Ruthenium, Rhodium, Palladium, Osmium and Iridium.

Platinum in the massive state is a greyish-white metal having a specific gravity of 21·4 and is exceedingly malleable and ductile. It melts at about 1,755° C and volatilizes readily in the electric furnace. Its latent heat of fusion is 27·18 calories. It is a bad conductor of heat and electricity. When pure it is a soft metal and on this account is not suitable for some purposes, but on alloying it with iridium in small amounts the hardness is greatly increased. It is capable of being welded at a temperature near its melting point, but for easier working at a lower temperature gold is used as a solder in repairing damaged crucibles and other articles. It alloys easily with all the other metals of its own group, likewise with gold, silver and lead, but is scarcely acted upon by metallic mercury. It has been obtained in the crystalline condition by distillation in the electric furnace or by heating the fluoride to a red heat (Moissan). Spongy platinum is readily produced by ignition of the double chloride $(NH_4)_2PtCl_6$; it possesses a much greater surface area than the massive metal and hence is more active when employed in catalysis. Platinum black is best prepared by warming a solution of any of the chlorides or double chlorides of platinum in caustic alkali with alcohol or some similar reducing agent, or by dissolving the lead in nitric acid from a not very rich lead–platinum alloy. It has an enormous surface area and hence is the most usual form in which platinum is employed in catalytic reactions. The platinum black, for convenience in handling and also to minimize loss, is usually deposited upon some suitable material such as asbestos or barium sulphate. Colloidal platinum can be obtained in solution by passing an electric arc between platinum terminals under pure water.

Uses.—Platinum is used in the laboratory in the form of dishes, crucibles and weights, although a small amount of iridium is generally added to increase its hardness and hence its durability. Platinum vessels, however, should never be used for heating caustic alkalis, as they undergo corrosion producing platinates, and no metal of low melting-point should ever be heated in them. At one time platinum vessels were almost exclusively used in concentrating sulphuric acid (*q.v.*) made by the chamber process; this use has been abandoned as sulphuric acid made by the contact process is already concentrated, and the chamber acid is now concentrated in cheaper vessels.

Platinum is the best catalyst for the manufacture of sulphuric acid by the contact process; at a temperature below a red heat it is capable of causing the reaction $2SO_2+O_2=2SO_3$ to be nearly completed. The resulting SO_3 is dissolved in water till an acid of the required strength is obtained (*see* Sulphuric Acid). Its use for this purpose has been partly given up, as some cheaper catalysts such as the oxides of iron and chromium, although less efficient, have been found more economical. In this process platinum is always used as platinum black. The material to be platinized (asbestos, pumice, brick, barium sulphate, etc.) is dipped in a dilute solution of platinum chloride, dried and ignited, an enormous catalytic surface of platinum black being thus produced. Another large and rapidly extending use for platinum is in the catalytic production of nitric acid from ammonia by oxidation. A mixture of ammonia gas and air (or oxygen) in the right proportion is passed in a very rapid stream over a network of heated platinum gauze. Either ammonium nitrate or nitric acid can be produced according to the proportions of oxygen and ammonia in the reaction mixture. The reaction is exothermic, and by adjusting the rate of flow of the mixed gases the reaction temperature can be kept constant.

Platinum or, better, iridium-platinum alloy is the most suitable anode material for electrolysis of all kinds. It remains unattacked under practically all conditions, but owing to the initial expense, some form of carbon, especially Acheson graphite, is now generally used for this purpose. Two methods of measuring high temperatures depend upon the use of platinum; the first is the platinum resistance thermometer, which depends upon the change of resistance of a platinum coil with temperature when a constant current is passing through it; the second is the use of a platinum and rhodium–platinum thermocouple. By careful calibration either of these instruments is capable of giving a very exact measurement of high temperatures. As platinum is not oxidized by air at the temperature of the electric spark, it is very suitable in electro-technics for contact-points of magnetos and induction coils and the armatures of electric bells; it can

also be used when caused to glow by the passage of an electric current as a heating-element; for some of these uses it has now been displaced by cheaper materials, one of the best being a chromium–nickel alloy known as nichrome.

Platinum is extensively used for some surgical instruments such as needles for hypodermic syringes, for the metal can be sterilized even in the flame of a match; it is also used in the incandescent state as an electric cautery. Unfortunately it cannot be hardened sufficiently to make a good cutting edge. In dentistry platinum was formerly used extensively for making dental plates, etc., as an alloy of 2 parts of silver to one of platinum possesses the same coefficient of expansion as the hard porcelain-like material of which artificial teeth are composed. Owing to the rise in the price of platinum, gold or gold alloys have now almost entirely displaced it for this purpose. The use of platinum in jewellery is considerable; during World War I palladium replaced it to a large extent and now an alloy called white gold, which consists chiefly of gold alloyed with a small quantity of either palladium or platinum, is largely displacing it. Another use for platinum is the production of photographic prints by the platinotype process. These prints are of great beauty owing to the variety of tones that can be thus produced, and have the advantage over silver prints of being absolutely permanent.

Platinum Compounds.—Platinum does not combine directly with oxygen at any temperature, although in the molten state it absorbs several times its volume of this gas, which, however, is released when the metal cools. Four oxides of platinum are obtainable by indirect methods, viz., PtO, Pt_3O_4, PtO_2 and PtO_3. Of these, PtO and PtO_2 are important as they are the bases of the platinous and platinic salts. *Platinous oxide,* PtO, is obtained by gentle ignition of the corresponding hydrate, $PtO,2H_2O$, which is obtainable by precipitating either $PtCl_2$ or K_2PtCl_4 with caustic alkali. It is a black powder, soluble in acids when freshly prepared. *Platinic oxide,* PtO_2, is known in the hydrated form $Pt(OH)_4$, but only a portion of the combined water can be removed before deeper decomposition begins to take place. The hydroxide is obtained by adding excess of caustic soda to a boiling solution of $PtCl_4$, which gives a yellow solution of sodium platinate, and then precipitating the cold solution with acetic acid. It is a white or yellowish solid soluble both in dilute acids and in alkalis when freshly prepared, but after losing water on heating it becomes black and insoluble. The peroxide, PtO_3, is obtainable by electrolyzing an alkaline solution of $Pt(OH)_4$ at 0° C. It is a red-brown unstable solid which readily parts with some of its oxygen at ordinary temperatures.

Two well-defined chlorides of platinum are known—platinous chloride, $PtCl_2$, and platinic chloride, $PtCl_4$. *Platinous chloride* is formed by heating chloroplatinic acid to 300° C or evaporating a solution of the same substance with absolute alcohol to dryness several times. It is a greenish or sometimes brownish substance insoluble in water but soluble in hydrochloric acid or alkali chloride solutions, with which it forms double chlorides of the form M_2PtCl_4; these are the alkali salts (platinochlorides) of chloroplatinous acid, H_2PtCl_4. This acid, which is known only in solution, can be obtained also from either its barium or silver salt by exact precipitation by means of sulphuric or hydrochloric acid respectively. The best known salt of the acid is the potassium compound, which is easily produced by reducing a boiling solution of potassium chloroplatinate with sulphur dioxide. It crystallizes in dark red prisms easily soluble in water, and in the case of certain unfortunate persons, traces of it act as a violent irritant to the mucous membrane of the eyes and nose. Platinous chloride combines with various unsaturated substances to form double compounds; it combines directly with carbonic oxide at 250° C to form three compounds, $PtCl_2,CO$; $(PtCl_2)_2,3CO$; and $PtCl_2,2CO$; with phosgene to form $PtCl_2,2COCl_2$; with ethylene to produce $PtCl_2,2C_2H_4$; and with phosphorus trichloride to form compounds $PtCl_2,PCl_3$ and $PtCl_2,2PCl_3$.

Platinic chloride, $PtCl_4$, is formed by the action of chlorine on platinum at a temperature below 500°. If platinum is dissolved in aqua regia or in hydrochloric acid in a stream of chlorine and the solution is evaporated with hydrochloric acid till free from nitric acid, reddish-brown crystals of chloroplatinic (platinichloric) acid, $H_2PtCl_6,6H_2O$, are produced: these if ignited in a stream of hydrogen chloride gas at 165° give a residue of $PtCl_4$ as a reddish-brown, very hygroscopic, crystalline mass. The pure chloride, however, is rarely met with, and the platinic chloride of commerce is the compound $H_2PtCl_6,2H_2O$ formed by heating the hexa-hydrated compound to 100° C. Chloroplatinic (platinichloric) acid is a weak acid, it reddens litmus paper and decomposes metallic carbonates producing the corresponding platinichlorides. It forms potassium and ammonium compounds which are nearly insoluble in water and quite insoluble in a mixture of alcohol and ether; the corresponding sodium compound is soluble in this mixture, and this circumstance affords the best method of separating potassium from sodium quantitatively. Chloroplatinic (platinichloric) acid forms compounds with organic bases which are usually difficultly soluble in water.

Platinum is not attacked by fluorine at a low temperature, and advantage of this was taken by Moissan when he first isolated that element and by Moissan and Dewar when they first liquefied this gas. At higher temperature (500°–600° C) Moissan obtained two fluorides, PtF_2 and PtF_4. Platinum does not readily form stable salts with oxy-acids. A sulphate $Pt(SO_4)_2$ is said to have been produced by dissolving platinic hydroxide in sulphuric acid but no nitrate of platinum is known. A series of salts known as platino-nitrites having the general formula $M_2Pt(NO_2)_4$ is well known, and another series, the platino-oxalates of the composition $M_2Pt(C_2O_4)_2$ has also been recorded. Two sulphides of platinum, PtS and PtS_2, are definitely known, and the existence of various intermediate ones has been announced from time to time. PtS and PtS_2 are produced by acting upon solutions of corresponding platinum compounds with sulphuretted hydrogen. Both sulphides are black powders; PtS_2 must be dried without access of air as it readily undergoes oxidation.

Platinous cyanide, $Pt(CN)_2$, is best produced by precipitating a solution of potassium platinochloride, K_2PtCl_4, with mercuric cyanide. It is of importance as it combines with cyanides of the alkali and alkaline-earth metals to produce a series of salts known as platinocyanides which are remarkable for their wonderful colours and for their use in radiography. They are derived from platinocyanic acid, $H_2Pt(CN)_4$, which can be prepared by decomposing the mercury or copper salt with sulphuretted hydrogen. The acid crystallizes from water in deliquescent prisms but is better crystallized from an ether–alcohol mixture. Potassium platinocyanide, $K_2Pt(CN)_4,3H_2O$, is easily produced by dissolving spongy platinum in a solution of potassium cyanide, preferably in the presence of air, or by the interaction of a solution of platinous chloride with excess of potassium cyanide; in the latter method recrystallization is necessary to remove the potassium chloride simultaneously produced. It crystallizes in rhombic prisms which are yellow by transmitted light but have a blue metallic lustre by reflected light. The magnesium salt, $MgPt(CN)_4,7H_2O$, crystallizes in beautiful red tetragonal prisms with metallic moss-green reflex. Its solution in water is colourless. Barium platinocyanide, $BaPt(CN)_4,4H_2O$, is the compound used for X-ray screens. It occurs in citron-yellow monoclinic prisms with a green reflex.

Platinum salts combine with ammonia in various proportions to form two series of bases, platinous and platinic ammines (*see* AMMINES). In the platinous series there are two compounds having the formula $PtCl_2,2NH_3$; they are probably cis- and trans-isomerides. A polymeride having the formula $(Pt,4NH_3)PtCl_4$ has long been known as the "green salt of Magnus," and is made by the action of ammonia upon platinous chloride. These compounds, although of great interest theoretically, are of little practical value. A complete account of these interesting compounds may be found in Gmelin-Kraut's *Handbuch.* (F. E. M.)

See L. Duparc and M. N. Tikhonovich, *Le Platine et les gîtes platanifères de l'Oural et du Monde* (1920); C. Janin, *World's Outlook for Platinum* (1928).

PLATINUM METALS. Although generally found in nature in the metallic condition, native platinum is never chemically pure. With it in varying proportions five other metals are generally associated, and to this group of six elements the name

"platinum metals" has been given. The six metals in the order of their atomic numbers and weights are as follows:—

Metal	Symbol	Atomic No.	Atomic Wt.	Metal	Symbol	Atomic No.	Atomic Wt.
Ruthenium	Ru	44	101·7	Osmium	Os	76	190·8
Rhodium	Rh	45	102·91	Iridium	Ir	77	193·1
Palladium	Pd	46	106·7	Platinum	Pt	78	195·23

Although certain properties are common to the whole group, yet very great chemical and physical differences are found between the various members. It will be noticed that the atomic numbers of the first three and second three members are consecutive and that a common difference of 32 separates them. This common difference in atomic number corresponds to similarity in chemical properties between members differing by this constant number; at the same time similarities, more especially physical, are noticed amongst the members of each group.

One property common to the whole of the platinum metals is the high temperature of their melting points. The most easily fusible of them, palladium, only assumes the liquid condition at about 1,550° C; platinum comes next with a melting point of about 1,750° C and the other metals fuse at temperatures intermediate between these and the melting point of osmium, which is about 2,700° C. Another property common to this group of metals is the valuable one of resisting chemical action and especially oxidation (the particular cases of ruthenium and osmium as regards oxidation will be dealt with when those metals are considered in detail).

Another property common to all members of the group is their great catalytic action, that is, the power of bringing about chemical action between other substances without themselves undergoing any alteration. In small chemical operations platinum and palladium are extensively used, but for large-scale or commercial working these metals, on account of their high cost, are not suitable unless the wastage is very small or negligible. Thus platinum and palladium are most efficient catalysts in the hydrogenation of oils and fats for the production of edible glycerides (*q.v.*); they are, however, seldom used for this purpose since the inevitable wastage would cause the process to be too costly. Metallic nickel or certain of its compounds are used instead, with the result that the operation has to be carried out at a considerably higher temperature, resulting in the destruction of some of the important vitamins which would have survived had palladium been used instead of nickel.

As regards density or specific gravity, the platinum metals resolve themselves naturally into two groups: the three members of lowest atomic weight have specific gravities of 11–12, *i.e.*, somewhat higher than, but not far removed from, that of silver, 10–11; the three higher members, however, are much denser and their specific gravities range from 21·4 for platinum to 22·5 for osmium which is the heaviest massive substance known under terrestrial conditions. As the specific gravity of platinum is near to that of gold, 19·4, an alloy of platinum with some base metal is easily prepared possessing the same density as gold.

Being bad conductors of electricity, platinum and its allied metals in the form of wire easily become incandescent when an electric current is passed through them. Incandescent lamps with very luminous filaments for electric lighting could be made without any danger of fusing of these metals. The first practical success was attained with filaments of metallic osmium, which was found to glow more vigorously and thus give better illumination than the other platinum metals. This fact is perpetuated in the name "Osram" which is still a trade-mark of certain lamp manufacturers, although the use of osmium for this purpose has long been discontinued. Although the platinum filaments for lamps was soon displaced by tantalum and tungsten, yet for a considerable time platinum entered into their construction, as some material had to be used, which could be fused into the glass without cracking, to carry the necessary leading-in wires. The only suitable substance then known was platinum, which has a coefficient of expansion almost the same as that of glass, and for a considerable time this was the only available material. This wasteful use of platinum has now been obviated by the production of alloys of much cheaper material having the same coefficient of expansion as ordinary glass.

Occurrence.—The platinum metals appear to be widely distributed in nature, although generally in very small quantities. Localities in which they occur are Brazil, Colombia, Peru, Russia, Australia, Borneo, Tasmania, California and South Africa. Alluvial deposits have hitherto been the usual sources, but platiniferous reefs have now been found in the Transvaal and Natal. Alluvial platinum was reported in 1927 from Sierra Leone over an area of 40sq. miles. The first definite recognition of crude platinum as a separate metal occurs in the 18th century, when chemists obtained samples of platinum ore from Carthagena.

In 1803 and 1804 four new metals were obtained from platinum. Osmium and iridium were discovered and isolated by Smithson Tennant and palladium and rhodium by W. H. Wollaston. The remaining platinum metal, ruthenium, was not discovered till 1828 when Osann succeeded in isolating it from the platiniferous ore of the Ural mountains, a deposit discovered in 1819. The platinum ores obtained from various localities differ greatly in composition. Platinum is generally found as the chief metal and the other metals of the group occur in relatively small and variable quantities. Occasionally, however, and especially in Australia and South Africa, small nuggets or grains of osmiridium are found, and recently considerable amounts have been found in Tasmania which is now its chief source. This mineral consists chiefly of the metals osmium and iridium, and also usually of a certain amount of ruthenium, the other platinum metals occurring to a small extent only. In addition to the six platinum metals, platinum ores contain other elements, the most common being gold, copper, silver, iron, chromium and nickel.

Separation.—The methods in general use for the separation of the six platinum metals are here outlined, detailed accounts of their purification being shown under the headings of the several metals. A platinum ore which has been freed from base metals and other impurities is treated with aqua regia (*q.v.*); osmium, most of the iridium and a small amount of ruthenium remain undissolved. The solution, containing platinum, palladium, rhodium and small amounts of ruthenium and iridium, is evaporated to dryness, when the metals are obtained as chlorides. These chlorides are then heated to about 150° C whereby the chlorides of palladium and iridium are partly decomposed giving lower chlorides. The residual mass is dissolved in very dilute hydrochloric acid, and ammonium chloride is added to precipitate most of the platinum and iridium as double chlorides, the other metals remaining in solution. This solution is then treated with metallic iron (technically termed "footing"), which throws all the metals completely out of solution; this precipitate, like all others similarly obtained, is technically called "foots." The precipitate after thorough washing is again dissolved in aqua regia, the solution is concentrated and again treated with ammonium chloride to remove further amounts of platinum and iridium and then treated with ammonium hydrate, when nearly all the palladium is thrown out as a difficultly soluble ammine, $Pd(NH_3)_2Cl_2$. The solution now containing rhodium and ruthenium is evaporated to dryness and strongly ignited, leaving the metals themselves. These are fused with potassium bisulphate, when the rhodium forms a soluble double sulphate leaving the ruthenium unattacked.

The foregoing residues containing osmium, iridium and some ruthenium are heated in a tube in a stream of air or preferably oxygen. Osmium and ruthenium form volatile oxides which are deposited in the cold parts of the tube. The residue, iridium with some ruthenium and small amounts of other platinum metals, is purified by suitable methods. A method of treating crude platinum ores, particularly useful in concentrating the platiniferous portion, is to heat the ores with metallic lead or to make a mixture of the ores with galena, scrap iron, glass and borax, the last two materials serving as a flux. The platinum metals, except most of the osmiridium, are dissolved in the lead which is removed by ordinary cupellation, the platinum metals remaining ready for subsequent treatment. In modern reef-mining, the platiniferous ores are concentrated after grinding by methods of oil flotation.

Another method of opening up platinum ores is to treat a heated mixture of the substance and common salt with chlorine. All the platinum metals are attacked by this process giving double chlorides of the metal with sodium. As these double chlorides differ in stability, variations of the temperature of treatment give different products. Even if the double chloride is decomposed at or below the temperature of formation, the metal resulting from this decomposition remains in a finely divided condition and subsequent treatment is facilitated, and at the same time some of the stable double chlorides, especially that of iridium, are soluble in water and are easy to treat subsequently. It is obvious that with ores of different compositions some of the foregoing methods are more suitable than others in particular cases. Furthermore, all firms engaged in the refining of these metals have their own special secret methods. (F. E. M.)

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PLATO (*c.* 428 B.C.–*c.* 348 B.C.), Greek philosopher, son of Ariston and Perictione, was born in the year 428–427 B.C. and died in 348–347 at the age of over 80. His family was, on both sides, one of the most distinguished of Athens. Ariston is said to have traced his descent through Codrus to the god Poseidon; on the mother's side, the family, that was related to Solon, goes back to Dropides, archon of the year 644 B.C. Perictione apparently married as her second husband her uncle Pyrilampes (*Parm.* 126 *C*) a prominent supporter of Pericles, and Plato was probably chiefly brought up in his house: Critias and Charmides, leading men among the extremists of the reactionary Terror of 404, were respectively cousin and brother of Perictione; both were old friends of Socrates, and through them Plato must have known the philosopher from boyhood.

His own early ambitions as he tells us in the seventh *Epistle* (324 *b.*–326 *b.*) were political. The reactionaries urged him to enter public life under their auspices—at the age of 24—but he wisely held back till their policy should declare itself. He was soon repelled by their violences, particularly by their attempt to implicate Socrates in the illegal execution of their victim Leon. He hoped better things from the restored democracy, but its condemnation of Socrates finally convinced him that there was no place for a man of conscience in active politics. Hermodorus, an immediate disciple, is the authority for the statement that, on the execution of Socrates in 399 B.C., Plato and other Socratic men took temporary refuge with Eucleides at Megara. The later *Lives* represent the next few years as spent in extensive travels in Greece, Egypt, Italy. Plato's own statement is only that he visited Italy and Sicily at the age of 40 and was disgusted by the gross sensuality of life there, but found a kindred spirit in Dion, brother-in-law of Dionysius I. of Syracuse.

The Academy.—About or soon after 387, Plato founded the Academy as an institute for the systematic pursuit of philosophical and scientific research. He presided over the society for the rest of his life, making it the recognized authority alike in mathematics and in jurisprudence. From the allusions of Aristotle we gather that Plato lectured without manuscript, and we know that "problems" were propounded for solution by the joint researches of students. On the political side there are traces of tension between the Academy and the rival school of Isocrates.

The one outstanding event in Plato's later life is his intervention in Syracusan politics. On the death of Dionysius I. in 367, Dion conceived the idea of bringing Plato to Syracuse as tutor to his successor, whose education had been neglected. Plato himself was not sanguine of results, but as both Dion and the philosopher-statesman Archytas of Tarentum thought the prospect promising, he felt bound in honour to risk the adventure. The project was by training Dionysius II. in severe science to fit him for the position of a constitutional king who might hold Carthaginian encroachment in Sicily at bay. The scheme was crushed by his natural jealousy of the stronger Dion, whom he drove into virtual banishment. Plato paid a second and longer visit to Syracuse in the year 361–360, in the hope of still effecting an accommodation, but failed, not without some personal danger. When Dion captured Syracuse by a coup-de-main in 357, Plato wrote him a short letter of congratulation and warning against his own lack of tact and graciousness. After the murder of Dion in 354 the philosopher drew up the important seventh and eighth *Epistles*, reviewing and justifying the policy of Dion and himself and making proposals, unsuccessfully, for a conciliation of Sicilian parties.

The prejudice which led students in the 19th century to discredit the *Epistles*, in spite of the favourable opinion of scholars such as Bentley, Cobet, Grote, Blass, E. Meyer, worked havoc with their accounts of Plato's life. It is safe to say that at present the authenticity of the two letters of chief biographical importance, VII. and VIII., is established. I. and perhaps XII. are admittedly unauthentic; on the rest opinion is divided. It seems to be inclining (rightly, as the present writer thinks), in favour of acceptance. The best recent account of the events in Sicily is in E. Meyer, *Geschichte des Altertums*, vol. 5.

To us Plato naturally is important primarily as the greatest of philosophical writers, but to himself the foundation and organization of the Academy must have appeared his chief "work." In the seventh Epistle he utters on his own account the same comparatively unfavourable verdict on written works, in contrast with the contact of living minds, as a vehicle of "philosophy," which he ascribes to Socrates in the *Phaedrus* (Ep. VII. 341 *b.–e.*, 344 *c.*). It can hardly be doubted that he regarded his dialogues as intended in the main to interest an educated outside world in the more serious and arduous labours of his "school."

All the most important mathematical work of the 4th century was done by friends or pupils of Plato. Theaetetus, the founder of solid geometry, was a member of the Academy, as were also the first students of the conic sections. Eudoxus of Cnidus, the author of the doctrine of proportion expounded in Euclid's *Elements*, inventor of the method of finding the areas and volumes of curvilinear figures by exhaustion, and propounder of the astronomical scheme of concentric spheres adopted and altered by Aristotle, removed his school from Cyzicus to Athens for the purpose of cooperation with Plato. Archytas, the inventor of mechanical science, was a friend and correspondent. The Academy is thus the connecting link between the mathematics of the 5th century Pythagoreans and those of the geometers and arithmeticians of Alexandria.

Science.—Nor were other sciences neglected. Speusippus, Plato's nephew and successor, was a voluminous writer on natural history; Aristotle's biological works have been shown to belong largely to the early period in his career immediately after Plato's death, before the breach between the younger philosopher and the Academy. The comic poets found matter for mirth in the attention of the school to botanical classification. The Academy was particularly active in jurisprudence and practical legislation. "Plato sent Aristonymus to the Arcadians, Phormion to Elis, Menedemus to Pyrrha. Eudoxus and Aristotle wrote laws for Cnidus and Stageirus.

"Alexander asked Xenocrates for advice about kingship; the man who was sent to Alexander by the Asiatic Greeks and did most to incite him to his war on the barbarians was Delius of Ephesus, an associate of Plato." (Plutarch, *against Colotes*, 1126 *c.–d.*) The creation of the Academy as a permanent society for the prosecution of both exact and humane sciences was, in fact, the first establishment of a University.

Socrates.—The most important formative influence to which Plato's mind was exposed in youth and early manhood was that of Socrates. But it does not appear that Plato, whose first ambitions were political, belonged to the innermost circle of the old man's intimates, or regarded himself as a "disciple." In *Ep.* VII. he is careful to speak of Socrates not as a "master" but as an older "friend" (ἑταῖρος) for whose character he had a profound respect, and has recorded his own absence (through indisposition) from the death-scene of the *Phaedo*. It would seem that his own vocation to philosophy only dawned on him afterwards, as he reflected on the moral to be learned from the treatment of Socrates by the democratic leaders. Aristotle incidentally ascribes to him an early familiarity with the Heracleitean Cratylus, a younger man than Socrates and apparently an admirer of the philosopher. This may be only Aristotle's inference from the existence of the dialogue

Cratylus. It is more important to remember Plato's connection with Pyrilampes and Critias. Pyrilampes was a Periclean politician, and Critias was known as a democrat until his moral balance was upset by the collapse of the Periclean system in 404. Early upbringing in a family of Periclean politics having connection with Solon may explain why Plato's own estimate of democracy in the *Politicus* and *Laws* is much less unfavourable than that which he ascribes to Socrates in the *Gorgias* and *Republic*.

Beyond this, we can say only that Plato in early life must have been exposed to the same influences as his contemporaries. His early experiences covered the disastrous years of the Deceleian War, the shattering of the Athenian Empire and the fierce civil strife of reactionaries and democrats in the year of anarchy 404–403. He was too young to have known anything by experience of the imperial democracy of Pericles and Cleon, or of the full tide of the "sophistic" movement. It is not from memory that he depicts Protagoras or even Alcibiades, as they were in their great days.

The Works.—The canon and text of Plato appears to have been fixed by two scholars, Dercylides and Thrasylus, either shortly before or shortly after the Christian era. Thrasylus is uncertainly identified with a grammarian of the name who flourished in the reign of Augustus and was "heard" by Tiberius. By reckoning the *Epistles* as one item, the list was made to consist of 36 works, arranged in nine "tetralogies," or groups of four. (Aristophanes of Byzantium had already attempted an arrangement in "trilogies," or groups of three, which, however, he did not carry through.)

Textual Problems.—No genuine work of Plato has been lost, but there is a general agreement of modern scholars to reject a number of small items from the text. Their verdict may be said to have gone definitely against the following, *Alcibiades I., Alcibiades II.* (suspected by some even in ancient times), *Theages, Erastae, Clitophon, Hipparchus, Minos*. Most or all of these are probably early Academic work, and possibly not all later in date than Plato's death. Most, though not all, contemporary scholars also regard the *Epinomis*—in the present writer's opinion wrongly—as an appendix to the *Laws* added *de suo* by the mathematician Philippus of Opus, who is recorded by Diogenes Laertius (III. 37) to have transcribed the work for circulation. The *Greater Hippias* and *Menexenus* are still regarded as doubtful by some, though Aristotle used both, and expressly quotes the latter, in a way which seems to prove that he regarded them as Platonic. (The wild negative criticism of German scholars of the middle of the 19th century, which received its death-blow in 1867 from L. Campbell's proof of the genuineness of *Sophistes* and *Politicus*, is now universally recognized to have been an aberration.) Plato's will, preserved by Diogenes (III. 41–43), is pretty certainly authentic. Some of the 32 epigrams ascribed to him in the *Anthology*, may conceivably be genuine.[1]

Order of Dialogues.—Plato's literary career extended over the greater part of a long life. The *Apology* must have been written while the memory of Socrates' appearance before his judges was still fresh; the *Laws* is confessedly the work of an old man with a long experience of life behind him, and the state of its text fully bears out the tradition, preserved by Proclus, that its aged author never lived to give it final revision. Some half a century or more must have elapsed between Plato's last and his earliest composition.

This of itself would prove that Schleiermacher, with whom modern critical study of Plato begins, went astray in assuming that Plato started his career with a ready-made complete "system" to be disclosed. We must expect to find in his writings evidence of the development of his mind. But if we are to read the development aright we must have some trustworthy way of determining the order of the dialogues. Plato himself has only given us the scantiest indications of the order. He has linked the *Sophistes* and *Politicus* externally with the *Theaetetus* as professed continuations of the conversation reported in that dialogue; he has also, as most students recognize, linked up the *Timaeus* in the same way with the *Republic*. Aristotle adds one other piece of information, that the *Laws* were written after the *Republic*. Further investigation of the problem opens in 1867 with L. Campbell's edition of the *Sophistes* and *Politicus*, and the work thus begun was continued by others, notably W. Dittenberger, C. Ritter and W. Lutoslawski.

By consideration of numerous independent stylistic criteria (for which *see* the works named at the end of this article), it has been definitely established that the dialogues *Sophistes, Politicus, Philebus, Timaeus* (with its fragmentary sequel *Critias*), *Laws*, form a distinct linguistic group, which must belong to the later years of Plato's life, as we might have presumed from the consideration that Socrates, the central figure of other dialogues, becomes, in those of this group (with a solitary exception for the *Philebus*, the one member of the group which is wholly preoccupied with ethics), a secondary personage, and disappears altogether from the *Laws*. The whole group must therefore be later than the *Sophistes*, which professes to be a sequel to the *Theaetetus*. Now the *Theaetetus* can be dated with some accuracy, since it commemorates the recent death of the eminent mathematician after whom it is named from disease and injury contracted in a campaign before Corinth, which, as elaborately proved by Eva Sachs (*de Theaeteto Atheniensi*, Berlin, 1914), must be that of 369 B.C. The dialogue may thus be safely ascribed to 368–367, the eve of Plato's departure for Syracuse, and the marked change of style visible in the *Sophistes* is best explained by the supposition that there was a break in Plato's literary activity during the years 367–360 when he was specially occupied with Sicilian affairs. So much may be regarded as fairly certain.

The Earlier Dialogues.—It is not so easy to reach definite conclusions about the order of composition of the more numerous earlier group of dialogues. It is generally recognized, on linguistic and other grounds, that the series ends with the *Theaetetus* and the closely related *Parmenides*. Attempts have been made by C. Ritter, Lutoslawski and others, to determine the internal order of the group on linguistic evidence, but there are obvious reasons for doubting whether the methods which have been successful in establishing the distinction between the two great groups of earlier and later dialogues can be applied with the same confidence to works belonging to the same general period of their author's life and composed probably at no great distance of time from one another.

In point of fact, there is not complete agreement between the arrangements proposed by different "stylometrists," and their advocates have usually eked out the strictly philological argument by more or less dubious assumptions about the development of Plato's thought, though it is very questionable whether any real development can be traced before the *Theaetetus* and *Parmenides*.[2] Perhaps all that can be said with certainty is that the great outstanding dialogues, *Symposium, Phaedo, Republic* (and the writer of this article would be inclined to add *Protagoras*), in which Plato's dramatic power is at its highest, mark the culmination of this first period of literary activity. The comparative decline of dramatic power, accompanied by compensating maturity of critical acumen is the most striking contrast between the dialogues of the second and those of the first period.[3] A good account of the work done by the "stylometrists" will be found in H. Raeder, *Platons philosophische Entwickelung* (1905).

The Socrates of the Dialogues.—The great initial difficulty which besets the modern student of Platonic philosophy is that created by the dramatic form of Plato's writings. Since Plato

[1] The most dubious are also the best known. That on Agathon (imitated by Shelley, "Kissing Helena") and that on Alexis and Phaedrus are condemned by the occurrence of the names Agathon and Phaedrus. They are obviously suggested by the parts played by the tragic poet Agathon and Phaedrus of Myrrhinus in the *Symposium* and *Phaedrus*. The author has forgotten that both were grown men in Plato's childhood. This suggests suspicion of all the "amatory" verses. The syntax of the first of the epigrams on Aster is also singular.

[2] *See* in particular the important study of P. Shorey, *The Unity of Plato's Thought* (1903).

[3] In *Ep.* VII. 326*a* Plato seems to refer to *Rep.* VI. 499 *b.–c.* as already written before his first visit to Sicily in 387. It has been argued that the *Symposium* must be later than 385 since Aristophanes, who died in that year, is introduced into the dialogue. But it is not clear that Plato made it an absolute rule never to introduce living speakers. It is hard *e.g.*, to believe that Eucleides must have died while the *Theaetetus* was being written.

never introduces himself into his own dialogues, he is not formally committed to anything which is taught in them. The speakers who are formally bound by the utterances of the dialogues are their protagonists, Socrates, Parmenides, the Pythagorean Timaeus, and all these are real historical persons. The question thus arises, with what right do we assume that Plato means us to accept as his own the doctrines put into the mouths of these characters? Is his purpose dogmatic and didactic, or may it be that it is mainly dramatic? Are we more at liberty to hold Plato responsible for what is said by his *dramatis personae* than we should be to treat a poet like Browning in the same fashion?

It is tempting to evade this formidable issue in one of two ways. One is that of Grote, who held that Plato allows himself freely to develop in a dialogue any view which interests him for the moment, without pledging himself to its truth or considering its compatibility with other positions assumed elsewhere in his writings. Thus, according to this theory, Plato can make Socrates advocate hedonistic utilitarianism in the *Protagoras,* or denounce it in the *Gorgias,* can assert the so-called "ideal theory" through the mouth of Socrates in the *Phaedo,* or refute it in the character of Parmenides in the dialogue of that name, with equal gusto and without pledging himself in either case. His championships are purely dramatic, or, at most, reflect his passing mood at the moment of composition.

The more common assumption of the 19th century was that some of Plato's characters, notably Socrates and Timaeus, are "mouthpieces" through whom he inculcates tenets of his own, without concern for dramatic or historical propriety. Thus it was, and often still is, held that the most famous philosophical doctrines of the *Phaedo* and *Republic,* the "ideal theory," the doctrine of "recollection" and of the tripartite soul, were actually originated by Plato after the death of Socrates, to whom these speculations were entirely unknown, and consciously fathered on the older philosopher by a mystification too glaring to deceive any one seriously. Careful study of the dialogues should satisfy us that neither of these two extreme views is tenable.

The Thought of the Earlier and Later Dialogues.—There is undeniably a real difference between the thought of the dialogues which are later than the *Theaetetus* and those which are earlier, and this difference will have to be accounted for. But there are no serious discrepancies of doctrine between the individual dialogues of the same period.[1]

Now Plato seems to announce his own personal conviction of certain doctrines of the second group of dialogues by a striking dramatic device. In the *Sophistes* and *Politicus* the leading part is taken by an Eleatic and in the *Laws* by an Athenian who are the only anonymous, indeed almost certainly the only imaginary, personages in the whole of Plato's writings.[2] It can hardly be doubted that the reason why these two characters have been left anonymous is precisely that the writer may be free to use them as "mouth-pieces" for his own teaching. Plato thus takes on himself the responsibility for the logic and epistemology of the *Sophistes* and *Politicus* and the ethics and educational and political theory of the *Politicus* and *Laws* in a specially marked way, and by doing so compels us to face the question how far he means the utterances of Socrates in his earlier dialogues to be taken as expressions of a philosophy of his own.

"Forms."—It may be regarded as an established result of the inquiries of Dr. Henry Jackson and others that there is a definite philosophical doctrine running through the earlier dialogues which has as its main features the theory of "Forms" (the "ideal" theory), the theory that knowledge is "recollection," and the theory of the "tripartite soul." In the dialogues of the second period these tenets, as we have learned to know them from the earlier dialogues, appear only in the mouth of Timaeus, a 5th century Pythagorean older than Socrates, and the most important of them all, the theory of "Forms" is actually made the object of what looks like a refutation in the *Parmenides.*

The problem is to find an explanation of this puzzling fact. Are we, with Dr. Jackson[3] and others to distinguish two philosophies, both originated by Plato after the death of Socrates, an earlier and a later? Or are we to suppose that in the main the object of the first group of Plato's dialogues is to preserve the memory of Socrates and that the philosophy expounded is in the main what it professes to be, the thought of Socrates, coloured, no doubt, unconsciously but not consciously distorted, in its passage through the mind of Plato? On the second view we should have to say that, strictly speaking, Plato had no distinctive Platonic philosophy until a late period in his life, much as we can say that, though Kant was all through his life a prolific writer on philosophy, there was no distinctive Kantian philosophy before the *Critique of Pure Reason.* Most Platonic scholars are still unwilling to accept this interpretation of the facts, though there are weighty considerations which plead strongly for it.

Socrates and Plato.—It is significant that the only dialogue not earlier than the *Theaetetus* in which Socrates takes a leading part is the *Philebus,* the one member of the second group which deals exclusively with those ethical problems on which the thought of the historical Socrates had been specially concentrated. This is most naturally explained by supposing that Plato, from regard to fact, was unwilling to make Socrates the exponent of doctrines which he knew to be his own property, though it is hard to understand his misgivings if he had already for years been employing him in that very capacity.[4] (If, as is most probable, *Ep.* II. is authentic, the question would be definitely settled by the sentence of the latter [314 *c.*] "there is not, and never will be, a work of Plato; the works which now go by that name belong to Socrates embellished and rejuvenated.")

It is notable, too, that Aristotle apparently knew nothing of an earlier and a later version of Platonism. He attributes a definite doctrine to Plato which is quite unlike anything to be found in the first great group of dialogues, and seems to be known to him from oral communications in the Academy, though something like it can, by looking hard, be read between the lines in the *Philebus.* It was also the view of Neo-Platonic scholars like Proclus that the "ideal theory" expounded in the great earlier dialogues really originated with Socrates and that something of the same kind was also held by contemporary Pythagoreans in Italy (Proclus *in Parmenidem* ed. Stallbaum 562, 610), and the fact that Proclus does not find it necessary to argue the point seems to show that this had been the standing tradition of the Academy. Similarly Galen, in the early 3rd century of our era, has preserved the definite statement of the learned Stoic Poseidonius that the doctrine of the "tripartite soul," often said in modern times to be another invention of Plato's, is as old as Pythagoras (Galen *de placit. Hipp. et Plat.* 425, 478).

Moreover, as Burnet has argued, it is very hard to believe that any writer would introduce a far-reaching novel speculation of his own to the world in the curious fashion which Plato is supposed to have adopted in the *Phaedo,* where Socrates is made to describe the "ideal theory" as something quite familiar which he has for years constantly canvassed with his intimates (nearly all, if not all, of whom, were certainly living when the *Phaedo* was circulated). It is not necessary here to determine the historical question. We may be content to turn to the Platonic dialogues, carefully distinguishing the successors of the *Theaetetus* from its predecessors, and attempt a summary of their contents. The general doctrine of the first period will be described without any more or less arbitrary attempt to say how much of it may be actually "Socratic." We may then consider how far this doctrine is modi-

[1] As there would be between the *Protagoras* and the *Gorgias* or *Phaedo* if the *Protagoras* really said that the pleasure is the good. What it actually says is only that "the many," "most men," hold this view (353 *d.–e.*), and ought not therefore to regard the doctrine that "goodness is knowledge" as paradoxical, since on their own theory, virtue will amount to right computation of pleasures and pains.

[2] Except the two minor personages of the *Laws,* a Spartan and a Cretan, who have really nothing to do except to say "Yes," "No," in the appropriate places.

[3] *Journal of Philology* X.–XII.

[4] It might be said that if the principal doctrines of the Platonic Socrates were known by Plato to be his own peculiar property, he might feel a difficulty about putting a new and more critical philosophy into the mouth of the speaker who had been used as the exponent of his "earlier" teaching. But this would not wholly explain why Socrates might not have been made to teach the logic of the *Sophistes.*

fied in later dialogues, or in the version of Platonism presupposed by Aristotle's criticisms.

No attempt will be made here to describe the personality or temperament of Plato which is, in fact, as elusive as that of Shakespeare and for the same reason. He is often credited with a strongly "mystical" and "erotic" temperament. He does ascribe such a temperament to Socrates, but it is puerile to treat his picture of Socrates as evidence about himself, though the mistake is constantly committed.

It should therefore be noted that the "mysticism" is confined to dialogues of the first period, in which Socrates is its exponent, and that the "erotic" language in which Plato's Socrates speaks of his devotion to his young friends was also used by the Socrates of Aeschines to describe his relations with Alcibiades (Fr. 4, Krauss). There is no evidence that Plato personally ever fired the imagination of gifted boys as Socrates did. Apart from the *Epistles*, the most valuable light we possess on Plato's personality is afforded by Aristotle's description of him as a man "whom it is blasphemy in the base even to praise" (*ὃν οὐδ' αἰνεῖν τοῖσι κακοῖσι θέμις*).

THE EARLIER DIALOGUES

In the *Republic*, the greatest of all the dialogues which precede the *Theaetetus*, there may be said to be three main strands of argument deftly combined into a consummate artistic whole, the ethical and political, the aesthetic and "mystical," and the metaphysical. Other major dialogues belonging to this period give special prominence to some one of these three lines of thought; the *Phaedo* to the metaphysical theme, the *Protagoras* and *Gorgias* to the ethical and political, the *Symposium* and *Phaedrus* to the aesthetic and "mystical," though in none does Plato make an artificially rigid separation of any one of the great ideal interests of human life from the rest.

The shorter dialogues deal with more special problems, usually of an ethical character, and mostly conform to a common type. A problem in moral science, often that of the right definition of a "virtue," is propounded, a number of tentative solutions are considered and are all found to be vitiated by difficulties which we cannot dispel; we are thus left, at the end of the conversation, aware of our discreditable ignorance of the very things it is most imperative for man to know. We have formally "learned" nothing, but have been made alive to the worthlessness of what we had hitherto been content to take for knowledge and the need of seeking further enlightenment.

The effect of these "dialogues of search" is thus to put us in tune with the spirit of Socrates, who had said that the one respect in which he was wiser than other men was just his keen realization of his own ignorance of the most important matters. We learn the meaning of his ruling principle that the supreme business of life is to "tend" the soul (to "make it as good as possible") and his conviction that "goodness of soul" means first and foremost, *knowledge* of good and evil. The three dialogues directly concerned with the trial of Socrates have manifestly a further purpose. They are intended to explain to a puzzled public why Socrates thought it stuff of the conscience neither to withdraw from danger before trial, nor to make a conciliatory defence, nor, finally, to avail himself of the opportunity of flight after conviction. Even well-wishers like Xenophon, as we know, were puzzled by what had seemed his wilfully defiant attitude; it was therefore a debt of honour to his memory to put the matter in the true light. In the remarks which follow, we will consider these shorter dialogues in an order adopted simply for purposes of convenience.

Hippias I. and II.—In these dialogues Socrates has as "respondent" the well-known polymath Hippias of Elis, whose self-complacency is sharply satirized. In the *Hippias Maior* the question propounded is "What is the fine" (*καλόν*)? "Fine" is a predicate by which we are constantly expressing both aesthetic and moral approval; do we really know what we mean by it? We discover that we do not, though incidentally we also learn that "fine" or "beautiful" is certainly not a synonym for either "useful" or "pleasant." *Hippias Minor* deals directly with the famous Socratic paradox that "wrong-doing is involuntary." It is commonly held that it is much worse to tell a wilful untruth than to blunder into an unintentional false statement. Yet the analogy of the arts and professions seems to show that the man who errs intentionally, if there is such a person, is a better man than he who errs unintentionally. (The suggested thought, of course, is that there "is no such person." The man who knows what is good will always aim at this and at nothing else,—the familiar doctrine of Socrates.)

Ion, Menexenus.—Both these are "occasional" works. Socrates had said that he found the poets, who as a class are commonly reckoned "wise," quite unable to explain to him how they came to say their best things, or what they meant by them. (*Apol.* 22 *a.–c.*) The *Ion* develops this thought into the theory that neither the poet, nor his interpreter the "rhapsode," produces his effects "by science," *i.e.*, as a result of conscious "artistry"; the effect in both cases is due to a non-rational "inspiration," or, as we now say, "native genius." (The importance of this is that it rules out appeal to the poets as specially competent authorities on the conduct of life.)

The *Menexenus*, which professes to repeat a "funeral oration" learned from the famous Aspasia, is apparently meant as a satire on "patriotic" distortion of history. Apparently the "discourses" satirized are those of Pericles in Thucydides, Lysias (Lysias II.) and Isocrates (the Panegyricus). The singular anachronism by which Socrates (and Aspasia) are represented as commenting on the events of the Corinthian War down to the year 387 must be intentional, whatever its object.

Charmides, Laches, Lysis.—These are typical "dialogues of search." The question of the *Charmides*, which contains a particularly delightful picture of the way of Socrates with a promising lad, is what is meant by *sophrosyne*, the virtue which is shown alike in graceful and easy command of one's appetites and passions, in dutiful behaviour to parents, elders, official "superiors," in balance and sanity amid the ups and downs of fortune. We seem to be in a fair way to identify this virtue with "knowledge of self"—the self-knowledge Socrates had valued so highly—when we are confronted with an ambiguity. "Self-knowledge" might be taken to mean a knowledge which has knowledge itself for its object, in fact for "epistemology." But it is hard to be sure that there is any such science as "the knowledge of knowledge," and harder still to see how such knowledge could be directive of conduct.

In the *Laches* we are concerned with valour, the soldier's virtue. Here again we are on the point of defining the virtue as knowledge of what is and what is not really to be dreaded. But this is tantamount to saying the true knowledge of evil and good, and the resultant definition, "valour is knowledge of good" would identify valour with the whole "goodness of man." That is, the definition is only possible if we can meet the popular objections to the Socratic thesis of the "unity of virtue."

The *Lysis* examines in the same tentative way, friendship, the relation in which self-forgetting devotion most conspicuously displays itself. The *crux* of the problem is that after many false starts, we seem to have reached a promising result in the view that each friend is really "a part of" the other in "soul or temper or body," and yet it is hard to reconcile this position with the facts which seem to show that "unlikeness" is a potent source of attraction. Aristotle has taken up and discussed the issues raised in the dialogue in his own treatment of the same subject. (*E.N.* VIII.–IX.).

Cratylus.—The question here, one much agitated in the age of Socrates, is whether names are significant by "nature" or "convention." Is there some special appropriateness of the sounds of names to the objects called by them, or is there no bond between the thing and its name but that of the "usage of the community"? The absurdity of attempts to get metaphysics out of etymologies is humorously exposed by showing that the method can be used at pleasure to prove either that the "giver of names" agreed with Heracleitus that motion is the sole reality or that he held, with Parmenides, that motion is an illusion. Yet there are real analogies between "vocal gestures" and the things signified by them, which are pointed out with a good deal of insight. The main purpose of Plato, however, is to dwell on the point that language

is an instrument of thought; the test of its rightness is not mere "social usage," but its capacity to express true thought accurately.

Euthydemus.—The dialogue is, in large part, broad satire on "eristics" who misapply the logic of Zeno for the purpose of entangling anyone who commits himself to any assertion in fallacies due to the ambiguity of language. (Aristotle has drawn freely upon it in his own essay on Fallacies, the *de Sophisticis Elenchis.*) Its more serious purpose is to contrast this futile contradiction-mongering with the "protreptic" of Socrates. The lad Clinias is simply bewildered by the questions of the two professors of "eristic"; those of Socrates have the purpose of convincing him that the happiness we all desire is not guaranteed by the *possession* of the things the world accounts good, but depends on our making the right *use* of them. If we would attain happiness we must "tend" our "souls," and that means that we must acquire the "royal" science which ensures that we shall make the right use of all the gifts of mind, body and fortune, in other words, the knowledge of true and absolute good.

Gorgias.—The *Gorgias* is a much greater, as well as a much longer work than any of those we have considered, and has always been a prime favourite with serious moralists. Beginning ostensibly as an enquiry into the nature and worth of "rhetoric," the art of advocacy professed by Gorgias, it develops into a plea of sustained eloquence and logical power for absolute right, as against expediency, as the sovereign rule of life private and public, and ends with an imaginative picture, on Orphic lines, of the eternal destinies of the righteous and the unrighteous soul. Literature has no more impressive presentation of the claim of conscience to unqualified obedience and the impossibility of divorcing the politically from the morally right.

Gorgias holds that "rhetoric" is an "art," the application of knowledge to practice, and the queen of all "arts," since it gives its possessor the object of man's highest ambition, power to enforce his will on society. The statesman, who is the man of men, is just a consummate advocate speaking from a brief. If he is clever enough he will, though a layman, carry the day with an audience of laymen, even against the expert specialist. To his audience he will seem, though he is not, the superior of the real expert. Socrates declares that "rhetoric" is not an "art," a matter of native principles, but a mere "empiric knack" (*τριβή*) of humoring the prejudices and pleasing the tastes of an audience. It is a subspecies of *κολακεία*, "parasitism."

There are two genuine "arts" conducive to the health of the body, those of the trainer and the physician; each has its parasitic counterfeit, the one in the profession of the "beautifier," the other in that of the confectioner. So there are two "arts" conducive to "health of soul," those of the legislator, who lays down the rule of morally sane life, and of the judge, who corrects moral disorders. The "sophist" counterfeits the first, as the "rhetorician" the second, by taking the "pleasant" instead of the "good" as his standard. The "rhetorician" is thus not the wise physician of the body politic but its "toady" (*κόλαξ*). This severe judgment is disputed by Polus, the ardent admirer of Gorgias, on the ground that the successful "rhetorician" is virtually the autocrat of the community; every man's life and property are at his mercy.

To be such an autocrat is the summit of human happiness; even if, like Archelaus of Macedonia, the aspirant only reaches the position by a series of shocking crimes, he is the most enviable of mankind, because he is above law and can do "whatever he likes." Socrates denies this. The autocrat always does "as he pleases," and for that reason never does "what he wishes"; like all mankind, he wishes for true happiness or good, but no act which is immoral ("unjust") ever leads to happiness. To suffer a wrong is an evil, but to inflict one is much worse. And if a man has committed a wrong, it is much worse for him to go unpunished than to be cured of his moral malady by the sharp but wholesome medicine of punishment. If "rhetoric" is of real service to men, it should be most of all serviceable to an offender. If he knew his own interest, he would employ all his powers of persuasion to move the authorities to inflict the penalties for which the state of his soul calls. Polus is unable to meet this reasoning, because he had at least conceded to current morality that it is more disgraceful, though not more evil to inflict wrong than to suffer it.

This is denied by Callicles of Acharnae, an otherwise unknown politician, who proceeds recklessly to develop the doctrine of the "will to power." It may be a convention of the herd that unscrupulous aggression is discreditable and wrong, but "nature's convention" (the *νόμος τῆς φύσεως*, a phrase which appears here for the first time in literature) is that the strong are justified in using their strength as they please, while the weak "go to the wall." Callicles and Socrates thus appear as champions of two contrasted moralities of private and public life. Callicles stands for self-assertion in ethics and aggressive "Imperialism" in politics. Socrates opposes both. In his judgment the creators of the imperialistic Athenian democracy were no true statesmen, because they were content to give Athens a navy and a commerce without creating a morally sound national character. They may have been capable "domestic servants" of the democracy for whose tastes they catered; they were not its physicians. The one true statesman of the past was the "just" Aristeides; in the present, Socrates himself is the one man who shows a statesman-like mind, though it is perfectly true that he might at any moment have to pay with his life for refusing to call that good which pleases the public fancy. It is not true, as Callicles supposes it to be, that the secret of happiness is to have strong and vehement passions and be able to gratify them to the full. That would be a condition like that of the fabled sinners who are punished in Hades by being set to spend eternity in filling leaking pitchers. The truly happy life is that of "measure" in which the gratification of desire is strictly regulated by regard for justice and *sophrosyne.* If we may believe the Orphic doctrine of judgment to come, the votary of "passion" and injustice has a heavy reckoning to await hereafter.

Meno.—The *Meno* is nominally concerned with the question what virtue is and whether it can be taught, but it is further interesting for two reasons. It states clearly the doctrine, which we have not met so far, that knowledge is "recollection"; it also introduces as a character the democratic politician, Anytus, the main author of the prosecution of Socrates. It seems plain that Plato wishes to indicate his opinion that it was Socrates' severe criticism of the great figures of the history of Athenian democracy which led to the prosecution.

Can virtue be taught or learned (as must be the case, if the professional sophists can really do what they profess)? That depends on what virtue is. We are on the way to define it as "ability to secure good things by honest means," when we reflect that honesty itself is a "good thing," and the definition consequently is circular. This reminds us of the current dilemma that all such inquiries are futile because it is idle to inquire into what you already know, useless to inquire into what you do not know (since you could not recognize the unknown, even if you found it). This difficulty would vanish if it were true that the soul is immortal and has long ago learned all truth, so that it needs now only to be "reminded" by sense-experiences of truths it once knew and has forgotten. This (Orphic) doctrine seems to be supported by the experience that a lad who has never studied geometry can be brought to recognize mathematical truths by merely showing him a diagram and asking him appropriate questions about it. He produces the right answer "out of himself." (The point thus is the presence of an *a priori* element in mathematical truth.)

In any case, we may say that if "virtue" is knowledge, it can be taught; if it is not knowledge, it cannot. But is it knowledge? If it is, one would suppose that there must be professional teachers of it. But Anytus assures us vehemently that the sophists, who claim to be such professionals, are mischievous impostors, and we can be sure that the ordinary decent citizen cannot "teach virtue," as Anytus maintains, since the "best men" of the democracy, Themistocles and the rest, have been unable to teach it to their own sons. Perhaps, then, we must say that the "best men" of Athens have no genuine knowledge of good; their successes have been due not to knowledge, but to

mere "correct opinions." Still, for practical purposes a correct opinion will serve as well as knowledge. The trouble is that you cannot depend on its permanency unless you fasten it down by thinking out the reason why of it (*αἰτίας λογισμῷ*). Then it becomes knowledge. If a man should arise who could actually teach statesmanship to others, he would be one who really *knew* what good is; the virtue of such a scientific statesman would be to that of other men as substance is to shadow.

Protagoras.—This finely dramatic dialogue gives us the completest presentation to be found in Plato of the main principles of the Socratic morality, and is the direct source of Aristotle's statements about the teaching of Socrates in the *Nicomachean Ethics*.

Socrates meets, in the house of Callias, the eminent sophist Protagoras, who is very attractively drawn and represented as a great admirer of the younger man's ability. Protagoras explains that his profession is the "teaching of goodness," and that by "goodness" he means the art of making a success of one's own life, that of one's household and that of one's "city." (Thus he teaches "the conduct of life, private and public," and has done so for years with success.) Socrates urges that there are two considerations which make it look doubtful whether this art can be taught. The Athenians have a high reputation for intelligence, but it is notorious that the Ecclesia requires no evidence of expert knowledge in a speaker who discusses the morality of a proposed course of action.

Also the eminent democratic statesmen have never taught their own "goodness" to their sons. Public opinion and the practice of the eminent few alike suggest that the "conduct of life" is not teachable. Protagoras, to be sure, thinks that the absence of special teachers only proves that every citizen of a civilized city can, in his degree, act as teacher, exactly as he can teach his children his native language or his trade. Goodness depends on *δίκη* and *αἰδώς*; the sense of right and conscience, and the whole of life in a civilised society, is a process of education in these. His exposition at once raises the problem of the unity of virtue. Are the various commonly recognized "virtues" really different, so that a man may be strong in one but weak in another? Protagoras is at first inclined to say that they are, but on reconsideration is ready to identify all of them but one with wisdom or sound judgment.

An exception must be made for courage, a virtue which is popularly regarded as having something conspicuously non-rational about it. The dialogue culminates in an argument by which Socrates attempts to show that there is no need to make this exception. The general public, the party which insists so much on the non-rational character of courage, would be ready to accept the identification of the good and the pleasant, and to grant that the goodness of courage means that by facing pain and danger one escapes worse pain or danger. On their own theory, then, courage, and the rest of virtue, can be reduced to prudent computation of pleasures and pains. The humour of the situation is that Socrates and Protagoras have thus changed places. Socrates, who had raised a difficulty about the teachability of virtue, is left satisfied that virtue must be knowledge; Protagoras, who claimed to be able to teach it, ends by declaring that, whatever virtue may be, it cannot be knowledge. It is important to observe that the dialogue does not teach Hedonism. The equation good=pleasant is advanced only as one which would be accepted by "the mass of men," and should forbid them to find a paradox in the identification of virtue with knowledge; it is expressly repudiated by Protagoras as unworthy of a man of high character.

All that Socrates asserts is that virtue is knowledge and wrong-doing consequently involuntary. There is no disagreement in moral principle between the *Protagoras* and the *Phaedo* or *Gorgias*. If the "mass of men" are ready to accept the Hedonist formula, that is because they are votaries of the body-loving life (*βίος φιλοσώματος*); this is why we are told in the *Phaedo* that "popular" virtue is illusory. The true explanation of Socrates' doubts is that though he holds that true virtue, being knowledge, is teachable, he does not believe that what Protagoras is trying to teach is true virtue. "Success" depends on personal "tact" and "tact" cannot be learned from an instructor.

Euthyphro, Apology, Crito.—The main purpose of these three works, which deal with the bearing of Socrates before, during and after his trial, is to obviate possible serious misunderstandings of the Master's position and motives; the theme of all three may be said to be the true meaning and importance of "care" or "tendance" of the soul.

The problem of the *Euthyphro* is what is religion (*τὸ ὅσιον*). The respondent Euthyphron is certainly meant to be a kind of Orphic sectary, not, as has been fancied, a representative of ordinary Athenian belief and practice. Socrates had associated with such men and was known to hold unusual beliefs about the soul; hence it was important to make it plain that he was something different from a fanatic. The dialogue, interesting also from its well-developed logical terminology, enables Socrates to repudiate immoral mythology and to reject the conception of "religious duty" as fulfilment of purely arbitrary commands. Its central thought, which, however, is not formally asserted as a conclusion, is that the "service" (*θεραπεία*) of God which is religion means co-operation with God and under God in the production of a "noble work" (*πάγκαλον ἔργον*), the nature of which is not further defined, though it is sufficiently clear that the "work" meant is the "tendance of the soul."

Consideration of the *Apology* and *Crito* in detail belongs rather to the study of Socrates (*q.v.*) than to that of Plato. Of the *Apology* we must be content to say here that the real defence of Socrates is contained in the pages which explain that the mainspring of his life has been his conviction that he has a mission from God to spend his life in "philosophy," the endeavour to "make his own soul as good as possible," and to incite mankind to do the same; to this mission it is his duty to be strictly faithful, even if faithfulness means condemnation as a traitor by the democracy. The *Apology* thus depicts Socrates as carrying out in his own practice the ethical programme of the *Gorgias*. The actual accusation is treated with contempt and satirical humour. (*See* article SOCRATES.)

The point of the *Crito*, though simple, is often missed. Was Socrates wantonly throwing away a valuable life by refusing to escape from prison? Why did he make this refusal? Because, though the conviction was materially iniquitous, it was the verdict of a legitimate court, which could not be disregarded without real disloyalty. Socrates has been wronged not by the law, but by politicians who have abused the law. If he disregarded the conviction, he would be directly doing a wrong against the whole social system.

Foundation of Plato's Doctrine.—In the works so far considered we have the foundation of a moral and political doctrine based on Socratic principles, from which Plato never departed. The main underlying thought is that the great concern of man, a concern not limited to this earthly life, is the development of a rational moral personality (the "tendance of the soul"). Our felicity depends wholly on our success in this task (to use Butler's language, on "our conduct," not on "our condition"). And this success, again, depends on rational insight into the true scale of good. Men do not miss felicity because they do not desire it; on the contrary no man ever really desires anything else. The reason why men forfeit felicity is that they mistake apparent good for real, the conditionally for the absolutely good. If a man ever knew with assurance what absolute good is, he would in practice never pursue anything else. It is in this sense that "all virtue is knowledge" and that "all wrong-doing is involuntary" (*i.e.*, consists in the pursuit of what is falsely supposed to be good).

"Popular morality" is confused in theory and unreliable in practice because it does not rest on any assured insight into absolute good; "philosophic morality," just because it does rest on such certain insight, is a morality of absolute and unconditional obedience to conscience, such as Socrates had shown. Since the task of the statesman is simply the task of "tending the soul" extended to the "national" soul as its object, the "philosophical" moralist is also the only true statesman. True states-

manship means the promotion of national character as the one thing which matters, and is therefore simply the application, on the grand scale, of the principles of absolute morality; what falls short of this is opportunism masquerading as statesmanship.

These convictions clearly imply a far-reaching metaphysic as their foundation and justification. The principles of this metaphysic, though they are frequently hinted at in passages of dialogues already reviewed, are put before us more explicitly in those we have now to consider; in connection with them we shall also observe an explicit theory of knowledge and scientific method.

Phaedo.—The *Phaedo* is often treated as though its object were to provide a demonstration of the immortality of the soul. It does not really profess to do this. The object is to justify faith in immortality as a rational faith by showing that it follows naturally from a fundamental metaphysical doctrine (the "ideal theory" or "doctrine of Forms"), which seems to afford a rational clue to the structure of the universe, though it is expressly said at the end of the whole discussion that this doctrine itself still requires further examination. At the same time, it is made fully clear that the writer accepts this metaphysical doctrine, with the reservation just mentioned, and is passionately sincere in the faith in "personal immortality" which he brings into connection with it. To be strictly accurate, indeed, we ought to say that the faith to be defended goes beyond belief in "immortality." What is being maintained is the "divinity" of the soul; its survival of death is a consequence of this inherent divinity.[1]

The argument is briefly as follows. A true philosopher may naturally look forward to death without dismay. For death is the separation of soul from body, and the philosopher's whole life has been spent in trying to liberate the soul from dependence on her body. In life, the body is always interfering with the soul's activity. Its appetites and passion interrupt our pursuit of wisdom and goodness; its infirmities are perpetually hindering our thinking. Even in our scientific work, we only attain exact and certain truth in proportion as we detach ourselves from reliance on sense-perception and learn to depend on pure thinking.

Death, then, only completes a liberation which the philosopher has been "rehearsing" all through life—if, that is, the soul continues to exist after death, as there are reasons for thinking. For:

I. There is a belief that the soul has a succession of many lives, and that when it is born into this world, it has come back from another. And there are two considerations to be urged on behalf of this belief. (*a*) The processes of nature in general are cyclical. The hot becomes cold, the cold hot; the waking go to sleep, the sleeping wake. It is reasonable to suppose that this applies to the case of dying and coming to life, so that the dead return to life, just as the living die. If this were not so, if the process of dying were not reversible, life would ultimately vanish from the universe. And (*b*) we may appeal to the doctrine that what we call "learning" is really "recollection," "being reminded" of something. This certainly seems to be the case, for in all our science we are perpetually being "put in mind of" precise ideal standards, mathematical or moral. We reason about exact quality, absolute justice and the like. Sense or experience never presents us with such perfect equality or justice; it only suggests them or "reminds us of them." We must therefore have become acquainted with them before we were confined to our bodies, and therefore must have existed before our birth. Now (*a*) and (*b*) together would prove what we want to prove, the soul's survival of death, though our "dread of the dark" makes us demand a more convincing argument.

II. We may consider the antithesis between the divine and eternal and the temporal and mutable, which runs through the universe. The body is certainly temporal and mutable. The soul is relatively immutable, like the fixed ideal standards or norms which she contemplates in her scientific thinking. Her thought is concerned with eternal objects and she herself has the likeness of that which she contemplates. If, then, some constituents of the body are nearly indestructible how much more should one expect the divine element in us, the soul, to resist destruction, as the traditions about re-birth assert that it does.

There are two grave "scientific" difficulties still to face. It may be argued: (*a*) that the soul is an "epiphenomenon," the "tune" (ἁρμονία) given out by the body, and if so, its superior "divinity" will not protect it from vanishing when the instrument which makes the music is broken; (*b*) that though the soul actually makes its own body, and perhaps can make a long succession of bodies, it cannot do so without "expending energy"; a time will come when it can no longer make a fresh body, and then it will itself disappear. We must not be driven into misology, antipathy to science, by this apparent clash between science and a faith to which we are attached.

The answer to (*a*) is that there are good souls and bad ones, and the good soul is "more in tune" than the bad one. But that which can be more or less "in tune" is clearly not itself a "tune." And if the soul were the "tune" resulting from the functioning of the body, its character at any moment would be a resultant of the condition of the body. How then could we have the experience, characteristic of the moral life, of the conflict between the soul with its aspirations and the body with its carnalities? The answer to (*b*) can only be given as part of a whole theory of the causes of "coming into being and passing out of being." Socrates had been led, early in life, to frame a tentative theory of the matter in consequence of his dissatisfaction with the chaotic state of physical speculation, and in particular with the failure of Anaxagoras to make any satisfactory use of his apparently teleological principle that "mind is the cause of all order and structure." He fell back on the method of "hypothesis."

What distinguishes this method from all others is that it begins by making an undemonstrated "postulate" (ὑπόθεσις). It then proceeds from this point to consider the truth or falsehood of the consequences which follow logically, from the initial postulate; the question of the truth of the postulate is, for the present, left unasked. Socrates' own fundamental unproved postulate has always been that usually, but loosely, called the "theory of Ideas." The postulate is that there really is a single determinate and immutable something (εἶδος, ἰδέα) answering to every significant "general term," and apprehended only by pure thought. The sensible things of which we predicate general terms temporarily "partake in" or "communicate with" the Idea or Form (ἰδέα, εἶδος). When we say that a thing becomes *e.g.*, beautiful, what we mean is that the Form (ἰδέα) "beauty" begins to be "present to" that thing, the thing begins to "partake of" the Form. When we say that a thing ceases to be beautiful, we mean that this relation of "presence," "participation," "communication" (παρουσία, μέθεξις, κοινωνία) is dissolved. This is the true account of the cause of "coming into and passing out of being," and if we accept it, we may proceed to our final argument for immortality.

III. There are Forms which are mutually incompatible, such as warmth and cold. Heat is never cool, and cold is never warm. But there are also certain sensible things of which it is an essential character to "partake of" a given Form. Such things will never admit an incompatible Form. Thus it is an essential character of snow to "partake of" cold. It will never, therefore, "partake of" the Form "heat." Similarly it is an essential character of a soul to be alive, to "partake of" the Form "life." It refuses to "partake of" the Form "death." At the approach of death, the soul must either retire or be annihilated (the metaphors are military). What we have said of its divinity forbids us to think that it is annihilated; we must therefore assume that it "retires" to some other region. The proof of immortality is thus hypothetical; it is shown to be involved as a consequence by the doctrine of Forms. This doctrine has been stated as a fundamental unproved postulate and it is admitted that it demands fuller consideration.

But our enquiry has at least satisfied us that the hope of immor-

[1] Plato's belief in immortality ought never to have been disputed. It is re-affirmed in the most unqualified way in the seventh *Epistle* (335*a*–*b*) and his very latest work, the *Laws* (904*c*–905*d*), though the particular arguments of the *Phaedo* do not re-appear there. Aristotle, too, in his early days as a member of the Academy, had taught the doctrine in his *Eudemus* (*Fragmenta*, ed. Rose 37–48). This consideration is really decisive. The characteristic argument of the *Laws*, from the "self-moving" nature of the soul had already been used in the *Phaedrus* (245*c*). *Timaeus* 41*a*, where the final appeal is to the goodness of the Creator, formally applies not to men but to the stars.

tality is a reasonable one. (To distrust it would be to call the foundation of our whole philosophy into question.) The discourse ends with an imaginative cosmological myth depicting the future of the just and the unjust respectively.

In this statement of the theory of Forms (ἰδέαι, εἴδη) we may note the following points: (1) The doctrine is a piece of "realist" metaphysics. It is assumed that a universally predicated "general term" denotes or stands for an individual reality, apprehensible by thought, though not by sense. (2) There are a plurality of such Forms, standing in various logical relations with one another; whether they constitute a system with a definite structure the *Phaedo* does not tell us. (3) They are at once the objects known in all genuine science and the formal causes of all the temporal processes of the sensible world. (4) The sensible things which have the same names as Forms are said to owe their character to their "participation" (μέθεξις) of the Forms, or, equivalently, to the "presence" (παρουσία) or "communication" of the Forms to them. The precise character of this relation of "participation" is admitted to need further explanation. So far as the language of the *Phaedo* goes, a sensible thing would seem to be thought of as a temporary "complex" or meeting-place of universal characters and as nothing more.

Symposium, Phaedrus.—It is by no means clear that these two dialogues are closely connected in point of date, but they may be considered together as both presenting the Forms in a special light, as objects of mystical contemplation and excitant of mystical emotion.

The argument of the *Symposium* cannot be reproduced here as a whole. The immediate object of the dialogue, which professes to record the discourses made in eulogy of Eros by a group of eminent speakers at a banquet in honour of the tragic poet Agathon, in the year 416–5, is to find the highest manifestation of the "Love" which controls the world in the mystic aspiration after union with the eternal and super-cosmic Beauty, to depict Socrates as the type of the aspirant who has reached the goal of "union," and to set in sharp opposition to him the figure of Alcibiades, who has sold his spiritual birthright for the pleasures and ambitions of the world. The centre of philosophical interest lies in the discourse of Socrates, which he professes to have learned a quarter of a century ago from the priestess Diotima of Mantineia.[1]

The main argument may be summarized thus. Eros, *desirous* love, in all its forms, is a reaching out of the soul to a good to which it aspires but has it not yet in possession. The desirous soul is not yet in fruition of good. It is on the way to fruition, just as the "philosopher" is not yet in possession of wisdom but is reaching out after it.

The object which awakens this desirous love in all its forms is Beauty, and Beauty is eternal. In its crudest form, love for a beautiful person is really a passion to beget offspring by that person and so to attain, by the perpetuation of one's stock, the *succedaneum* for immortality which is all the body can achieve. A more spiritual form of the same craving for eternity is the aspiration to win immortal fame by combining with a kindred soul to give birth to sound institutions and rules of life. Still more spiritual is the endeavour, in association with chosen minds, to enrich philosophy and science with "noble discourses and thoughts."

But the goal still lies far ahead. When a man has followed the pilgrimage so far, he "suddenly descries" a Supreme Beauty which is the cause and source of all the beauties he has discerned so far. The true achievement of immortality is finally effected only by union with this. The philosopher's path thus culminates in a supreme "beatific vision." It is clear that the object of this vision, the "Beauty sole and eternal" of the dialogue, means what the *Republic* calls "the Good" or "Form of Good," which by its presence actually causes the goodness of everything else to which the name of good can be given. The Forms are thus thought of as a hierarchy with a supreme Form at their head, though no attempt is made at a rational theory of the way in which the supreme Form unites the rest into the system.

The immediate subject of the *Phaedrus* is the principles of "rhetoric" or, as we should say, prose composition. The *Gorgias* had told us that "rhetoric" as commonly practised is not a matter of rational principles at all, but a mere empirical trick of adapting one's tone to the prejudices of an audience. The *Phaedrus* aims at showing how a really scientific "rhetoric" might be built on the double foundation of logical method and scientific study of human passions. Plato contrives, however, by making a real or supposed "erotic" composition of Lysias the starting-point of his criticisms, to unite with this topic a discussion of the psychology of "love," and this, as in the *Symposium*, leads him to speak of the Forms as the objects of transcendental emotion. The soul is immortal, because it has within itself a native source of spontaneous movement.[2] In its disembodied state it shared the life of the gods and could enjoy the direct contemplation of "unbodied" reality, that is, of the Forms. It has suffered an antenatal fall into an embodied condition in which it is blind to everything which does not come in at the avenues of sense.

Now our senses only suggest few and faint images of such Forms as Justice and Temperance, but they can suggest Beauty in a much more impressive and startling way. To "fall in love" is to come under the influence of such sudden and arresting suggestions of Beauty; the "unreason" and "madness" of the lover mean that he is being awakened to realities which other men ignore. The "wings" of his soul are beginning to grow again, and his experience, rightly used, will be the first step in the soul's return to its high estate. This section of the *Phaedrus* is the *locus classicus* in Plato for the Forms as objects of mystical contemplation.

Republic.—The philosophy pre-supposed in all these dialogues receives its fullest exposition in the *Republic*. Here the immediate problem is strictly ethical. What is Justice (τὸ δίκαιον, δικαιοσύνη)? Can it be shown that Justice is always a boon, injustice a curse, to its possessor, apart from all consideration of consequences in this life or another? That is, is there a rational principle at the root of moral distinctions, and does the principle carry with itself its own intrinsic and indefeasible authority?

Plato's answer is that there is such a principle; each of us, in virtue of his special endowments and aptitudes, has a specific "work" or "vocation"; there is some special contribution which he, and no other, can make most effectively to the life of a rational society. Morality, "Justice," is to discharge that vocation to the height and with a single mind (τὰ αὑτοῦ πράττειν καὶ μὴ πολυπραγμονεῖν). To live thus is to be in spiritual health; to live otherwise is to be spiritually diseased. The obligation is thus intrinsic and absolute. This position has to be made good against the incoherencies of a morality of uncriticized traditional maxims, as well as against the "inmoralism" of advanced thought (represented by Thrasymachus in Bk. I., expounded more intelligently by Glaucon in Bk. II.).

This leads us to consider what would be the general type of life in a society where the principle of Justice had power as well as manifest authority, and how it might acquire that power. Hence the need for a sketch (II., III.) of the institutions of the reformed society, and particularly of its moral and religious education. We have next to satisfy ourselves that the principles which regulate the public life of the morally healthy society are also recognizably the principles of the great virtues of private life. For this purpose, we need a psychology of voluntary action which is provided (Bk. IV.) by the doctrine of the "tripartite soul." This is not, indeed, a scientific psychology, but proves adequate to describe the moral life of the ordinary good citizen of such a society as we have conceived. The foundation of all this moral excellence

[1] It is important to remember that Socrates professes to be repeating a lesson he had learned at about the age of 30. This explains at once the words of *Symposium* 210*a*, where Diotima expresses uncertainty about Socrates' achievement of the complete "vision." He has his life yet to live; what it will be is not revealed. That the words have gravely been interpreted as a claim on Plato's part to have transcended his Master's limitations is only one example of the perversity with which he has been misunderstood.

[2] This is the argument for immortality to which Plato trusts in the *Laws*. It is not specially mentioned in the *Phaedo*, but this can hardly mean that Plato had not yet discovered it, since it is, in fact, taken from Alcmaeon of Crotona, a medical man of the beginning of the fifth century.

is thus laid in absolute loyalty to a sound moral tradition enforced by education. To ensure that the tradition shall be thoroughly sound, we must stipulate that the authorities who create it do not themselves depend on tradition for their convictions about good and evil; they must not "opine," but know, by personal insight. The statesmen at the head of the community must be "philosophers" as well as kings (Bk. VI.).

But the vision of "the Good" will only dawn on them if they have been prepared for it by an intellectual discipline in hard thinking which leads them through the curriculum of the exact sciences to the critical study of the metaphysical principles involved in science (Bk. VII.). The central books of the *Republic* thus present us with an outline of metaphysics and a philosophy of the sciences. We now turn back to consider the various stages of degeneration through which national and personal character pass when the true moral ideal is allowed to fall more and more completely out of view. As we pass them in review, we are increasingly confirmed in our conviction that, in respect of happiness, the life of regard for right is immeasurably superior to that of sating one's cupidities or gratifying one's personal ambitions (VIII.–IX.), and this conclusion is finally clinched (X.) by re-affirmation of the immortality of the soul. Since the soul is immortal, the issue which hangs upon our choice to live well or ill is one of infinite moment (X.).

The ethical scheme of the *Republic*, like that of the *Gorgias* and *Phaedo*, is dominated by the conception of the "three lives," ascribed by credible tradition to Pythagoras. The "lives" are those of the philosopher, the "man of action" (*φιλότιμος*), the votary of enjoyment (*φιλήδονος, φιλοσώματος, φιλοχρήματος*). The end of the first is wisdom, of the second, distinction, of the third, the gratifications of "appetite." Distinction is a worthier end in life than mere satisfaction of appetite; the supremely worthy end is wisdom. In a well-lived life, then, the attainment of wisdom will be the paramount end, and ambition and appetite will only be allowed such gratification as is compatible with loyalty to the pursuit of that paramount end. The psychological foundation of this doctrine is the theory of the "tripartite" soul, expounded fully in *Rep.* IV. Analysis of familiar experience reveals three "elements" (*μόρια, εἴδη*) or "active principles" within us, (1) considered rational judgment of good (*τὸ λογιστικόν*); (2) a multitude of clamant appetites for particular gratifications, which may be in violent conflict with our own considered judgment of good (*τὸ ἐπιθυμητικόν*); (3) a factor of "spirit," higher "ideal emotion," which manifests itself as "resentment" against both the infringement of our just rights by others and the rebellion of our own appetites against our judgment (*τὸ θυμοειδές*).

The same distinctions reappear in the structure of society. A society naturally falls into three divisions, the statesmen, who direct the public life, the general civilian population, who carry on the business of providing for material needs, and the executive force (army and police), whose function is, in a rightly ordered society, to give effect to the counsels of the statesmen by repressing attacks from without and rebellion from within.

These three "orders" are thus respectively, the judgment, the "appetitive" and "spirited" elements in the national soul. On this basis, we can proceed to work out an ethical and political theory. In ethics we can define the great leading types of "goodness," the quadrilateral, later known as the four "cardinal" virtues. *Wisdom* is the "excellence" of the "thinking part," clear and assured knowledge of the good; *courage*, the fighting man's virtue, is the "excellence" of the "spirited" part, unswerving loyalty, unshaken by pain, by danger, by the seductions of pleasure, to the rule of life laid down by judgment; *temperance*, the special excellence of the "appetitive" part, is the contented acquiescence of the non-rational elements in the soul in the plan of life prescribed by judgment; *justice* is just the state in which each of the elements is vigorously executing its own function and confining itself within the limits of that function. In the rightly ordered society, the national wisdom has the statesmen as its organ, the national courage the executive force; the national temperance is shown in the loyal contentment of each class in the community with its prescribed place and its duties.

Such a society is a true aristocracy, or rule of the best; "timocracy" the military state, in the better sense of that phrase, arises when the mere "man of action," only competent to fill the part of a good soldier, takes the place which rightly belongs to the thinker as directing statesman; "oligarchy" (*i.e.*, the dominance of "merchant princes," plutocracy), is a further deviation from the ideal, which arises when political power is bestowed on property as such. A still worse system is democracy, in which no attempt is made to connect political power with any special qualifications. Worst of all is tyranny, exercise of irresponsible power by the positively disqualified, the man of "criminal" will. The psychological scheme on which this construction is based is not given by Plato as a piece of strict science. We are carefully warned that exact truth is not to be reached by such an analysis of *prima facie* facts of social life (435 *d.*), and reminded later on that this apparent triplicity of the soul may prove to be only a temporary consequence of its conjunction with the body (611 *b.*).[1] The "tripartite" psychology, it is meant, enables us to give an account of the moral life, as it actually appears in a good citizen, which will fairly describe the facts. It is good popular psychology, useful for the moralist, but it is no more.

Hence it is improbable that the analysis originated with Plato himself. More probably it was, as the Stoic Poseidonius asserted, a piece of earlier Pythagorean doctrine, as is also suggested by the constant recurrence, throughout the section of the *Republic* in which the analysis is offered, of analogies from the specially Pythagorean science of Harmonics, and by the fact that the same doctrine is taught by the Pythagorean speaker in the *Timaeus*. Plato has, however, worked the theory into his ethics so completely that through him it has actually become a part of the psychology of Thomism, where it has to be squared, not quite satisfactorily, with the radically divergent psychological scheme of Aristotle.

In point of fact, the tripartite *schema* proves inadequate in the *Republic* itself when we advance in Bk. VI. to the consideration of the moral life of the "philosopher-king," whose "virtue" is founded on a personal *knowledge* of good. A higher level of moral goodness is demanded of him than of other citizens even of the ideal Utopia; his courage, for example, is declared to be no mere loyalty to right opinions inculcated by early education, but a high serenity arising from the knowledge of the relative insignificance of a brief individual life in the great universe which lies open to his contemplation. This has an important bearing on the teaching of the *Republic* about the unity of virtue.

In the ideal State itself, virtue does not appear as a complete unity. The leading types of moral excellence receive their several definitions. It is recognized that a special demand may be made on a particular section of the society in respect of a particular virtue of which it is, so to say, the public organ, as the fighting force is of the valour of the whole society. This is because, even in the ideal state, the moral convictions of citizens, other than the men of superlative intelligence and character who become "kings," are not supposed to arise from personal insight. They rest on opinions implanted by education, and are thus taken on trust. The good civilian or soldier, after all, is not living by a knowledge which is his own. But the rulers, by whose knowledge the rest of the community lives, must not, of course, themselves take their convictions on trust. They must know with a personal knowledge. The foundation of their virtue must be *insight* into a system of absolute values embodied in the very structure of the universe. In virtue of this deeper foundation the virtues in them are, so to say, transubstantiated and can no longer be distinguished from one another. They will fuse in knowledge of the good, as, in the Christian saints, they are fused in knowledge and love of God. It is in this form that the Socratic doctrine, "all virtue is one thing, knowledge" reappears in the *Republic* as the foundation of a society in which mankind has at last "escaped from its wretchedness," because knowledge rules.

In the *Republic*, as in the *Phaedo*, the Forms (*ἰδέαι, εἴδη*) ap-

[1] Timaeus is expressly made to teach that the *θυμοειδές* and *ἐπιθυμητικόν* are a "mortal element" (*θνητὸν εἶδος*) added to the immortal soul to fit it for its habitation in the body (*Tim.* 69*c.*).

pear in the double character of objects of all genuine science and formal causes of the world of events and processes. It is expressly denied that there can be knowledge, in the proper sense of the word, of the temporal and mutable. In the scheme laid down for the intellectual training of the philosophic rulers, ten years, from the age of 20 to that of 30, are assigned for systematic study of the exact sciences in the order: arithmetic, plane geometry, solid geometry, astronomy and harmonics. Special stress is laid on the points that the object of these studies is not practical applications but the familiarizing of the mind with relations between terms which can only be apprehended by thought, and that diagrams and models are to be treated merely as incidental aids to imagination. Five years are then further to be given to the still severer study which Plato calls "dialectic," a study which avails itself of no sensible aids to imagination. It proceeds "by means of Forms, through Forms, to Forms" (511 *b*.). It is, in fact, what we should call a critical metaphysic of the sciences. It examines the *ὑποθέσεις* or unproved postulates, of the various sciences, and its object is to "destroy" their character as unproved ultimate postulates (*τὰς ὑποθέσεις ἀναιροῦσα* 533 *c*) by discovering some still more ultimate really self-evident principle (an *ἀνυπόθετον*, 511 *b*) from which they follow as consequences.

There can be no doubt that this most ultimate principle which is more than a "postulate" means the Good or Form of Good (*ἰδέα τἀγαθοῦ*) which is said to be the source at once of the reality and the knowability of all that is real and knowable, though it is itself neither knowledge nor being, but transcendent of both (509 *b*.). On the methodological side the *Republic* thus completes the teaching of the *Phaedo* by providing the answer to the question then left open, when a "postulate" (*ὑπόθεσις*) may be regarded as finally established. It may be so regarded when it is seen to follow itself from the Good, which is the principle at once of existence and of value.

Socrates is made to confess (506 *d-e*) that he can give no positive account of this supreme metaphysical principle; he can only indicate its nature by an analogy. It is to the whole system of Forms what the sun is to the system of visible things, the source at once of their existence and of the light by which they are apprehended. The Good is thus thought of, to use scholastic terminology, as a transcendent reality which can be apprehended but never fully comprehended. The comparison with the sun and the free employment of the metaphor of "vision" indicate that the thought of the *Republic* is here the same as that of the *Symposium;* the Good is no other than the supreme Beauty which was there said to dawn suddenly upon the pilgrim of "Love" as he draws near to the goal of the journey. R. L. Nettleship rightly says that it holds the place taken in later philosophies by God, when God is thought of as the "Light of the world." But it would be deforming Plato's thought to call the Good of the *Republic* "God." The *Republic* is permeated by religious faith, but Theism as a principle of metaphysical explanation only makes its appearance in Plato's latest dialogues, and there as the solution of a problem which can hardly be said to have been adequately faced in the dialogues so far considered.

How the Good gives systematic structure to the plurality of Forms, the *Republic* does not tell us.

Development of the Doctrine of Forms.—So far we have been presented with a body of thought which has remained recognizably the same without serious modification throughout its various expositions. When we come to the two works which there is reason to regard as directly preluding to the dialogues of Plato's old age, the *Parmenides* and *Theaetetus,* we are struck by a remarkable difference of tone. With Plato, as with Kant, the "middle years" of life were clearly a period of fruitful critical reconstruction. There is an obvious motive for each reconstruction suggested by the *Phaedo* and *Republic* themselves.

The theory there expounded does not allow enough reality to the sensible world. It is quite false to say that even the *Phaedo* teaches an "absolute dualism" of two disconnected worlds, a realm of genuine being which never "appears" and a realm of sensible appearances which are merely unreal. What is true is that both *Phaedo* and *Republic* leave us with an unsolved problem. They tell us that a sensible thing is a complex or meeting-place of a plurality of Forms. What else, or what more, it is they do not tell us. And yet it is clear that a "thing" is not simply a bundle of "universal predicates."

Or, to put the point rather differently, according to the *Phaedo* a thing becomes for a while beautiful because Beauty "becomes present to it." But why does Beauty become present to this particular thing at just this particular moment? Clearly the relation between a "thing" and a Form which has been called "participation" needs further elucidation. Again the simple epistemological formula that knowledge is confined to Forms and their relations, while we can only have shifting "opinions" about temporal facts does less than justice to our scientific knowledge of the natural world; "truths of fact" have not yet come by their rights. Finally, if the Forms constitute a rationally ordered system, there must be definite principles of inter-relation between Forms themselves as well as between Forms and sensible things and these principles demand investigation. (If the Good is what the *Republic* says it is, not only will things "participate" in Forms; Forms also will "participate" in it.) Here are internal motives for active re-examination of the whole system.

It is clear that there was also an external motive. *Parmenides, Theaetetus, Sophistes,* all reveal a special interest in the Eleatic philosophy, and the first and third show an anxiety on Plato's part to maintain that, in spite of important divergences, he, and not the professed Eleatics, is the true spiritual heir of the great Parmenides. This is easily explained when we remember that Plato was personally a friend of the chief representative of Eleaticism among the Socratic circle, Eucleides of Megara, while Polyxenus of Megara, an associate of Eucleides, was a hostile critic of the doctrine of "participation."[1] The doctrine of Eucleides, like that of Parmenides was that "sensible appearances" are illusions with no reality at all. Against criticism from this quarter, it would be necessary for Plato to show that the *Phaedo* itself does not allow too much reality to the sensible; the attempt to prove this point would inevitably show that it had conceded too little. Continued reflection on the same problem of the worth of propositions about sensible fact leads straight to the discussion of the meaning of the *copula,* and the significance of denial, which is the subject of the *Sophistes.*

Parmenides.—Formally the dialogue conducts to an *impasse.* In its first half the youthful Socrates expounds the doctrine of the "participation" of things in Forms to the Eleatic philosophers, Parmenides and Zeno, as the solution of the problem of the One and the Many. Parmenides raises what appear to be insoluble objections to the conception of "participation," though he admits that "dialectic" would be impossible if the existence of Forms were denied; he hints that the helplessness of Socrates under his criticism arises from insufficient training in logic.

In the second and longer half, Parmenides gives an example of the logical training he recommends. He takes for examination his own thesis, "the One is," and constructs an elaborate set of antinomies after the fashion of Zeno, apparently proving that whether this thesis be affirmed or denied, in either case we are compelled either to affirm simultaneously or to deny simultaneously a series of contradictory predicates, alike of the "One" and of the "Many." The conclusion is patently ironical, and we are left to divine the author's purpose, if we can.

The objections to "participation," which is formulated precisely as in the *Phaedo,* are directed not against the existence of Forms, but against the possibility that sensible things should "participate" in them. From the point of view of this criticism Socrates' error is that he attributes some sort of secondary reality to the sensible. The main arguments are two: (1) the doctrine does not really reconcile unity with plurality, since it leads to a *regressus in indefinitum.* It says that the many things which have a common predicate "participate of" or "imitate" a single Form. But the Form itself also admits of the common predicate, and there must therefore be a second Form, "participated" or "imitated" alike by the sensible things and the first Form, and so on endlessly. We could not escape by the suggestion that the Form exists only "in our

[1]Alexander Aphrodis. on Aristot. *Met.* 990 b. 17.

minds," since that would mean that a Form is a thought, and it would follow that "things" are made of thoughts. But if so, either everything thinks, or there are thoughts which do not think, and both alternatives are absurd; (2) it is a still graver difficulty that if there are two realms, a realm of Forms and a realm of sensible things, the relations between Forms must belong to the realm of Forms, those between sensible things to the realm of things. We ourselves belong to the second, and therefore all our knowledge belongs to it too; we know nothing of the true realities, the Forms: if anyone knows them, it is God, but God's knowledge, being knowledge of realities, will not extend to *our* world, the sensible. The purpose of the objections is thus to suggest that the "manifold of sense" has not even a derivative reality; it is mere illusion.

This is precisely the position of the Eleatics and their Megarian continuators. The inference is that Plato is reproducing Megarian criticisms of the doctrine ascribed by himself to Socrates, an inference confirmed by the notice preserved by Alexander of Aphrodisias (on *Met.* 990 *b* 15) of the "third man" argument of the Megarian Polyxenus against "participation." Plato does not indicate his own opinion of the cogency of the reasoning, which is, in fact, fallacious, as was properly pointed out by Proclus.[1]

The purpose of the antinomies which follow has been very differently understood. In the present writer's opinion, they are deliberate parody, the object being to show that the methods of the Megarian logicians are even more damaging to their own fundamental metaphysical tenet than they are to the doctrine of "participation." Megarian logic is a double-edged weapon, and Plato, if he chooses, can apply it even more dexterously than its inventors.

Theaetetus.—Except for a magnificent interlude in praise of the contemplative life, the dialogue is a straightforward discussion of the question how knowledge should be defined. It naturally ends negatively. None of the proposed definitions will stand examination (the reason is that we are really trying to define truth and truth is an ultimate). But the incidental results of the discussion are of the first importance. We learn (*a*) that knowledge cannot be identified with sensation nor with any formless "simple apprehension"; (*b*) that pure relativism is as impossible in epistemology as in metaphysics. We have the beginning of a doctrine of the "categories" which is further developed in the *Sophistes*.

The increasing value which Plato is coming to put upon "natural knowledge" is marked by the use of the word δόξα, which in earlier dialogues had commonly meant mere uncertain "opinion" as contrasted with knowledge, in the new sense of "judgment" which it retains in Plato's subsequent work. The most striking negative feature of the *Theaetetus* is that it discusses knowledge at length without making any reference to the Forms and the mythology of "recollection." It remains to this day the best of introductions to the "problem of knowledge."

The main argument may be very briefly summarized thus: I. It seems plausible at first to say that knowledge (ἐπιστήμη) *is* sensation (αἴσθησις). This sounds very much like the proposition of Protagoras, "what seems to me is so to me; what seems to you is so to you." We might base such a thorough-going doctrine of the relativity of all knowledge on a still more ultimate metaphysical theory, if we said—it is implied that Protagoras himself said nothing of the kind—that, within us and without us, the only reality is motion. "Organ" and "environment" are both motions; when these motions impinge on one another, they give rise to the twin-product, felt sensation–sensible quality.

Both the sensation and the quality "sensed" will therefore be affected by any difference in the pair of slower "motions" which cause them (the "organ" and its "environment"), and each precipient, therefore, is confined to his strictly private world, which exists only "for" him. There is no "common" perceived world, and therefore no standard of truth or reality other than the individual percipient. A teacher does not aim, any more than a physician, at convincing his pupil of the "falsity" of his judgments, but at giving him "useful" or healthy convictions in place of harmful or diseased convictions.

[1]For a detailed discussion of it, *see* A. E. Taylor, *Parmenides, Zeno and Socrates* (Transactions of Aristotelian Society, N. S. xvi. 234 ff.)

The full discussion of such a theory would demand a thorough study both of the Heracleitean philosophy, which says that there is nothing but motion, and the Eleatic philosophy which says that motion is an illusion. But for our immediate purpose, a more summary argument is sufficient. It is certain that even the relativists, who hold that each man is the one infallible "measure" of his *present* perceptions, do not hold that he is the only and inerrant measure of his *future* sensations. A physician can often judge better than his patient whether the patient is going to have, *e.g.*, the sensations of an ague. A man's own opinion whether a certain course will be expedient or good for him is often far from being the soundest. We must distinguish carefully between what the mind perceives "through bodily organs"—the data of sense—and the things she apprehends "by herself" (αὐτὴ δι' αὑτῆς) without "organs." These latter include number, sameness, difference, likeness, unlikeness, being, good, bad, right, wrong, *i.e.*, the great universal "categories" of fact and value. These are apprehended not by sense, but by thinking, and as they are the formal element in all knowledge, knowledge must be found not in our sensations, but in "the judgment (συλλογισμός) of the mind upon" them.

II. Is knowledge, then, "true judgment"? The statement implies that we know what we mean by "false" judgment, error. But is this the case? Error must not be confused with mere false recognition, misinterpretation of present sensation, since there are purely intellectual errors, and we find ourselves unable to explain the nature of this kind of error. And, in fact, it is clear that persuasive rhetoric may produce in the hearer judgments which are true, but have no claim to be called knowledge. III. Finally, is knowledge "true judgment accompanied by discourse (μετὰ λόγου), true judgment for which we can give grounds"? This would distinguish knowledge from "simple apprehension," and would harmonize with the theory of those who hold that knowledge is always of complexes, never of their simple constituents. But this doctrine has difficulties of its own, and, in any case, if we say that knowledge is true judgment + "discourse," the "discourse" meant must be a statement of the logical *differentia* of the object of which I have knowledge. The proposed definition therefore amounts to saying that knowledge is true judgment about an object + *knowledge* of the *differentia* of that object, and so is circular.

LATER DIALOGUES

Sophistes and Politicus.—Formally these two important dialogues are closely connected. They are made to appear as a sequel to the *Theaetetus*, and a further connection is afforded between them by the fact that both are ostensibly concerned with a problem of definition, which is treated by the characteristic Platonic method of repeatedly subdividing a *genus* until we obtain the *definiendum* as a sub-species. The real purpose of the *Sophistes* is logical or metaphysical; it aims at explaining the true nature of negative predication and so disposing of the Eleatic thesis that the temporal and sensible realm, containing, as it does, a negative moment, must be mere unreal illusion. The object of the *Politicus* is to consider the respective merits of two contrasted forms of government, "personal rule" and "constitutionalism," and to recommend the second, particularly in the form of "limited monarchy," as most suitable to the actual condition of mankind. The *Sophistes* lays the foundations of all subsequent logic, the *Politicus* those of all "constitutionalism."

A more temporary purpose in both dialogues is to illustrate the value of careful classification as a basis for scientific definition. In both dialogues Socrates is almost silent; his place as chief speaker is taken by an unnamed and very unorthodox Eleatic, who seems to be a purely fictitious character. Plato is, in fact, claiming that he, and not the formal logicians of Megara, is the continuator of Parmenides, much as Aristotle in his polemic against Xenocrates claims to be the true successor of Plato.

In the *Sophistes* the main discussion is led up to through a definition of the "sophist" as an "illusionist," a person who, by abuse of logic, produces the illusion, or false appearance, that nature and human life are alike riddled by insoluble contradictions. (This shows that the persons aimed at under the name "sophist" are the

Megarian controversialists who make an illegitimate use of the dialectic of Zeno and Socrates.) Now the "sophist" himself would retort that this definition is senseless, for there can be no such thing as a false statement or a false impression. For the false means "what is not," and "what is not" is nothing at all, and can neither be uttered nor thought. To refute him we need to correct the fundamental thesis of so venerable a thinker as Parmenides.

We must either admit that there can be no false statements, or we must be prepared to maintain that "what is not, in some sense also is," and "what is, in some sense is not" (*i.e.*, we must explain what is the meaning of a significant negative proposition). In our theory of "being" we have to meet at once Parmenides and two different types of pluralist opponents of Parmenides, (*a*) the corporealists who say that the real, "what is," is just visible and tangible body, and (*b*) certain "friends of Forms" who maintain that the real is a multitude of incorporeal Forms, denying that sense-perception gives us any apprehension of it. The corporealist is sufficiently refuted by the consideration that he himself cannot deny the reality of "force" (δύναμις) and that force is not a body. The incorporealist "friends of Forms" cannot be met in this way. They regard force, or activity itself as belonging to the unreal realm of "becoming." We meet them by urging that knowing is itself an activity and that we cannot deny intelligence and knowledge to the supreme reality. This means that it has a "soul" and is alive. But if life is real, movement and repose from movement must be real too.[1]

This leaves us free to attack the Parmenidean Monism itself. That is refuted by drawing the distinction between absolute and relative "non-being." A significant denial, *A is not B*, does not mean that *A* is nothing, but that *A* is other than *B*. Every one of the great categorical features of reality is other than every other, and the true business of "dialectic" is to study the various possible combinations of these universal "categories." The dialogue mentions five of them, being, identity, difference, motion and rest. It is not said that this is a complete list of "categories," though it was treated as such by the Neo-Platonists.

The important result is thus that we have learned to think of Forms themselves as an inter-related system, with relations of compatibility and incompatibility among themselves. Negation is a moment in the system of intelligible reality, and therefore its presence in the sensible realm does not stamp that realm as illusion. This is the ontological position which interests Plato; the recognition of the function of the logical *copula* is a consequence.

The *Politicus* has as its main result the conclusion that government by the personal direction of a benevolent "dictator" is not suitable to the conditions of human life, where the direction is necessarily that of a fallible man, not of a god. In an actual human society, the surrogate for personal direction by a god is the impersonal supremacy of inviolable law. Where there is such a recognized sovereign law, monarchy is the most satisfactory type of constitution, democracy the least satisfactory, but where there is no "fundamental law," this situation is inverted. A "sovereign" democracy is preferable to an irresponsible autocrat. The dialogue is rich in thoughts which have passed into the substance of Aristotle's ethics and politics. Aristotle took directly from it the conception of "politics" as the "architectonic" practical science to which all others are subordinate; the formula of the "right mean" comes from it together with the *Philebus*.

Philebus.—The subject of the dialogue is a strictly ethical one, and this, no doubt, explains why it is the only dialogue after the *Theaetetus* in which Socrates is the principal speaker. The issue propounded is the question whether the "good" is pleasurable feeling or whether it is thought, the exercise of intelligence.

Comparison with the notices of Aristotle in the *Nicomachean Ethics* shows that this was the subject of a sharp division in the Academy, the Hedonist party being led by the mathematician and astronomer Eudoxus, the anti-Hedonists by Speusippus. Under the guidance of Socrates the question is narrowed down to a consideration of the good for *man* in particular, and a mediating conclusion is reached. The best life for man contains both elements, but intelligence is the "predominant partner."

All forms of knowledge find a place in it, but only those pleasures which are compatible with wisdom and virtue, *i.e.*, those which are "unmixed," not preceded by a sense of want or craving, and those of the "mixed" pleasures, the satisfactions of appetite, which are innocent and moderate. The *Philebus* contains Plato's ripest moral psychology; it is the immediate source of the famous "doctrine of the Mean."

Philosophically the most important feature of the dialogue is a classification adopted with a view to determining the formal character of the two claimants to recognition as the good. All components of the actual belong to one of four classes, (1) the infinite or unbounded (ἄπειρον), (2) the limit (πέρας), (3) the mixture or combination of (1) and (2), (4) the cause of the mixture. ([1] and [2] are just the two fundamental "opposites" of Pythagoreanism.) All the good things of life belong to (3), that is, they are produced by the introduction of definite "limit" or "ratio" into an indeterminate "continuum." (This is precisely the doctrine of the "Mean.") The establishment of such a "ratio" is a γένεσις εἰς οὐσίαν, a process resulting in a stable "being," and it is indicated that the cause or agent in such a process is always intelligence, human or divine.

There has been much discussion of the question in which of these "classes" the Forms should be placed. The only tenable alternatives would be to put them into the class of "limit" or into that of the "mixture" (a view suggested both by the teaching of the *Sophistes* and by Aristotle's express statement that Plato distinguished two constituents within the Form and advocated ably by Dr. H. Jackson). The truth seems to be that the particular classification in the *Philebus* is devised for a special purpose, and that it is not intended to apply to anything but the things and processes of the sensible realm. In that case, though there is a close correspondence between what the *Philebus* teaches about "stable being" in the sensible realm and what, as we know from Aristotle, Plato taught about the Forms, it will be a mistake to look for any actual exposition of the metaphysic of the Forms in the *Philebus*.

Timaeus.—The *Timaeus* is an exposition of cosmology, physics and biology put into the mouth of the astronomer Timaeus of Locri. Though Plato avoids expressly describing the speaker as a Pythagorean, his doctrine is revealed by attentive analysis as an attempt to combine the mathematics and astronomy of the Pythagoreans with the biology of Empedocles, the real founder of Sicilian medicine. The discussion is introduced by the famous narrative of the gallantry of the prehistoric Athenians who defeated the kings of the imaginary Atlantis in their ambitious attempt to become masters of the world. The story was to have been told more in detail in the unfinished *Critias*.

Timaeus opens his discussion by drawing a sharp distinction between eternal being and temporal becoming, and insisting on the point that it is only of the former that we can have exact and final knowledge. All accounts of the temporal can be only tentative and liable to repeated revision. Cosmology, then, at best, is not exact science. The visible world, being mutable and temporal, is a copy of a model which is eternal, and the copy is the work of God. The reason why there is a copy at all is the unceasingly active and generous goodness of God. (In the sequel Timaeus speaks of the Forms which God had before Him as His model in much the same language as the *Phaedo*, except that he uses the Pythagorean word "imitation," not "participation," to describe the relation of sensible things to Forms.)

The world, then, had a beginning. (The Academic tradition from the first was that this is not to be understood literally; Aristotle

[1] It is still a much agitated question who are the "logical atomists" described in the *Sophistes* as the "friends of Forms." The view that they are adherents of the philosophy of the *Phaedo* and *Republic* is deservedly dead. They are still often supposed to be Megarians, but this seems inconsistent with the way in which they are carefully distinguished from the followers of Parmenides as belonging to "the other side" at 245 *e*. Proclus (*in Parm.* 562 St.) says positively, as though it were the only view known to him, that they are Italian Pythagoreans, and this is probably correct, since the Eleatic of the dialogue refers to them as persons with whom he is "familiar." It is important to remark that the identification of "being" with "force" is given merely as a consequence which would follow from, and contradict, the corporealist "hypothesis." The implication of the passage is rather that the identification is false than that it is true.

insists on taking it literally.) God first formed its soul out of three constituents, Identity, Difference, Being. Its body was made later from the four Empedoclean "elements." The world-soul was placed in the circles of the sidereal Equator and Ecliptic, the latter being split into seven lesser circles, those of the planets, and the two were animated with movements in opposite senses. Subsequently were formed the various subordinate gods and the souls of human beings, that is the "immortal" and rational element in the human soul, which come straight from the hands of God Himself. The formation of the human body and of the two lower "mortal" components of the human soul was effected through the intermediacy of the "created gods" (*i.e.*, the stars). The most important question of detail arising from this part of the dialogue is that debated between Boeckh and Grote. Does Timaeus ascribe a motion to the earth? The restoration of the correct text at 40*c*[1], proves definitely that he does, but it is not a diurnal revolution, as Grote supposed; it must be rectilinear displacement of unknown period. The contact is made between Pythagorean geometry and the Empedoclean biology which will be needed for the physiology and medicine of the dialogue by a mathematical construction of the "elements."

Starting with two primitive triangles, the isosceles right-angled, and the right-angled scalene in which the hypotenuse is double the shortest side, Timaeus constructs four of the regular solids, cube, tetrahedron, octahedron, icosahedron, and these are assumed to be the shapes of the corpuscles of earth, fire, air, water. These four in their turn are the immediate constituents of all organic and inorganic compounds.

The important features of the dialogue are not the particular tentative scientific hypotheses but its leading methodological principles. We should note the introduction of God as the intelligent efficient cause of all order and structure in the world of "becoming," which preludes to the natural theology of the *Laws*, and the emphatic recognition of the essentially tentative, and therefore progressive, character of natural science. It is also noticeable that though Plato's scientific ideal is a mathematical corpuscular physics—his influence in creating this ideal has been much more important than that of the ancient Atomists—he constructs his physical world without "matter" as a metaphysical "substrate." The place of matter is taken in his analysis, as Aristotle complained, by χώρα, space, as in the *Principia* of Descartes, a point of view to which physical speculation seems to be returning. He analyses the "passage of Nature" into three factors: ὄν ("being": a Form), χώρα (space), γένεσις (happening), much as Whitehead analyses it into "objects," "events" and the "ingredience of object into event."

It is a fundamental point that the presence of χώρα as a factor makes it necessary to recognise over and above "God" or "mind" a subordinate element of ἀνάγκη, "necessity" in events. Since necessity is also called the "errant" cause, πλανωμένη αἰτία (with an allusion to the name of the "planets" or "tramp-stars") the word clearly does not mean "conformity to law." It is rather a name for the fact that there is always in the actual an irreducible remainder of "brute" datum, "conjunctions" in Hume's phrase, which we cannot rationalize completely into intelligible "connections." Thus ἀνάγκη is not a rebel or evil principle in the constitution of things; its function is everywhere to be instrumental to the intelligent and beneficent purpose of "mind" or God. There are many facts which we have to be content to accept simply as facts without seeing their "reason why." We do not know and may never know, why it is "best" that they should be as they are—*e.g.*, why "it is best" that we should live on a moving earth—but we may be sure that, since it is the fact, it is in some way best that it should be so. This seems to be what is meant by the statement that God or "mind" (νοῦς) persuades ἀνάγκη. It is the expression of a rational faith in Providence and the supremacy of the moral order. The details of the cosmology, physiology and psycho-physics of the dialogue are of great importance for the history of science, but metaphysically of secondary interest.

Laws and Epinomis.—The *Laws*, Plato's longest, is also his most intensely practical work, and contains his ripest utterances on ethics, education and jurisprudence, as well as his one entirely non-mythical exposition of theology. The immediate object is to meet a practical need by providing a model of constitution-making and legislation for members of the Academy who may be called on to assist as advisers in the actual founding or re-founding of cities.

Plato's attempt to do work of this kind himself, at Syracuse, had borne no immediate fruit, but had given the Academy a recognized standing as a school of scientific politics and jurisprudence. The work of constitution-making and legislation was going on in many quarters at the end of his life, and his experience might be made fruitful in sage counsels to younger men. The practical character of the subject explains some novelties in the outward form of the work. As the dialogue is assumed to be dealing with the actual present, Socrates has disappeared and his place is taken by an unnamed Athenian who is, to all intents, Plato himself.

The scene is laid in Crete; the imagined situation is that the Cretans are about to found a settlement on the site of a long deserted city. The chief Commissioner for the project is walking out to inspect the proposed site with a Spartan friend, when they fall in with the Athenian, and being favourably impressed by his conversation invite him to join them as an "expert adviser."

The problem thus differs from that of the *Republic;* the question is not the construction of an ideal Utopia, but the framing of a constitution and code which might be successfully adopted by a society of average Greeks in the middle of the fourth century. Hence the demands made on average human nature, though exacting, are not pitched too high; the communion of the *Republic* is dropped. And for the same reason it is assumed all through that the regulations are carefully adapted to the particular economic and geographical conditions, though it is said that these conditions will not really suit any actual Cretan locality. If so, we must suppose that Plato, under a transparent disguise, is contemplating the actual conditions in quarters from which the Academy was more likely to receive appeals for help.

The special purpose of the work also explains why purely speculative philosophy and science are excluded from its purview. The metaphysical interest is introduced only so far as to provide a basis for a moral theology; the one matter of first-rate scientific importance touched on is the diurnal motion of the earth, and this is only hinted in connection with the practical problem of the construction of the Calendar. In compensation, the *Laws* is exceptionally rich in political and juristic wisdom, and appears, indirectly, through its influence on the law of the Hellenistic age, to have left its mark on the great system of Roman jurisprudence.

It is impossible to do more than to call attention to a few of the striking features of this great work. The ethical ideal is still that familiar from earlier dialogues. It is interesting that the demand is expressly made that all "unnatural" vices shall be completely suppressed, and that the rule of sexual life is to be monogamous marriage with strict chastity, outside the limits of marriage, for both sexes. In politics, Plato declares himself definitely in favour of a "mixed" constitution; a good government demands a balance between two principles, ἐλευθερία, "popular control," and μοναρχία, "personal authority." Persia is an illustration of the mischief of unqualified autocracy, Athens of the evils which come from elimination of the "authoritarian" principle, and considerable care is taken in the suggested system of magis-

[1]The words used of the earth ἰλλομένην τὴν περὶ τὸν διὰ παντὸς πόλον τεταμένον admit of only one rendering "going up and down on the path about the axis of the universe." Timaeus thinks of the earth as placed about the axis of the whole universe and being displaced to North and South by a sliding movement along this axis. Aristotle was then exactly right in saying that Timaeus teaches that the earth "is at the centre" and moves there (*de Coelo* 293 *b*30) and distinguishing this view carefully from that which he ascribes to the Pythagoreans, "that the earth revolves as a planet about the centre." It is this second view which is implied in the language of *Laws* 822*a* and *Epinomis* 987*b* and expressly attributed to Plato "in his later years" by Theophrastus ap. Plutarch *Quaest. Plat.* 1006*c*. There is no reason to suppose that Plato ever himself held the curious view he has ascribed to his fifth century Pythagorean. He has his own reasons for insisting as strongly as he does on the provisional character of all the science of the dialogue.

tracies to secure both genuine "popular representation" and the proper regard for personal qualifications. The basis of society is to be agriculture, not commerce; the citizens are to be "peasant proprietors"—communism is regretfully abandoned as impracticable in a society of ordinary human beings. But the patrimony of each household is to be strictly inalienable, and differences in "personal" property are to be kept within strict bounds by what amounts to a super-tax of 100% on incomes beyond the statutory limits. Education, as in the *Republic,* is regarded as the most important of all the functions of government; it is placed under the control of a minister who is the "premier." As far as possible, the distinction between the sexes is, as in the *Republic,* to be treated as irrelevant to the educational programme.

The most striking features of the scheme are the careful attention paid to the problems of the physical training of children in their earliest infancy, and the right utilization of the child's instinct for play, and the demand, made now for the first time, that in adolescence, the young shall be taught in institutions where expert instruction in all the various subjects is co-ordinated. It is from this proposal that the "grammar school," or secondary school, has taken its origin. Though we hear no more of "philosopher-kings" the demand is still made that the members of the "Nocturnal Council," the supreme Council of the State, which is always in permanent session, and exercises a general control over administration, shall be thoroughly trained, not only in the exact sciences, but in the supreme science, which "sees the One in the Many and the Many in the One;" that is, they are to be "dialecticians."

The work is full of suggestions for the practical application of science, such, for example, as that of the necessity of strictly standardizing all weights and measures, or that of basing the Calendar on a solar year (of 365 days). The object of the apparently arbitrary selection of the number of patrimonies and the scheme of sub-division of the whole society into smaller groups appears to be the practical one of making it easy to determine exactly what quotum each subdivision may justly be called on to contribute to the revenue or the defences.

At least two fundamental improvements are made on the Attic jurisprudence which Plato has adopted as the foundation of his own code. One great blot on the Heliastic system is removed by the regulations which ensure that trials for serious offences shall take place before a court which contains highly qualified magistrates, and shall proceed with due deliberation, and that there shall be provision for appeals from the primary tribunal to a "Court of Cassation." It is even more important, perhaps, that *Laws* IX. by drawing a clear distinction between *βλάβη,* detriment, and *ἀδικία,* infringement of rights, lays the foundation for the discrimination between civil and criminal actions at law.

An incidental passage in the Laws (822 *a-b*) and another in the *Epinomis* (987*b*) definitely show that Theophrastus was right in crediting Plato with belief in the earth's motion. In the *Laws* it is said that the real orbit of each planet is a single closed curve, in the *Epinomis* the view that the "circle of the stars" communicates its motion to those of the planets is called that of men "who know but little of the subject." The allusion is to the famous theory of the celestial motions put forward by Plato's friend and associate, the great mathematician Eudoxus.

According to this, the first great "geocentric" theory in scientific astronomy, the movements of each planet can be analyzed into a combination of circular revolutions, the unmoved earth being taken as the common centre of all. What Plato asserts is that each planet has only one "proper" revolution, the remaining revolutions are apparent, not real. The implication is that these apparent revolutions of the planet must be real motions of the earth from which we make our observations. The earth is thus a planet, though not a satellite of the sun. The language of the *Epinomis*—which may be safely regarded as at least true to Plato's thought—definitely makes the sun, itself, one of the planets. We have, therefore, to think of the earth as also a planet revolving with the rest round an unseen centre. We may infer from the words of Theophrastus that Plato, like some of the Pythagoreans, held that there is a luminary, the "central fire," at this centre. The period of the earth's revolution would certainly be taken to be the natural day, so that the motion ascribed to the earth is equivalent to the diurnal rotation, though from Plato's point of view, it is not a rotation on an axis, but a revolution round a centre. It follows that the alternation of day and night is no longer accounted for by a rotation of the "heaven of the fixed stars." This "outermost circle" is still credited in the *Epinomis* with a revolution in the sense E. to W., but its period is not specified. We need not suppose either that Plato could have specified the period or that he used it to explain any special appearances.[1]

What is to Plato's credit is that he has the insight to see that, with all its attractions, the scheme of Eudoxus starts from a wrong pre-supposition, a stationary earth.

In *Laws X.* Plato, for a practical purpose, creates natural theology. There are three false beliefs which are fatal to moral character, atheism, denial of the moral government of the world, the belief that divine judgment can be bought off by offerings. Plato holds that he can disprove them all. The refutation of atheism turns on the identification of the soul with the "movement which can move itself," already used in the *Phaedrus.* All motion is either communicated from without or self-initiated, and the ultimate source of all communicated motion must be self-initiated motion. The only thing which can move itself is a soul. It follows that all motion throughout the universe is ultimately initiated by souls. It is then inferred from the regular character of the great cosmic motions and their systematic unity, that the souls which originate them form a hierarchy with a "best soul," God, at their head. Disorderly and irregular motions are equally due to souls, but to bad and disordered souls, and since there are disorderly motions, it is inferred that the "best soul" cannot be the only soul.

There is no suggestion that there is a "worst soul," a "devil" or "evil world-soul"; all that is said is that there *must* be one soul which is not the best, and may be more. This is Plato's way of excluding Pantheism, as incompatible with the reality of evil. The argument thus establishes at once the immortality of the soul and the existence of God. The other two heresies can now be disposed of. It is inconsistent with the goodness of the best soul to be indifferent to our conduct, and still more so to be venal. The moral government of the world is, in fact, assured by the establishment of the single principle that every soul gravitates into the society of its likes, and consequently "does and has done to it what it befits such a soul to do and have done to it." Plato thus becomes definitely the originator of the view, that there are certain theological truths which can be strictly demonstrated by reason.

It is these demonstrable truths which are subsequently named by Varro "natural" or "philosophical" theology in contradistinction to the "poetical theology," the myths related by the poets, and the "civil theology," the ritual cultus instituted by politicians. From Varro the distinction of three theologies passed to St. Augustine, and thus in the end became the foundation of the scholastic distinction between natural theology, those truths about God which can be ascertained independently of any specific revelation, and revealed theology, the further truths which are only made accessible by the Christian revelation. Since Plato's object in demonstrating his three propositions is an ethical one, he goes on to enact that the maintenance of any of them shall be a grave crime to be visited by the State with penalties ranging from a minimum of five years' solitary confinement, and with death on a second conviction. Plato is thus the inventor, so far as European society is concerned, of the proposal to make an official creed for the State and to treat dissent from it as criminal, an innovation foreign to the spirit of the Hellenic cities, in which religion was a matter not of beliefs but of cultures. Plato's last word, then, on the problem how the sensible comes to "partake" of Form is that it does so through the agency of divine goodness and wisdom. God moulds the sensible upon the pattern of the intelligible. The obvious question, how God, who is a "soul"

[1] It has nothing to do with "precession of the equinoxes," being in the wrong sense for that purpose.

not a Form, is related to "the Good" which is the supreme Form never receives discussion or solution. To answer it was to be the main business of Plotinus.

PLATONISM AFTER PLATO

Aristotle's Account of Platonism.—Since Plato refused to write any formal exposition of his own metaphysic, our knowledge of its final shape has to be derived from the statements of Aristotle, which are confirmed by scanty remains of the earliest Platonists preserved in the Neo-Platonist commentaries on Aristotle. These statements can, unfortunately, only be interpreted conjecturally. According to Aristotle (*Metaphysics, A* 987, *b* 18–25) Plato's doctrine of Forms was, in its general character, not very different from Pythagoreanism, the Forms being actually called Numbers. The two points on which Aristotle regards Plato as disagreeing with the Pythagoreans are, that (1) whereas the Pythagoreans said that numbers have as their constituents, the unlimited (ἄπειρον) and the limit (πέρας), Plato taught that the forms have as constituents "the One" and the "great and small"; (2) the Pythagoreans had said that things are numbers, but Plato intercalated between his Forms (or Numbers) and sensible things an intermediate class of "mathematicals." It is curious, that in connection with the former difference Aristotle dwells mainly on the substitution of the "duality of the great-and-small" for the "unlimited," not on the much more significant point that the "One," which the Pythagoreans regarded as the simplest complex of unlimited and limit, is treated by Plato as itself the element of limit. He further adds that the "great-and-small" is, in his own technical terminology, the "matter," the One, the formal constituent, in a Number.

If we could be sure how much of the polemic against Number-Forms in *Metaphysics M-N* is aimed directly at Plato, we might add considerably to this bald statement of his doctrine, but unluckily it is certain that much of the polemic is concerned with the teaching of Speusippus and Xenocrates. It is not safe, therefore, to ascribe to Plato statements other than those with which Aristotle explicitly credits him. We have then to interpret, if we can, two main statements: (1) the statement that the Forms are Numbers; (2) the statement that the constituents of a Number are the "great-and-small" and "the One."

Light is thrown on the first statement if we recall the corpuscular physics of the *Timaeus* and the "mixture" of the *Philebus*. In the *Timaeus*, in particular, the behaviour of bodies is explained by the geometrical structure of their corpuscles, and the corpuscles themselves, are analysed into complexes built up out of two types of elementary triangle, which are the simplest "elements" of the narrative of Timaeus. Now a triangle, being determined in everything but "absolute magnitude" by the numbers which express the ratio of its sides, may be regarded as a triplet of numbers.[1] If we remember then, that the triangles determine the character of bodies, and are, themselves, determined by numbers, we may see why the ultimate Forms on which the character of Nature depends should be said to be Numbers, and also what is meant by the "mathematicals" intermediate between the Forms and sensible things. According to Aristotle, these "mathematicals" differ from Forms because they are many, whereas the Form is one, from sensible things in being unchanging. This is exactly how the geometer's figure differs at once from the type it embodies and from a visible thing. There is, for example, only one type of triangle whose sides have the ratios 3:4:5, but there may be as many "pure" instances of the type as there are triplets of numbers exhibiting these ratios; and again, the geometrical triangles which are such "pure" instances of the type, unlike sensible three-sided figures, embody the type exactly and unchangingly. A mathematical physicist may thus readily be led to what seems to be Plato's view that the relations of numbers are the key to the whole mystery of nature, as is actually said in the *Epinomis* (990*e*).

We can now, perhaps, see the motive for the further departure from Pythagoreanism. It is clear that the Pythagorean parallelism between geometry and arithmetic rested upon the thought that the "point" is to spatial magnitude what the number 1 is to number. Numbers were thought of as collections of units, and volumes, as, in like fashion, collections of points; that is, the point was conceived as a minimum volume. As the criticisms of Zeno showed, this conception was fatal to the specially Pythagorean science of geometry itself, since it makes it impossible to assert the continuity of spatial magnitude. (This, no doubt, is why Plato, as Aristotle tells us, rejected the notion of a point as a fiction.)

There is also a difficulty about the notion of a number as a "collection of units," which must have been forced on Plato's attention by the interest in "irrationals" which is shown by repeated allusions in the dialogues, as well as by the later anecdotes which represent him as busied with the problem of "doubling the cube" or finding "two mean proportionals." "Irrational" square and cube roots cannot possibly be reached by any process of forming "collections of units," and yet it is a problem in mathematics to determine them, and their determination is required for physics (*Epin.* 990*c*–991*b*).

This is sufficient to explain why it is necessary to regard the numbers which are the physicist's determinants as themselves determinations of a continuum (a "great and small"), by a "limit" and why, at the same time "the One" can no longer be regarded as a "blend" of "unlimited" and "limit" but must be, itself, the factor of "limit." (If it were "the first result" of the blending, it would re-appear in all the further "blends"; all numbers would be "collections of one" and there would be no place for the "irrationals.") There is no doubt that Plato's thought proceeded on these general lines. Aristotle tells us that he said that numbers are not really "addible" (*οὐ συμβλητοὺς εἶναι τοὺς ἀριθμοὺς πρὸς ἀλλήλους, Met* M 1083 *a* 34), that is that the integer-series is not really made by successive additions of 1^2, and the *Epinomis* (*loc. cit.*) is emphatic on the point that contrary to the accepted opinion, "surds" are just as much numbers as integers. The underlying thought is that numbers are to be thought of as generated in a way which will permit the inclusion of rationals and irrationals in the same series. In point of fact there are logical difficulties which make it impossible to solve the problem precisely on these lines. It is true that mathematics requires a sound logical theory of irrational numbers, and again, that an integer is not a "collection of units"; it is not true that rational integers and "real numbers" form a single series.

The Platonic number-theory was inspired by thoughts which have since borne fruit abundantly, but it was itself premature. We learn partly from Aristotle, partly from notices preserved by his commentators, that in the derivation of the integer-series, even numbers were supposed to be generated by the "dyad" which "doubles" whatever it "lays hold of," odd numbers in some way by "the One" which "limits" (ὁρίζει) or "equalises" (ἰσάζει), but the interpretation of these statements is, at best, conjectural. In the statement about the "dyad" there seems to be some confusion between the number 2 and the "indeterminate dyad," another name for the continuum also called the "great-and-small," and it is not clear whether this confusion was inherent in the theory itself, or has been caused by Aristotle's misapprehension.

Nor, again, is it at all certain exactly what is meant by the operation of "equalising" ascribed to the One.[3] It would be improper here to propound conjectures which our space will not allow us to discuss.

The Academy After Plato.—Though Plato's Academy produced only one later philosopher of the first order, it continued to exist as a corporate body down to the year 529 A.D. when the Emperor Justinian, in his zeal for Christian orthodoxy, closed the

[1] Thus the two fundamental triangles of Timaeus may be called the triplets $(1,1,\sqrt{2})$ $(1,\sqrt{3},2)$ respectively.

[2] 2, for example, does not "contain" two 1's, 2 is not "1 and another 1"; it is "the integer after 1."

[3] A full collection and examination of all the available evidence is given by L. Robin in his *Théorie platonicienne des Idées et des Nombres d'après Aristote* (1908), and an admirable exposition of the significance of the problem of the irrational for Plato's philosophy by G. Milhaud in *Les philosophes-géomètres de la Grèce, Platon et ses prédécesseurs* (1900). For a recent conjectural interpretation *see* A. E. Taylor's essay, "Forms and Numbers," in Mind, N.S. 140, 141.

schools of Athens and appropriated their emoluments. Plato's greatest scholar, Aristotle, finally went his own way and organised a school of his own in the Lyceum, claiming that he was preserving the essential spirit of Platonism, while rejecting the difficult doctrine of the Forms; the place of official head of the society was filled first by Speusippus, Plato's nephew (347–339 B.C.), then by Xenocrates (339–314 B.C.). Under Arcesilaus (276–241 B.C.) the Academy began its long-continued polemic against the sensationalist dogmatism of the Stoics, which accounts both for the tradition of later antiquity which dates the rise of a "New" (some said "Middle") and purely sceptical "Academy" from Arcesilaus, and for the eighteenth-century associations of the phrase "academic philosophy."

In the first century B.C. the most interesting episode in the history of the school is the quarrel between its President, Philo of Larissa and his scholar Antiochus of Ascalon, of which Cicero's *Academica* is the literary record. Antiochus, who had embraced Stoic tenets, alleged that Plato had really held views indistinguishable from those of Zeno of Cittium, and that Arcesilaus had corrupted the doctrine of the Academy in a sceptical sense. Philo denied this. The gradual *rapprochement* between Stoicism and the Academy is illustrated from the other side by the work of Stoic scholars like Panaetius of Rhodes, and Poseidonius of Apamea, who commented on Platonic dialogues and modified the doctrines of their school in a Platonic sense.

The history of the Academy after Philo is very obscure, but early in our era we meet with a popular literary Platonism of which the writings of Plutarch are the best example. This popular Platonism insists on the value of religion, in opposition to Epicureanism, and on the freedom of the will and the reality of human initiative, in opposition to the Stoic determinism; a further characteristic feature, wholly incompatible with the genuine doctrine of Plato, is the notion that matter is inherently evil and the source of moral evil.

Genuine Platonism was revived in the third century A.D. at Rome, and independently of the Academy, by Plotinus. His Neo-Platonism (*q.v.*) represents a real effort to do justice to the whole thought of Plato, but there are two sides of it which inevitably, in the changed conditions, fell into the background, the mathematical physics and the politics. The third century A.D. had no understanding for the first, and the Roman Empire under a succession of military chiefs no place for the second. The doctrine of Plotinus is Platonism seen through the personal temperament of a saintly mystic, and with the *Symposium* and the teaching of the *Republic* about the "Form of Good" always in the foreground. Plotinus lived in an atmosphere too pure for sectarian polemic, but in the hands of his successors, Neo-Platonism was developed in conscious opposition to Christianity. Porphyry, his disciple and biographer, was the most formidable of the anti-Christian controversialists; in the next century, "Platonists" were among the allies and counsellors of the Emperor Julian in his ill-advised attempts to invent an Hellenic counterpart to Christianity.

Early in the fifth century, Neo-Platonism flourished for a short time in Alexandria (which disgraced itself by the murder of Hypatia in 415) and captured the Athenian Academy itself, where its last great representative was the acute Proclus (A.D. 410–485). The latest members of the School, under Justinian, occupied themselves chiefly with learned commentaries on Aristotle, of which, those of Simplicius are the most valuable. The doctrine of the school itself ends in Damascius with complete agnosticism.

Influence on Christian Thought.—Traces of Plato are probably to be detected in the Alexandrian *Wisdom of Solomon;* the thought of the Alexandrian Jewish philosopher and theologian Philo, at the beginning of our era, is at least as much Platonic as Stoic. There are, perhaps, no certain marks of Platonic influence in the New Testament[1], but the earliest apologists (Justin, Athenagoras) appealed to the witness of Plato against the puerilities and indecencies of mythology. In the third century Clement of Alexandria, and after him, Origen, made Platonism the metaphysical foundation of what was intended to be a definitely Christian philosophy. The Church could not, in the end, conciliate Platonist eschatology with the dogmas of the resurrection of the flesh and the final judgment, but in a less extreme form the Platonizing tendency was continued in the next century by the Cappadocians, notably St. Gregory Nyssen, and passed from them to St. Ambrose of Milan. The main source of the Platonism which dominated the philosophy of western Christian divines through the earlier Middle Ages, were, however, Augustine, the greatest thinker among the Western Fathers, who had been profoundly influenced by Plotinus, read in a Latin version, before his conversion to Christianity, and Boethius, whose wholly Platonist vindication of the ways of Providence in his *Consolatione Philosophiae* was the favourite "serious" book of the Middle Ages.

A further powerful influence was exerted by the writings of the so-called Dionysius the Areopagite, which laid down the main lines of mediaeval mystical theology and angelology. These works are, in fact, an imperfectly Christianized version of the speculations of Proclus, and cannot date before the very end of the fifth century A.D. at the earliest, but they enjoyed an immense authority based on their attribution to an immediate convert of St. Paul.

After their translation into Latin in the ninth century by Johannes Scotus Erigena, their vogue in the West was as great as in the East. Apart from this theological influence, Plato dominated the thought of the earlier Renaissance which dates from the time of Charlemagne in another way. Since the West possessed the philosophical writings of Cicero, with the Neo-Platonic comment of Macrobius on the *Somnium Scipionis,* as well as the Latin translation of the first two-thirds of the *Timaeus* by Chalcidius, with his commentary on the text, and versions, also, at least of the *Phaedo* and *Meno,* whereas nothing was known of the works of Aristotle except Latin versions of some of the logical treatises, the Middle Age, between Charlemagne and the beginning of the 13th century, when the recovery of Aristotle's physics and metaphysics from Moors, Persians and Jews began, was much better informed about Plato than about Aristotle; in particular in the various "encyclopaedias" of this period, it is the *Timaeus* which forms the regular background.

The thirteenth century saw a change. Aristotle came to displace Plato as "the philosopher," partly in consequence of the immediately perceived value of his strictly scientific works as a storehouse of well-digested natural facts, partly from the brilliant success of the enterprise carried through by St. Thomas Aquinas, the reconstruction of philosophical theology on an Aristotelian basis. Plato is, however, by no means supplanted in the Thomist system; the impress of Augustine on Western thought has been far too deep for that. Augustine's "exemplarism," that is, the doctrine of Forms in the version, ultimately derived from Philo of Alexandria, which makes the Forms "creative thoughts" of God, is an integral part of the Thomist metaphysics, though it is now denied that the exemplars are themselves cognizable by the human intellect, which has to collect *its* "forms," as best it can, from the data of sense.

Directly or through Augustine, the influence of Plato, not only on strictly philosophic thought but on popular ethics and religion, has repeatedly come to the front in ages of general spiritual requickening, and shows no signs of being on the wane.

Two "revivals" in particular are famous. The first is that of the 16th century, marked by the Latin translation of Marsilio Ficino and the foundation of Lorenzo dei Medici's fantastic Florentine Academy. What was revived then was not so much the spirit of Plato as that of the least sober of the Neo-Platonists; the influence of the revival was felt more in literature than in philosophy or morals, but in literature its importance may be measured by the mere mention of such names as Michelangelo, Sidney, Spenser.

In the 17th century, Plato, seen chiefly through the medium of Plotinus, supplied the inspiration of a group of noble thinkers who were vindicating a more inward morality and religion

[1] We may perhaps detect it in John i. 18 if the true text is "the only begotten God (μονογενὴς θεός) which is in the bosom of the Father." This may be an echo of the phrase used in the *Timaeus* (92*d*) about the visible world "A God apprehensible to sense ... one and only begotten" (μονογενὴς ὤν). But it is not safe to assert it.

against the unspiritual secularism and erastianism of Hobbes, the so-called "Cambridge Platonists," Whichcote, Henry More, Cudworth, John Smith. At the present moment the writings of A. N. Whitehead contain an attempt to work out a philosophy of the sciences which confessedly connects itself with the ideas of the Timaeus.

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PLATO, Athenian comic poet of the Old Comedy, flourished between 428–389 B.C. According to Suïdas, he was the author of 30 comedies. Some of these deal with political matters. Such were the *Cleophon* and *Hyperbolus,* directed against the well-known demagogues. His later plays are satires handled in a burlesque spirit. Such were the *Sophistae,* akin to the *Clouds* of Aristophanes; the *Cinesias,* an attack on a contemporary poet and the *Festivals.*

See T. Kock, *Comicorum atticorum fragmenta,* i. (1880); A. Meineke, *Poetarum comicorum graecorum fragmenta* (1855).

PLATON, LEVSHIN (1737–1812), Russian divine, was born at Chashnikovo near Moscow, and educated in the academy of that city. In 1763 the empress Catherine II. invited him to instruct her son Paul in theology, and he became one of the court chaplains. Three years afterwards Platon was appointed archimandrite of the monastery of the Trinity (Troitskaya Lavra) near Moscow, in 1770 archbishop of Tver, and in 1787 archbishop of Moscow and metropolitan. He died in 1812, one of his last acts having been to write an encouraging letter to the emperor Alexander I. in view of the French invasion. Platon was a brilliant and learned man, and the author of *A Short History of the Russian Church.*

PLATONIC LOVE, a term commonly applied to an affectionate relation between a man and a woman into which the sexual element does not enter. The term in English goes back as far as Sir William Davenant's *Platonic Lovers* (1636). It is derived from the conception, in Plato's *Symposium,* of the love of the idea of good which lies at the root of all virtue and truth.

PLATOON, a sub-division of a company of infantry. In the 17th century it was, in some cases, the infantry tactical unit and was commanded by a captain. At the beginning of the 18th century the term referred to a small body of musketeers of about 40 or 50 men arranged in a square to strengthen the angle of the battalion when formed in hollow square. About the middle of the 18th century a battalion was generally organized into 16 platoons, of about 24 men each, plus two or four platoons of grenadiers. In the 19th century, the term has been applied solely to a squad of recruits under training. "Platoon fire" was the systematic and regulated fire of platoon volleys. Hence a "platoon" sometimes meant a volley. The term was retained for a type of manual exercise. As a sub-division of an infantry company it was re-introduced into the British service in 1913 and became the name of the sub-division of a company in most modern armies (*see* COMPANY).

PLATOON SCHOOL, a work-study-play school organization found in the educational system of the United States. It was originated by William Wirt who started the first school of this type in Bluffton, Ind., in 1902. When he became superintendent of schools of Gary, Ind., in 1907, he organized all the schools of that city on the work-study-play plan.

The theory was based on the proposition that modern cities

were bad for children since they deprived them of the healthful work and play which are as essential elements in a child's education as study. The platoon school returned opportunities for work and play to children by providing schools containing not only classrooms but well-equipped shops, science rooms, drawing and music studios, cooking rooms, auditoriums, playgrounds and gymnasiums. The traditional public school operated on a "peak-load" plan of operation, *i.e.*, on the principle of reserving a school seat for the exclusive use of one child during the entire year. When the children left these seats to go to shops or playgrounds the seats remained vacant. Under such a plan there were seldom enough seats, playgrounds or shops to accommodate all the children in a city at one time.

Under the platoon plan, on the contrary, all facilities in the school—classrooms, auditoriums, gymnasiums, shops and laboratories—were put to use every hour of the day. The school was divided into two parts, each having the same number of classes and each containing all the eight or nine grades. While one of the schools was in classrooms, the other was in special activities, auditorium, playgrounds and gymnasiums. This meant that only half the usual number of classrooms was needed.

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PLATT, CHARLES ADAMS (1861–1933), U.S. architect, was born in New York, N.Y., on Oct. 16, 1861, and educated in the National Academy of Design, and in Paris under Gustave Boulanger and Jules J. Lefebre. At first he intended to become a painter and etcher, but the outcome of a visit to Italy was a book, *Italian Gardens* (1892). This explained his adoption of architecture, and his work showed the marked influence of Italian form. He designed many private houses and gardens in addition to public buildings, among the latter being the Maxwell Memorial library, Rockville, Conn. (1917); the Freer Gallery of Art, Washington, D.C. (1918); the library, Connecticut College for Women, New London, Conn. (1922); the agricultural building, University of Illinois, Urbana, Ill. (1923); and the Lowell memorial fountain, New York, N.Y.

See *Monograph of the Work of Charles A. Platt*, with an introduction by Royal Cortissoz (1913).

PLATT, THOMAS COLLIER (1833–1910), U.S. politician, born in Owego, N.Y., July 15, 1833, studied at Yale university, New Haven, Conn., 1849–52. He became a banker and speculated in lumber. In the 1860s Platt was chairman of the Tioga county (N.Y.) Republican committee, and in 1877, after having been elected for two terms to the U.S. house of representatives, he became chairman of the state Republican convention. Elected to the U.S. senate in Jan. 1881, Platt soon resigned, and within ten years he became the Republican boss of the state. Although he again served in the U.S. senate, his political power waned steadily after about 1903. He died in New York city, March 6, 1910.

PLATTE, a river system of Colorado, Wyoming and Nebraska, tributary to the Missouri river, which it enters immediately north of Plattsmouth, Neb., 18 mi. below Omaha, in about 41° 3′ N. latitude. Including the North Platte it is about 928 mi. long from its headwaters, with a drainage basin for the entire system of 90,000 sq.mi. The tributaries of the main stream all flow in from the north; the most important being the Loup and the Elkhorn. The main stream west of Kearney, as well as the North and the South Platte, are extensively used for irrigation.

See R. P. Teele, "Water Rights in Interstate Streams," U.S. Dept. of Agriculture *Bulletin No. 157* (1905) and J. C. Stevens, *Surface Water Supply of Nebraska* (1909).

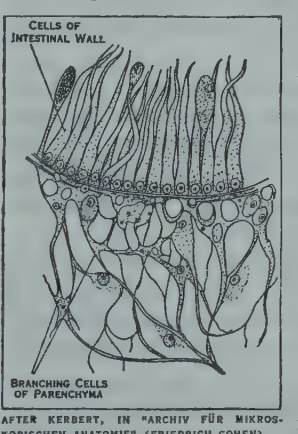
PLATTEVILLE, a city of Grant county, Wis., U.S., 20 mi. from the southwest corner of the state; on federal highway 151 and served by the Chicago and North Western and the Chicago, Milwaukee, St. Paul and Pacific railways. Pop. (1950) 5,718; (1940) 4,762. It is in a zinc and lead mining region, and is the seat of a state teachers college. The city was settled about 1827 and incorporated in 1880.

PLATTSBURG, a city of northern New York, U.S., on the west shore of Lake Champlain, is on federal highway 9 and is served by the Delaware and Hudson railway and Colonial Airlines. Pop. (1950) 17,726; (1940) 16,351; (1930) 13,349 by the federal census. Plattsburg is surrounded by beautiful scenery; the broad, island-studded lake in front, with the Green mountains beyond and, on the southern horizon, the distant Adirondacks. South of the city is Plattsburg barracks, an army post established in 1815, where thousands of reserve officers were trained during World War I. After World War II the first U.S. veterans' university was established on the site of the barracks in 1946; this institution later became a unit of the State University of New York. Plattsburg is a recreational centre and manufactures paper specialties, razor blades and wallpaper.

Plattsburg was founded by Zephaniah Platt (1740–1807), who brought a colony from Long Island. It was incorporated as a village in 1795 and as a city in 1902. The opening naval engagement of the Revolution (a victory for the British) took place at Valcour Island, 5 mi. S.E. of Plattsburg, on Oct. 11, 1776. In the War of 1812 Plattsburg was the headquarters of the U.S. army on the northern frontier. On Sept. 6, 1814, the village was besieged by land, and on Sept. 11, the "Commodore Thomas Macdonough" defeated the invading fleet.

PLATTSMOUTH, a city of eastern Nebraska, U.S., on the Missouri river, at the mouth of the Platte, 21 mi. below Omaha; the county seat of Cass county. It is on federal highways 34, 73 and 75, and is served by the Burlington Route and the Missouri Pacific railway. Pop. (1950) 4,880; (1940) 4,268. The city ships grain and cattle, and has large railroad shops, flour mills, garment factories, a cannery and other plants. It is one of the oldest settlements of the state. Nebraska Masonic home for the aged is located there. A trading post licensed by the U.S. government was opened there in 1853; a town was platted in 1854; and the city was incorporated in 1855.

PLATYHELMINTHES or PLATODARIA, a phylum of invertebrate animals, containing soft-bodied creatures which are bilaterally symmetrical and usually somewhat flattened in shape, and in which there is no true "coelom" or perivisceral cavity and no true (metameric) segmentation. The animals contained in this group (flatworms) are the simplest and probably the most primitive of those in which the tissues and organs of the body are developed from three, instead of two, original embryonic layers.



AFTER KERBERT, IN "ARCHIV FÜR MIKROSKOPISCHEN ANATOMIE" (FRIEDRICH COHEN)

FIG. 1.—SECTIONAL PORTION THROUGH THE BODY OF A TREMATODE (PARAGONIMUS), SHOWING STRUCTURE OF TISSUES

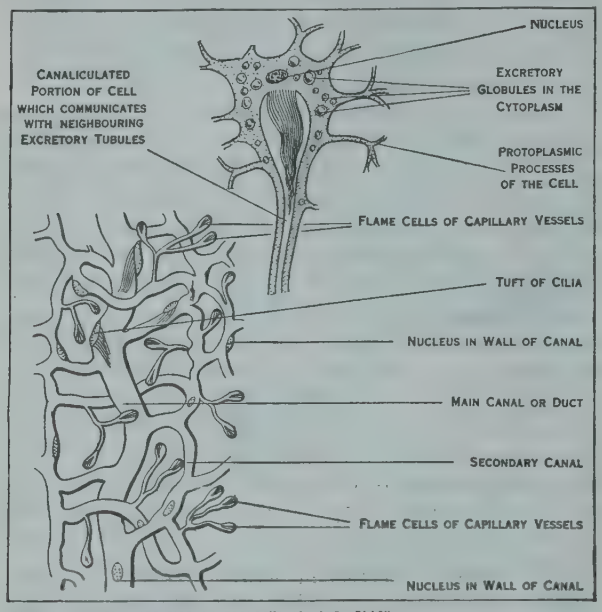
The external covering of the body is typically a cellular or syncytial epidermis provided with vibratile cilia. These serve partly for locomotion and partly for creating currents to be tested by the sense organs. In the adults of certain parasitic groups, the epidermis is replaced by a smooth or spiny cuticle. Pigment is commonly present beneath the epidermis in free-living forms, but is usually absent in those which are parasitic. The spaces between the internal organs are for the most part filled up with a kind of loose connective tissue called the parenchyma. A coelom is absent. The musculature of the body is mainly peripheral, consisting of layers of transverse, longitudinal and often also oblique muscle-fibres running beneath the epidermis.

These muscles render the body capable of extreme elongation and contraction, and often of surprising variability in shape.

Anterior and posterior ends of the body can usually be distinguished, the animals having a definite direction of locomotion, accompanied by a greater degree of specialization of the anterior extremity. Dorsal and ventral surfaces are also generally distinguishable, the latter being that on which the animal creeps, and on which the oral and genital apertures are commonly situ-

ated. In the parasitic flatworms special clinging organs are generally developed, in the form of muscular suckers, often supplemented by cuticularized hooks or spines.

An alimentary canal may or may not be differentiated. When present, it may either be a simple saclike organ or may be variously branched. With very few exceptions, its only aperture is the mouth, which may be situated subterminally, near the anterior end, or much further back, sometimes even behind the middle of the body. The mouth may be surrounded by an oral sucker, and usually a highly muscular, often protrusible pharynx intervenes between mouth and intestine.


NUCLEUS
CANALICULATED PORTION OF CELL WHICH COMMUNICATES WITH NEIGHBOURING EXCRETORY TUBULES
EXCRETORY GLOBULES IN THE CYTOPLASM
PROTOPLASMIC PROCESSES OF THE CELL
FLAME CELLS OF CAPILLARY VESSELS
TUFT OF CILIA
NUCLEUS IN WALL OF CANAL
MAIN CANAL OR DUCT
SECONDARY CANAL
FLAME CELLS OF CAPILLARY VESSELS
NUCLEUS IN WALL OF CANAL

FROM LANKESTER, "TREATISE ON ZOOLOGY" (A. & C. BLACK)

FIG. 2.—EXCRETORY SYSTEM OF A PLATYHELMINTH

Below, diagram of a portion of the excretory system showing branching ducts ending in flame cells. Above, a single flame cell more highly magnified

The main ganglia of the nervous system (the "brain") and the chief sense organs are generally concentrated towards the anterior end. In addition to tactile papillae or special sensory cilia, "eye-spots" or ocelli are frequently present in free-living forms, and sometimes in the free-living larval stages of parasitic forms. In certain free-living flatworms *statocysts* (saclike organs containing minute calcareous nodules or *statoliths*) and ciliated pits, probably sensory in function, also occur.

There is no blood-vascular system or haemocoele. The excretory organs consist of a branching system of canals ending internally in "flame-cells." These are minute pyriform structures containing cilia which keep up a constant flickering movement. The main collecting vessels of the system open to the exterior by one, two or many pores.

The Platyhelminthes are, with rare exceptions, hermaphroditic animals, each individual being functionally both male and female. The reproductive system is usually very complex. The male organs consist essentially of one or more (often very numerous) testes, whose ducts are usually connected with a protrusible intromittent organ (penis or cirrus). The essential organs of the female apparatus are an ovary (sometimes multiple ovaries) and a tubular duct communicating with the exterior. The arrangement of the parts of the female system is subject to great variation in different groups. Sometimes the same duct functions in turn as a vagina or fertilization canal, as a uterus or reservoir for fertilized eggs, and as an oviduct by which the eggs reach the exterior. In some cases (most cestodes) the only communication with the exterior is a vagina, which is connected internally with an oviduct leading from the ovary to a saclike uterus; but does not serve for the expulsion of eggs. In such forms the eggs are either shed only by the dehiscence of the wall of the uterus and of the body wall, or by a special (temporary or permanent) birth-pore. In almost all flatworms there is a yolk gland or vitellarium (often multiple vitellaria), producing yolk cells which form nutritive material for the developing embryos. The vitellarium, in the most primitive forms, appears to be developed as a sterile portion of the ovary. There is also usually a "shell-gland," which usually secretes adhesive material for fastening eggs together or to a substratum. The ducts of these glands open into the oviduct or into a specialized portion of it called the ootype. The external apertures of the male and female ducts are sometimes separate, but frequently both ducts open into a common "genital atrium," which is often muscular. Not infrequently a special duct and pore for copulatory purposes are present.

The Platyhelminthes are extremely widely distributed, free-living forms occurring in almost every kind of environment—in shallow or deep water, both fresh and marine, and on land—while parasitic forms occur on or in animals of almost every class. The free-living forms usually feed actively on small animals or plants. The parasitic forms show various degrees of modification in habits, some being external parasites and feeding on mucus or other matter derived from the skin of their hosts, while others are internal parasites and feed on partly digested food or on body fluids. Among the latter class some are without special digestive organs and can only feed by the absorption of liquid nourishment.

The phylum is usually considered to include three main divisions or classes: (1) Turbellaria (including Temnocephalidea), the majority of which are free-living, but some parasitic. This group is probably nearest to the primitive ancestral form. (2) Trematoda (flukes), all of which are wholly or partly parasitic either upon or within other animals. (3) Cestoda (tapeworms), all of which are wholly endoparasitic. *See* TAPEWORMS, TREMATODES, TURBELLARIA. (H. A. B.; X.)

PLATYPUS, a remarkable Australian aquatic mammal belonging to the primitive subclass Monotremata (*q.v.*). The duck-billed platypus (*Ornithorhynchus anatinus*), the only species, is oviparous; two eggs, ¾ in. long and ½ in. wide, each enclosed in a strong, flexible, white shell, are produced at a time. The animal shows many primitive features; there are no true teats in the female, the milk glands being probably modified sweat glands; the body temperature is relatively low. The platypus inhabits the streams and rivers of southeast Australia and Tasmania. About 20 in. long, it is clad in short, dense fur of a deep brown above, paler below. There are no teeth in the adult, their purpose being served by horny prominences, two on each side of each jaw. The broad horny muzzle is very beaklike. In the cheek are capacious pouches. The limbs are short and strong, each with five claw-bearing toes. In the forefeet, the web extends far beyond the ends of the claws, but it can be folded back on the palm when the animal comes out on to the land. On the heel of the male is a movable horny spur, perforated by a canal which communicates with a poison-gland. The platypus forms deep burrows in the banks, in which it sleeps and brings up its young, the entrance being under water. The food consists of aquatic insects, Crustacea and worms. The animal is nocturnal.

PLATYPUS (ORNITHORHYNCHUS ANATINUS), AN EGG-LAYING MAMMAL

See H. Burrell, *Platypus* (1927); D. Fleay, *Animal Kingdom* (1944).

PLATYRRHINE MONKEY, the name applied, in contradistinction to Catarrhine (*q.v.*), to the new world monkeys, on account of the broad septum between the nostrils. *See* PRIMATES.

PLAUEN, a town of Germany, in the *Land* of Saxony. Pop. (1939) 110,342. Plauen, probably founded by the Slavs, is first mentioned in 1122. It passed under the authority of Bohemia in 1327 and came to Saxony in 1466, remaining united with the electorate after 1569. The manufacture of white goods was introduced by Swabian, or Swiss, immigrants about 1570.

It was formerly the capital of Vogtland, or Voigtland, a territory governed by the imperial vogt, or bailiff, and this name clings to the district. The fine Gothic church of St. John, with

twin spires, was restored in 1886. The town hall dates from about 1550; and the old castle, Hradschin, is now a law court. Plauen manufactures embroidered white goods and makes lace. It manufactures much of the machinery used in the town and it has a trade in coal, yarn and cattle.

PLAUTUS, TITUS MACCIUS (originally, perhaps, MACCUS; *cf. Asin,* Prol. 11), the great comic dramatist of ancient Rome, was born at Sarsina in Umbria according to the testimony of Festus, who calls him *Umber Sarsinas,* and Jerome. The date of his death was 184 B.C. (Cicero, *Brutus,* xv. 60). The date of his birth depends upon an inference based on the statement of Cicero (*De senectute,* xiv. 50) that he was an old man, when he wrote his *Truculentus* and *Pseudolus.* The latter play was produced in 191 B.C.; hence we get 254–251 B.C. as the approximate date of his birth. The only record that we possess as to his life is that contained in Aulus Gellius iii. 3, 14 (based on Varro), the historical character of which is doubted by Leo (*Plautinische Forschungen,* ch. ii.). The chief fact that emerges is that he left his native Umbrian home and settled as a *peregrinus* at Rome, where, after earning some money and losing it again, he took to writing plays.

The Plays.—His literary activity may well have begun somewhat late in life; for it must have taken him a long time and much hard study to acquire the mastery of Latin and Greek which his dramas attest. The main body of his extant works belongs, so far as can be ascertained from the scanty evidence which we have, to the last 20 years of his life; 206–204 B.C. is the approximate date of the *Miles Gloriosus; cf.* line 211 *seq., quoi bini custodes . . . occubant* (present tense), which alludes to the imprisonment of Naevius. Of the extant plays the *Cistellaria* and the *Stichus* must be associated with the *Miles* as comparatively early works; for the former was clearly produced before the conclusion of the Second Punic War, *see* I. 201 *seq.;* and the *Stichus* is proved by its didascalia to have been produced in 200 B.C. The *Pseudolus* and the *Truculentus* fall within the last seven years of his life; and the *Trinummus* is later than 194 B.C.; *cf.* I. 990 *novi aediles.*

The dates of the other extant plays are uncertain. An interesting attempt to place them in chronological order according to the proportion in them of scenes written in lyrical metres and set to music (*cantica*) has recently been made by W. B. Sedgwick (*Classical Review,* xxxix., 1925, p. 55 *seq.*). It is at any rate not improbable that the poet gave greater scope to his musical innovation (*see* below) as his command over language and metres developed and the success of his experiment became assured. The titles of the other extant plays are (in alphabetical order) *Amphitruo, Asinaria, Aulularia, Bacchides* (later than the Epidicus, *see* l. 214), *Captivi, Casina, Curculio, Epidicus, Menaechmi, Mercator* (later than the *Rudens* according to F. Marx and E. Fränkel, but regarded as one of the earliest plays by P. J. Enk in *Mnemosyne,* liii., F. A. Wright in *Broadway Translations,* and W. Beare in *Classical Review* xlii., 1928, pp. 106 and 214 *seq.*), *Mostellaria, Persa, Poenulus, Rudens* (probably first acted 192 B.C.) *Vidularia* (existing only in a fragmentary condition in the codex Ambrosianus). Some of these may possibly be earlier than 204 B.C.; and it seems *a priori* likely that the 35 other Plautine plays known to us only by their titles and a few fragmentary quotations were not all written within the last 20 years of the poet's life.

Indebtedness and Originality.—The plays of Plautus are based on Greek originals of the New Comedy, of which one complete specimen is extant. But Plautus was not a mere translator. This was shown by K. M. Westaway (*The Original Element in Plautus,* 1917), and has been recently demonstrated in detail by E. Fränkel (*Plautinisches im Plautus,* 1922), who calls attention to certain mannerisms as evidence of unmistakable Plautine additions to the Greek texts, and also points out the originality of the Roman in the introduction of a musical element into his plays (*see* below). On the other hand, there are passages in which he does not hesitate to take over from his originals, allusions which can hardly have been intelligible to a Roman audience, *e.g.,* the reference to Stratonicus, a musician of the time of Alexander the Great (*Rudens,* 932); and in the delineation of character we have no reason to suppose that he improved on his models (*cf.* Aul. Gell. ii. 23). Even the bulk of the prologues may be of Greek origin, though certain passages in them must have been added by Plautus, and other passages (e.g., *Casina* 5–20) are post-Plautine. And where Plautus varies his plot on lines of his own by amalgamating the plots of two distinct Greek comedies (*e.g.,* in the *Miles* and the *Poenulus*) the result is generally not happy; the romanization of the plays by way of allusions to towns in Italy, to the streets, gates and markets of Rome, to Roman magistrates and their duties, to Roman laws and the business of Roman law courts, banks, comitia and senate, etc., involves the poet in all the difficulties of attempting to blend two different civilizations. The inconsistency of his attitude is shown by his use, side by side, of the contemptuous expressions *barbarus* (applied to the Romans) and *pergraecari* (applied to the Greeks). In some passages the poet seems to take delight in casting dramatic illusion to the winds (e.g., *Pseudolus,* 720; *Poenulus,* 550).

But as an adapter for the Roman stage Plautus is nothing less than masterly. His command of Latin is such that his plays read like original works, and it may be at least said that some of his characters stand out so vividly from his canvas that they have ever since served as representatives of certain types of humanity, *e.g.,* Euclio in the *Aulularia,* the model of Molière's miser. Alliteration, assonance, plays upon words and happy coinages of new terms, give his plays a charm of their own. "To read Plautus is to be once for all disabused of the impression that Latin is a dry and uninteresting language" (Skutsch, in *Die Cultur der Gegenwart,* 1905). It is a mistake to regard the Latin of Plautus as "vulgar" Latin. It is essentially a literary idiom, based upon the language of intercourse of the Roman society of the day (*cf.* Cic. *De oratore,* iii. 12, 45).

The Characters in his plays are the stock characters of the New Comedy, and they remind us also of the standing figures of the *Fabulae Atellanae* (Maccus, Bucco, Dossennus, etc.). We may miss the finer insight into human nature and the delicate touch in character-drawing which Terence presents to us in his reproductions of Menander, but there is wonderful life and vigour, and considerable variety in the Plautine embodiments of these different types. Their language is often coarse; and there is some deliberate obscenity in it, but not so much as has been discovered by Gurlitt and introduced into his German translation (1920–22). And the careful reader will take note of occasional touches of serious thought (no doubt derived from the Greek originals), as in the enumeration of the ten deadly political sins (*Persa,* 555 *seq.*) and allusions to ethical philosophy (*Pseud.* 972 *seq.; Stich,* 124; *Trin.* 305 *seq.,* 320 *seq.,* 363 *seq.,* 447; *Rud.* 767, 1235–1248, etc.). The *Captivi* is the story of the heroic self-sacrifice of a slave. The *Amphitruo* is a mythological burlesque. But most of his plays depend for their main interest in intrigue, such as the *Pseudolus, Bacchides, Mostellaria.* In the *Menaechmi* and as a subordinate incident in the *Amphitruo* we have a comedy of errors.

Metres.—In the metrical structure of his plays Plautus introduced an important innovation. The New Comedy of Greece had confined itself for the most part to the metres of dialogue: Plautus took the bold step of transposing whole scenes into metres suitable for singing to the accompaniment of the flute (*cantica*); and to other scenes he gave a quasi-operatic character by the use of recitative. But the *cantica* are not mere inserts or accessories, like the songs introduced in the Shakespearean drama; they form integral parts of the action, which would often be unintelligible without them (*see* Fränkel [*op. cit.*] whose theory is a development of that of Leo in *Die plautinischen Cantica und die hellenistische Lyrik,* 1897). The metres employed were, of course, not invented by Plautus; they are of Greek origin and are common to Roman tragedy and Roman comedy; but Plautus gave them a new development and a wider scope. Further light is thrown upon the immediate source of these Plautine metres by J. H. O. Immisch (*Zur Frage der plaut. Cantica,* in *Berichte der Heidelb. Akad.,* 1923). The Plautine metres are wonderfully varied, and the textual critic does well not to attempt to limit the possibilities of original metrical combinations and developments in the Roman

comedian.

Reputation.—Plautus was a general favourite in the days of republican Rome. Cicero, though he found fault with the iambics of the Latin comedians generally as *abiecti* "slovenly" (*Orator* lv. 184), admired Plautus as *elegans, urbanus, ingeniosus, facetus* (*De. offic.* i.,29,104). To the fastidious critics of the Augustan age, such as Horace, he seemed rude (*cf. Ars Poetica,* 270–274), just as Addison declared Spenser to be no longer fitted to please "a cultivated age." In another passage (Epist. ii. 1 170–176) Horace accuses him of clumsiness in the construction of his plays and the drawing of his characters, and indifference to everything except immediate success; *gestit enim nummum in loculos demittere, post hoc securus cadat an recto stet fabula talo.* That there are many inconsistencies and signs of carelessness in his work has been proved in detail by Langen. But that he found many admirers, even in the Augustan age, Horace himself bears witness (*ibid.* 1. 58), where he says that Plautus was regarded as a second Epicharmus: *Plautus ad exemplar Siculi properare Epicharmi; cf.* Varro's statement (in Priscian ix. 32), *deinde ad Siculos se applicavit.* It is possible that Plautus may have been working on the lines of the old comedy in the tell-tale names which he is so fond of inventing for his characters such as Polymachaeroplagides (*Pseud.* 988), Pyrgopolinices (*Mil.* 56), Thesaurochrysonicochrysides (*Capt.* 285)—names which stand in remarkable contrast to the more commonplace Greek names employed by Terence.

In the middle ages Plautus was little regarded, and 12 of his plays (*Bacchides—Truculentus*) disappeared from view until they were discovered (in the ms. called *D*) by Nicholas of Treves in the year 1429. But after the revival of learning Plautus was reinstated, and took rank as one of the great dramatists of antiquity; *cf.* Shakespeare, *Hamlet,* II., ii., 420, where Polonius says "The best actors in the world . . . Seneca cannot be too heavy nor Plautus too light."

Influence on Modern Literatures.—A comprehensive view of the widespread influence of Plautus on modern literatures is given by Reinhardstoettner, *Spätere Bearbeitungen plautinischer Lustspiele* (1886). Many adaptations for the Italian stage were produced between the years 1486 and 1550, the earliest (the *Menaechmi*) under the direction of Ercole I., duke of Ferrara. From Italy the practice spread to France, Spain, England and other countries.

Of English plays the interlude called *Jack Juggler* (between 1547 and 1553) was based on the *Amphitruo,* and the lost play called the *Historie of Error* (acted in 1577) was probably based on the *Menaechmi;* Nicholas Udall's *Ralph Royster Doyster,* the first English comedy (acted before 1551, first printed 1566), is founded on *Miles Gloriosus;* Shakespeare's *Comedy of Errors* (about 1591) is an adaptation of the *Menaechmi;* and his Falstaff may be regarded as an idealized reproduction or development of the braggart soldier of Plautus and Terence—a type of character which reappears in other forms not only in English literature (*e.g.,* in Shakespeare's Parolles and Ben Jonson's Captain Bobadil) but also in most of the literatures of modern Europe. Shakespeare's *Taming of the Shrew* has been influenced in several respects (including the names *Tranio* and *Grumio*) by the *Mostellaria.* Ben Jonson produced a skilful amalgamation of the *Aulularia* and the *Captivi* in his early play *The Case is Altered* (written before 1599). Thomas Heywood adapted the *Amphitruo* in his *Silver Age* (1613), the *Rudens* in his *Captives* (licensed 1624), and the *Mostellaria* in his *English Traveller* (1633). Dryden's *Amphitryon or the two Sosias* (1690) is based partly on the *Amphitruo,* partly on Molière's adaptation thereof; Fielding's *Miser* (acted 1732) on Molière's *L'Avare* rather than on the *Aulularia,* and his *Intriguing Chambermaid* (acted 1733) on Regnard's *Le Retour imprévu* rather than on the *Mostellaria.*

Bibliography.—Standard Texts and Editions with Notes: Texts by Goetz and Schoell (*editio minor,* 1893–1907), by Leo (1895–96), by Lindsay (1904–05). With notes: *Captivi,* by Lindsay (1900), by Brix (6th ed., 1910); *Menaechmi,* by Brix (5th ed., 1912); *Miles* by Lorenz (2nd ed., 1886), by Brix (3rd ed., 1901); *Mostellaria* by Lorenz (2nd ed., 1883), by Sonnenschein (2nd ed., 1907); *Pseudolus* by Lorenz (1876); *Rudens* by Sonnenschein (1891, ed. min., 1901); *Trinummus* by Brix (5th ed., 1907); other plays in Macmillans Classical Series and the Pitt Press Series. Lexicon: Gonzalez Lodge's *Lexicon Plautinum* (nearing completion and indispensable). Syntax: Lindsay, *Syntax of Plautus* (1907): Metre and Prosody: Lindsay, *Early Latin Verse* (1922); Vollmer, *Römische Metrik* (1923); and *Ueber die sogenannte Iambenkürzung* (1924); Sonnenschein in *What is Rhythm?* (1925, ch. vi.). E. Fränkel's *Iktus und Akzent im lateinischen Sprechvers* (1928) is an attempt to show that in the dialogue metres, as distinct from the metres set to music, the verse-stress (*ictus metricus*) nearly always coincides with a genuine speech-accent, or at any rate corresponds to some modification of accentuation or intonation. Translations: English prose by P. Nixon in the Loeb Series (1916–24; 2 vols. still to come); English verse by Wright and Rogers in *Broadway Translations*—select plays (1923).

PLAY: *see* Drama.

PLAYA (a Spanish word meaning "shore"), the name applied in America to a level plain formed of the deposits of a river which has no outlet to the sea or a lake. If at seasons of high water a river floods any area and temporarily converts it into a lake, which subsequently dries up in hot weather, the tract thus left dry is called a playa. The barren Black Rock desert in north-western Nevada, about 100m. in length by 15 in breadth, is typical.

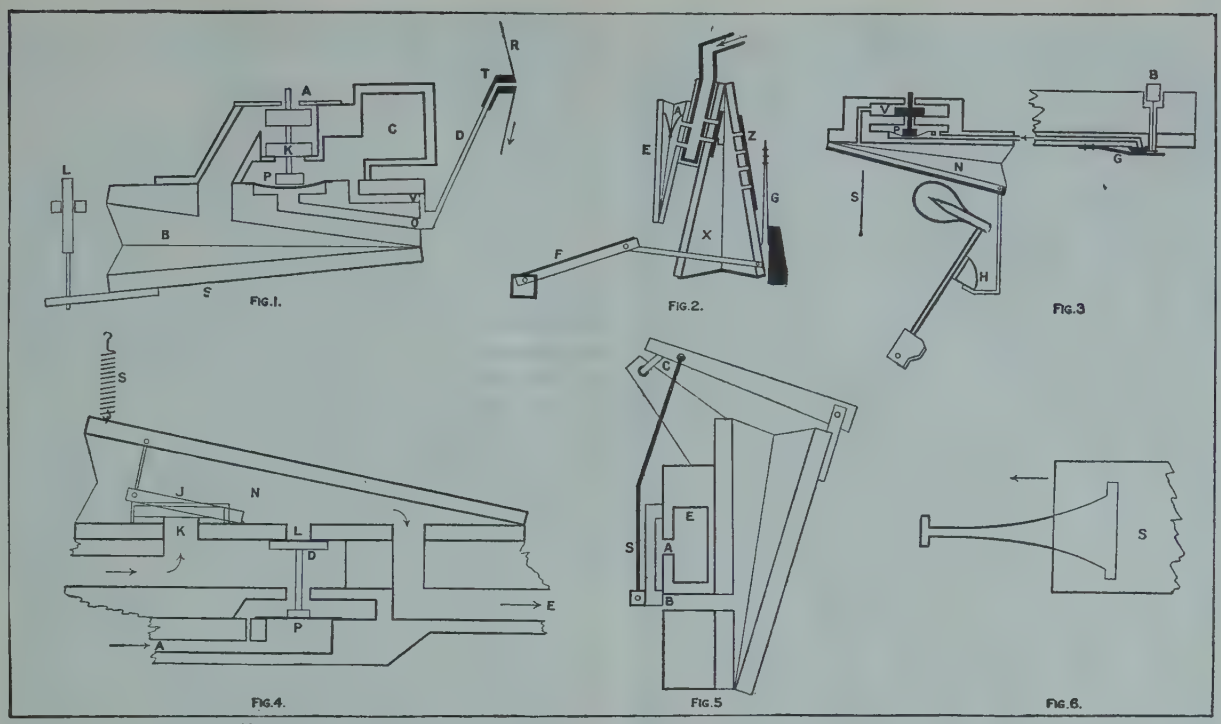
PLAYER-PIANO, a piano equipped with a mechanical device for automatically playing written music or for reproducing the playing of a pianist. All types of player-piano mechanism are operated by utilizing the difference between external and internal air pressures. In fig. 1, the tracker-bar, T, with its 88 holes, is represented as being closed by the paper roll, R, which lies closely against it. Some of the air has been extracted from the duct, D, and from the chamber, C, by means of an air-exhaust to which they are connected. There is a very tiny vent, V, which allows air from the tracker duct to leak into the chamber. A disk, K, closes the chamber from the outer air, being held down because the air in C, is at a lower pressure than normal. The pneumatic, B, is full of air at normal atmospheric pressure and is open to the external air by means of the port, A.

Should a hole in the paper come into line with any hole in the tracker-bar, the external air rushes into the duct and lifts the pouch, P, which is simply a circular piece of soft kid about $\frac{3}{4}$in. in diameter, and bigger than K. Hence it lifts K, connecting the pneumatic with the partial vacuum, C, and disconnecting it from the external air by closing the port A. The air in B spreads to C and, the external pressure on the surface, S, being greater than the reduced pressure inside, the pneumatic collapses suddenly, the movable leaf rising and lifting with it the pilot, L, which operates the piano action.

The pneumatic remains collapsed until paper again blocks the hole in the tracker-bar. The air in D then leaks through into C and can no longer hold up the pouch, which falls back into position and allows K to close the chamber C again, at the same time opening the pneumatic to the external air at A. The external and internal pressure on S now being the same, the pneumatic re-inflates and allows the pilot to drop back into position.

In the days of heavy and clumsy valves it was difficult to provide the necessary power to lift them rapidly without hard pedalling and consequent loud tone. To overcome this defect the more expensive player action was provided with an additional (or primary) valve of light construction, easily lifted by the inrush of air when a hole was opened on the tracker-bar. Its lifting admitted air to the other and heavier valve, through the port O, operating the striking pneumatic as previously described. Both single and double valve systems are still in use.

The interior of the player action is maintained in a steady state of reduced pressure by forcing the pedal, F, to open the exhaust, X (fig. 2). This allows all the interior air to spread itself into X past L, a flat strip of well-tanned leather, lying over holes. A fan spring, G (about 12lb. in strength), then closes the exhaust, expelling the air via another flap valve, Z. A strong spring, A, is always trying to open the equalizer, E, but is prevented from so doing when the external air pressure is much greater than the reduced pressure inside. When, however, there is not much difference between the external and internal pressures, the spring can open and in so doing allows air to spread into it from the interior. The effect is to reduce the internal pressure



MECHANISM OF THE PLAYER-PIANO. THE FIGURES AND LETTERS ARE EXPLAINED IN THE TEXT

once more to such an extent that the equalizer begins to collapse. Its constant to-and-fro motion enables a steady amount of reduced pressure to be maintained in the interior channels, despite unsteady working of the pedals.

Controls.—The simplest method of operating the "soft" and "sustaining" pedals is to connect the ordinary mechanism of the piano, by suitable levers, to finger controls in front of the keyboard. Many manufacturers prefer to control the distance from the hammers from the strings as shown in fig. 3. A button, B, opens a gate, G, when pressed down. This admits air to a pouch, P, which lifts the valve lying above it, and puts the pneumatic, N, into communication with a partial vacuum, V, thus collapsing it and causing it to lift the hammer rail, H, which softens the tone by giving the hammerhead less distance to travel towards the string, S.

A similar device withdraws all the dampers from the strings. This being a heavier task than shifting the hammers, a larger pneumatic has to be employed, and two valves instead of one. Music rolls are provided with an additional hole at the left-hand edge, which works the lifting of the dampers, if desired.

Change of power, in addition to the means above described, is provided by varying the strength of the blow given to the hammer. Fig. 4 shows how the normal amount of reduced air is altered by interposing a pneumatic, N, between the main exhaust, E, and the small playing pneumatics. Pressing a button (as in fig. 3), air is allowed to enter at A, the pressure from which lifts the pouch, P, and with it the valve, D. This closes the large hole, L, and leaves only the aperture, K, over which lies a knife-cutter valve, J, so called because it closes like the blade of a pen-knife. The spring, S, is of such strength that it governs the amount of air passing through to the bellows, hard pumping closing N and therefore closing the aperture K and preventing loud playing.

A slight alteration of fig. 4 would give a fair representation of the automatic Accenting Device, which is worked from marginal perforations in the music roll. The valve disk, D, is moved to the other side of the hole, L, keeping it normally closed and softening the tone until a marginal perforation allows air to rush towards P. The pouch lifts the valve, opens L and accents the note.

The pedals also provide sufficient power to work the spool which draws the music roll over the tracker-bar. Five pneumatics of the type shown in fig. 5 are fixed at equal angular distances upon a crank-shaft, C, each one collapsing in turn and so driving the shaft round steadily. Collapse is effected when the hollow slide, S, is covering both of the ports A and B, for the pneumatic is then in direct communication with the main exhaust, through E. As the crank-shaft is thus moved round, the slide is raised, and no longer covers both ports. External air is admitted to the pneumatic, and the collapse of one of its neighbours provides the power to lower its slide and again get into communication with the main exhaust.

All communication between motor and exhaust is by way of a governor pneumatic; powerful pedalling tends to collapse it, but directly this happens a knife-valve partly closes the passage-way (as in fig. 4), and thus prevents the motor from "racing." Variation in tempo is secured by deliberately altering the size of the passage-way within an enclosure known as the Tempo Box. The shape of the slot is usually as shown in fig. 6, over which passes a slide, S. When half the area of the slot is covered, the speed of the motor is half its maximum, and so on, the slide being worked mechanically from the control board.

The holes in the paper roll being so close together, it is essential that they should track correctly, despite the effects of wear and weather. Correct tracking is controlled in ways which vary in detail, but usually depends upon the action of two pneumatics, kept under exhaust. Holes in the tracker-bar are so placed as to be uncovered when (and only when) the roll goes to one side, letting air into one of the pneumatics and causing it to open slightly, taking with it either tracker-bar or spool.

Reproducing Pianos.—The "reproducing" instruments are in a separate class, designed to reproduce faithfully all the shades of tempo and expression made by well-known pianists. All control is rightly withdrawn from the operator when using the specially cut rolls, but the same instrument may be used for ordinary rolls by putting the reproducing mechanism out of action. Additions to the normal player mechanism are mostly for the purpose of controlling more completely the comparative loudness or softness of individual notes. To do this effectively it is necessary to have as many grades of power as possible, to include

smooth crescendo as well as sforzando effects.

The Ampico mechanism alters the size of the main passage-way (and hence the power) by means of a regulator valve, which is attached to a lever, controlled by a set of pneumatics under vacuum (three small "intensity" pneumatics above, balanced by a large "spring" pneumatic beneath). When marginal perforations connect up to the valves of the "intensity" pneumatics, these lift and allow the pneumatics to fill with air, thus exerting an up-push on the lever, raising the regulator valve and increasing the size of the passage-way. As these pneumatics lie along the lever, their lifting power depends upon position, those furthest from the fulcrum end being the most effective. When it is necessary for an intensity pneumatic to collapse again, another marginal perforation, connecting up to a "cancel" valve, admits air and allows this to happen. Further marginal perforations are provided, one for slow crescendo, and the other for fast crescendo, each connecting up to the same crescendo pneumatic, but in the latter case two ways are open for the air to escape, making the pneumatic collapse quickly. For "brilliant" or extra powerful performance, the Ampico can be switched over so as to close the slight "in-leak" provided on one of the three pumpers of the power mechanism. The whole system then works at maximum power. For subdued performance the main passage-way is blocked by a disk, operated pneumatically from a switch in the spool-box.

The Angelus Artrio system employs thirteen expression openings, all leading from the interior to the exhaust pumps. Five of these are in the controlling governor, and the others in the treble and bass sections. They vary in size from tiny vents to a large "melody" opening, and all air must pass through one or more openings on its way from tracker-bar to main exhaust. In addition, there is an "in-leak" as on the Ampico, but the Angelus system works it from the tracker-bar. When a perforation appears against the second hole from the left-hand side, the "in-leak" is closed and an increase of power results.

The Duo-Art (Aeolian Company) is essentially a theme and accompaniment expression arrangement, the former being at a higher dynamic power than the other. Each has a knife-valve control of the passage-way, operated by a set of four pneumatics, varying in their amount of possible collapse. In this way sixteen variants of power are obtained. There is also an "in-leak," automatically closed by another knife-valve so as to get maximum power when the passage-way is already nearly full open.

The Welte-Mignon is worked by suction fan instead of the usual pumpers. Its expression unit consists of a governor bellows, held open by a coiled spring. This controls the position of a conical valve in the passage-way, and is itself automatically responsive to the amount of work being done at any moment within the pneumatic system. The expression pneumatic, which also works the same conical valve, is operated from the tracker-bar, and can act slowly or quickly according to the perforations in operation. (S. A. H.)

BIBLIOGRAPHY.—S. Grew, *The Art of the Player-Piano* (1922), *The Book of the Player-Pianist* (1925); D. M. Wilson, *The Player-Piano: its Construction, how to play* (1923).

Value of the Player-piano.—The player-piano in its modern perfected form enjoys the whole-hearted support of musicians. In schools it has proved invaluable, while in musical colleges and academies it is utilized as a means of familiarising students with the interpretations of the greatest performers.

PLAYFAIR, JOHN (1748–1819), Scottish mathematician, was born at Benvie, Forfarshire, where his father was parish minister, on March 10, 1748. He was educated at home until the age of 14, when he entered the University of St. Andrews. He was ordained, and succeeded his father in the parish of Benvie, but continued his scientific studies. In 1785 he succeeded Dugald Stewart in the chair of mathematics at Edinburgh, which he exchanged in 1805 for that of natural philosophy. In 1795 he published his *Elements of Geometry*, which later passed through many editions. He enunciated the axiom now known by his name, viz., that two intersecting straight lines cannot both be parallel to the same straight line. He was elected F.R.S. in 1807. He died in Edinburgh on July 20, 1819.

His other publications include: *Illustrations of the Huttonian Theory of the Earth* (1802); *Outlines of Natural Philosophy* (2 vols., 1812–16). His collected works, with a memoir by J. G. Playfair, were published at Edinburgh (4 vols. 1822).

PLAYFAIR, LYON PLAYFAIR, 1ST BARON (1818–1898), was born at Chunar, Bengal province, on May 21, 1818, and educated at St. Andrews, Glasgow, Edinburgh, University College, London, and under Liebig at Giessen, where he took his doctor's degree. Playfair translated into English Liebig's *Chemistry of Agriculture*. From 1841–42, he was chemical manager of the Primrose print-works at Clitheroe, and in 1843 was elected honorary professor of chemistry to the Royal Institution of Manchester. Soon after he was appointed a member of the Royal Commission on the Health of Towns, a body whose investigations may be said to have laid the foundations of modern sanitation. In 1845 he was appointed professor in the new School of Mines, and chemist to the geological survey, and thenceforward was constantly employed by the public departments in matters of sanitary and chemical inspection. For his services as special commissioner of the 1851 Exhibition, he was made C.B. From 1856 to 1869 he was professor of chemistry at Edinburgh University. In 1868 he was elected to represent the universities of Edinburgh and St. Andrews in parliament, and retained his seat till 1885, from which date until 1892 he sat as member for Leeds. In 1873 he was made postmaster-general, and in the following year, after the dissolution of parliament, was made president of a commission to inquire into the working of the civil service. Its report established a completely new system, known as the "Playfair scheme." From 1880, when Gladstone returned to power, till 1883, Playfair acted as chairman of committees. In 1892 he received a peerage, and in 1895 the G.C.B. He died in London, on May 29, 1898, and was buried at St. Andrews. He published a volume, *Subjects of Social Welfare*.

A memoir by Sir Wemyss Reid was published in 1899.

PLAYFAIR, SIR NIGEL (1874–1934), actor and theatrical manager, was born in London on July 1, 1874. Educated at Harrow and at University college, Oxford, he acted with the Oxford University Dramatic Society. For some time he practised as a barrister. On July 30, 1902, he made his first appearance as a professional actor at the Garrick theatre, London, in "A Pair of Knickerbockers." He was chiefly associated with the Lyric theatre, Hammersmith, London, the management of which he assumed in 1919. Among his most famous productions at this theatre were John Drinkwater's *Abraham Lincoln* (1919) and the revival of Gay's *Beggar's Opera* (1920) which ran for over three years. He published *The Story of the Lyric Theatre, Hammersmith* (1925), and other works. He was knighted in 1928.

PLAYFORD, JOHN (1623–*c.* 1686), English musical publisher, was born at Norwich. From 1653 he was clerk to the Temple church, and from his shop in the Inner Temple issued most of the English music of his day. Of his own compositions the chief are numerous psalm tunes, the popular *Introduction to the Skill of Musick* (1654, 19 ed. 1730) and *The Dancing Master* (1650), a collection of airs for the violin used for country dances which constitute an invaluable treasury of English national tunes.

See F. Kidson, *British Music Publishers*.

PLAY IN ANIMALS. At the very beginning of any discussion of play in animals one is obligated to emphasize the fact that current understanding of the subject is extremely limited. The factual evidence consists exclusively of descriptions of a wide variety of responses which have arbitrarily been lumped together under the rubric of play. The explanations and interpretations presently available are speculative, deductively derived, and untested. Some of the theories purporting to elucidate the causes and results of play are emotionally appealing but scientifically unsound; others appear plausible and may be valid, but none has been subjected to objective verification.

Characteristics of Play.—The general characteristics of playful behaviour in animals as set forth by most students of the subject can be stated briefly: (a) It is almost universally agreed that in animals, as in men, playful responses carry an emotional element of pleasure. (b) Play is characteristic of the immature animal rather than of the adult. Mature individuals sometimes

play, but it is generally believed that they do so less frequently than juvenile members of their species. (c) The majority of authorities concur in the belief that play differs from non-playful activities in having no immediate, utilitarian result which affects the continued existence of the individual. (d) The type of play is characteristic of the species. Furthermore, the nature and amount of play exhibited by members of a particular species vary according to evolutionary position. Play is more frequent, occurs during a greater portion of the life span, and appears in more diversified form in the higher animals than in the lower.

It should be borne in mind that these generalizations refer to the commonly accepted characteristics of play. They are descriptive rather than analytical; and they cannot be used as explanations or interpretations.

Types of Behaviour Regarded as Play.—(a) *General Bodily Activity.*—Young children take delight in racing about a room at top speed, stamping violently upon the floor, shouting loudly in utter abandon. Many young animals display similar behaviour. Colts, calves, kids, puppies and kittens expend vast amounts of energy in vigorous locomotor activity to no apparent biologically useful end. They gallop, run, bound and gambol to the point of apparent exhaustion. Many observers regard this behaviour as a form of play. It is assumed to constitute an outlet for surplus energy, to bring pleasure to the performer, and to lack any practical purpose.

(b) *Youthful Practice of Adult Activities.*—The African lion cub lies in hiding and creeps forth, belly close to the ground, to stalk and leap upon an unsuspecting brother or sister. Two puppies wrestle and roll in mock combat, sinking tiny teeth into thick fur and uttering infantile growls. Twin lambs face each other with heads lowered and forefeet pawing the earth; charging forward, they meet head on and tumble awkwardly on the grass. The common element in such activities lies in their resemblance to similar behaviour patterns which the animal will display in somewhat different form later in life.

There are, however, several significant differences between the behaviour of the young and the adult individual. When they appear during infancy, the responses do not terminate in the same result which they will achieve in the adult stage. The kitten's chase of a ball or a blowing leaf mirrors the cat's pursuit of a mouse; but in one instance food is obtained and in the other it is not. The puppy's battle with his brother reflects the adult dog's combat with other grown animals; but in the infant's struggle no damage is inflicted. The young animal's performance is often imperfect and incomplete; whereas that of the adult is relatively polished and well-integrated. From such observations it has been deduced by Karl Groos and others that this type of play serves to prepare the animal for a more efficient adult life. It is thought that incomplete and imperfect instincts are modified, strengthened or suppressed during the practice period of youthful play. C. Lloyd Morgan has suggested that the play period of infancy permits the practice of vital responses under conditions in which error and incompleteness are not fatal. The perfection of essential reactions is thus held to take place before the animal is subjected to the exigencies of an independent existence, wherein the forces of natural selection are constantly operating to weed out inefficiency and the penalty for error may be sudden death.

It seems probable that this theory may hold good for the play of certain higher mammals. (The chimpanzee, for example, passes through a lengthy period of infancy and childhood during which a number of highly important reactions are exercised and possibly organized into biologically effective form.) There is, however, no proof that the generalization may correctly be extended to include all examples of this type of behaviour. The kitten's play with small, moving objects may indeed improve its abilities as a mouser; but there is no factual evidence to prove or disprove the assumption. In some cases youthful practice is demonstrably unnecessary. It is certain, for example, that the frequent sex play of some animals, such as the immature rat, has no demonstrable effect upon the efficiency of adult mating performance. It is important to recognize that the existence of a preparatory function of play can be established only by direct test of each activity in each species.

(c) *Exploration and Experimentation.*—Young animals often peck, scratch, claw, pull and bite at objects in their environment; and such activities are sometimes classified as experimental play. The puppy's destructive attentions to a book or pillow are interpreted as play which serves to acquaint the animal with the properties and potentialities of the object thus investigated. Similarly, certain reactions of the young animal to its companions can be listed under the heading of exploratory or experimental play. An eventually practical outcome of such behaviour is held to lie in its tendencies to promote the development of new modes of conduct and to inhibit biologically dangerous reactions. Although this assumed function of exploratory play is based chiefly upon *a priori* reasoning, there are some instances in which it can be shown to exist. Wolfgang Kohler reports that captive chimpanzees given stout sticks or poles soon devised a crude form of vaulting or jumping, using the pole as a sort of crutch. Originally this response was apparently indulged in as a form of amusement, and was not used as a means of achieving any secondary objective. Although further test and observation would be necessary to establish the point, it seems probable that the pole-vaulting response was a form of play, and the outgrowth of experimentation with the stick. Later, however, when the apes were confronted with the problem of obtaining a banana which was suspended above their reach they quickly turned the vaulting technique to good use, employing it as a means of getting the fruit.

(d) *Social Play.*—Young British warblers are described as engaging in "tilting matches," during which each bird commands a perch and attempts to dislodge other individuals from theirs. African lion cubs play "king of the mountain." When one assumes possession of a high spot of ground or climbs on top of some low object, all others try to force him off and take his place. "Follow the leader" games occur in the repertoire of several mammalian species. Otters have been observed sliding down muddy banks into the water, one after the other in quick succession, and then climbing out to repeat the performance time and again. Young monkeys in the jungle often swing single file through the branches, each copying roughly the actions of the animal ahead of him.

The group play of chimpanzees is highly diversified, and often resembles certain human activities. Kohler's description of "dancing" is illustrative. Several apes start to march in single file around a box or post. Gradually their pace quickens, and they trot, often with emphasis upon one foot so that a primitive kind of rhythm emerges; and as they trot and stamp the animals wag their heads in time with the rhythm. Other kinds of social play occur in this species; and O. L. Tinklepaugh has suggested that this type of behaviour early in life enhances the individual's adaptability and co-operativeness, both of which are essential characteristics of the chimpanzee.

(e) *Play Between Species.*—Although young animals of one species may investigate those of a foreign species, they do not often play together. Exceptions to this generalization sometimes occur when two domesticated animals are reared together. Thus a dog and a goat may engage in mock battles if they have been associated long enough to establish friendly relations, so to speak.

The outstanding type of interspecies play is that which occurs between man and his pets. If we are to accept any of the criteria of play which have been accorded common use, it must be agreed that the dog frequently plays with his master. The dog may enter into mock chases or battles with a man much as he would with another dog. On the other hand he will with equal willingness participate in a learned game such as fetching the ball, or performing tricks without any material reward. It is significant that the animal may initiate the play and in many different ways signalize his desire to stimulate playful relations with the human partner.

Explanations of Play.—Several theories have been formulated in an attempt to elucidate the causes of playful behaviour. None is completely satisfactory although several are partially serviceable.

(a) The *surplus energy theory* holds that play is a safety valve,

providing an outlet for unused vigour. This interpretation has little to recommend it. Energy is not stored up in the organism like water in a reservoir. Animals are either completely rested and ready to react quickly to stimuli from the environment, or they are tired and sluggish in their responses. All types of behaviour occur more promptly and persist longer in the rested individual. The energy expended in play differs in no way from that used in nonplayful pursuits.

(b) A second attempt to explain play is found in the *joie-de-vivre theory* which interprets play as the expression of a general exuberance, an overflowing enthusiasm for life itself. A serious objection to explanations of this type is that they add nothing to our basic understanding of natural phenomena; in actuality they explain nothing. They involve merely the substitution of one word or phrase for another, although the meaning or significance of the new term is no more precise nor illuminating than the old.

(c) The *instinctive theory* of play in animals was championed by Karl Groos, who interpreted all play as responses based upon inherited tendencies or predispositions. However, to label an act as "instinctive" is not to explain it; and although the form which play takes in various animal species is unquestionably influenced by hereditary constitution, the serious student of behaviour is still faced with the responsibility for determining the stimuli which evoke playful responses, identifying the physiological and psychological processes which mediate the behaviour, and describing in objective terms the eventual effects and results.

(d) *Future Theories.*—Although no completely satisfactory explanation for the occurrence of play in animals is yet available, it is possible to predict with reasonable certainty the form which such a theory must assume. In the first place it is obvious that no single hypothesis can be formulated to explain all forms of play in every animal species. The types of activity which have been labelled "play" are so variable in form and complexity that a different interpretation is indicated for each major category. Secondly, it must be recognized that playful behaviour differs from nonplayful pursuits in subtle and often elusive fashion. There is no sharp border line between play and work for animals, or for man. The two types of activity merge insensibly one into the other, and some complex responses may be partly play and partly work. Therefore, any acceptable definition of play must be based upon a list of predominating characteristics which combine to set it off from nonplayful behaviour, and can not be derived from adherence to a single, rigid criterion such as nonutilitarianism, or imperfect, juvenile performance. It is, for example, permissible to state that playful reactions as a class tend to lack the immediate, biologically practical results which normally accompany nonplayful responses; but one can not set up as an inflexible rule the dictum that no activity is play if it achieves a useful end.

Thirdly, play must be explained in purely objective terms. A small start in this direction has been made by workers such as J. B. Cooper, who suggests that the playful execution of certain behaviour patterns is characterized by the absence of the consumatory phase, and by the rapid shift from one element of the pattern to another. Cooper has noted that the play of lions is more prevalent on cool days, and tends to occur most frequently following a major change in the environmental situation (such as release of the animals from an indoor cage, the introduction of new lions into the pride, or the sudden appearance of the keeper). Much more extended analysis along lines such as these will provide the basis for an interpretation of play which is biologically significant and subject to direct test and verification.

It may be pointed out that the play of humans is no more clearly understood than is that of lower forms; and the careful study of animal play offers potentially important results in the increased understanding of similar behaviour in man.

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PLEADING: *see* PRACTICE AND PROCEDURE.

PLEASANTVILLE, a city of Atlantic county, New Jersey, U.S.A., 5 mi. W.N.W. of Atlantic City; served by the Pennsylvania and the Reading railways and by air lines. Pop. (1950) 11,938; (1940) 11,050.

PLEASURE: *see* FEELING, PSYCHOLOGY OF; HEDONISM; ETHICS.

PLEBISCITE, a term borrowed from the French for a vote of all the electors in a country or given area taken on some specific question. The most familiar example for the use of the plebiscite in French history was in 1852, when the coup d'état of 1851 was confirmed and the title of emperor was given to Napoleon III. Its essential characteristic, as distinguished from the referendum (*q.v.*), is this: a plebiscitary vote decides a specific question, *ad hoc* and *pro hac vice.* It is not, as in the case of the referendum, a normal method or procedure of voting applied on a general system to certain classes of legislation. It is sometimes used in England to decide questions of municipal rates or other local questions, and extensively in the dominions and the United States on certain local or state questions. In Europe its use has been almost wholly political and national.

In that sense it is a method of ascertaining the general desire of the inhabitants of a given territory or area. As a means of settling the destination of populations and territories, this method was first used in the French Revolution to defend the wholesale annexations of territory made by the conquering French republic, and subsequently by Napoleon I. It was revived by Napoleon III and applied (successfully for him) in the case of Nice and Savoy, and (successfully for Victor Emmanuel) in the duchies of north Italy during the years 1859–60. The peace conference of 1919 proposed the taking of 17 plebiscites to settle difficult national questions, of which 8 were actually held. Of these the Turkish plebiscite in Transcaucasia was a farce. Others, which decided the fate of Allenstein Marienwerder, of the Burgenland, of Klagenfurt, the economic destiny of Luxembourg, the attribution of the northern and southern zones of Slesvig, and the partition of Upper Silesia, had substantial and important results, which are noted elsewhere under the individual articles.

The Versailles treaty provided for a plebiscite of the Saar district in 1935 to decide the future of the region.

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PLEBS, the "multitude," or unprivileged class, in the early Roman state (from the root *pleo,* seen in Latin *plenus,* fill; *cf.* Gr. πλῆθος). For the origin and history of this order *see* PATRICIANS. Its disqualifications were originally based on descent, but after the political equalization of the two orders these ceased.

PLECOPTERA (Gr. πλέκος plaited, and πτερόν wing) is the order of insects known as stoneflies; by some authors it is termed Perlaria. It is one of the few orders in which the immature stages are aquatic. They are restricted to unpolluted streams and wave-washed, rocky lake margins. The female lays several thousand eggs, discharging them in masses into the water. The nymphs are active and elongate, have long antennae and a pair of long "tails." The larger forms have gills for respiration; others respire through the integument. Most of them feed on microorganisms on and in decaying organic matter, but some groups are predaceous on other aquatic insects and the like. The nymphs may be found in clumps of rotted leaves, masses of debris, or beneath submerged logs and stones, whence the name "stoneflies." When mature, the full grown nymph crawls out of the water and

BY COURTESY OF THE ILLINOIS STATE NATURAL HISTORY SURVEY

ISOPERIA CONFUSA, ONE OF THE TYPICAL STONEFLIES FOUND IN ILLINOIS

Left, adult, length about 0.8 in.; Right, nymph, length about 0.6 in.

attaches itself firmly by its leg claws to a rock or other support in preparation for its last moult. The nymphal skin is then burst along the back and the adult emerges, leaving the empty nymphal skin behind.

The adults are soft bodied and range in size from ¼ to 1½ in. in length. They have long, many-segmented antennae, a pair of "tails" (minute in some forms), and usually two pairs of membranous wings folded flat over the back. A few species have only one pair of wings, and in a few others the wings are mere stubs or entirely aborted. Most of the species are black or sombre-hued, some are leaf green, and others may be marked with yellow, orange or red. The stoneflies are relatively slow fliers but active runners. They are usually found on stones, foliage or tree trunks along the edge of the stream, or hiding in crevices in bridges or bark. Different groups are diurnal, crepuscular, or nocturnal; the latter are attracted to lights. Adult emergence begins in early winter and continues through summer. The adults have weak, biting mouth parts, and feed on algae, pollen and bud exudates. All forms are important elements in stream ecology and are important as fish food. Both adults and nymphs should be collected in 80% ethyl alcohol.

The order contains about 800 species comprising 14 families. The largest fauna is that of the holarctic region; there are about 250 species in North America and over 30 in the British Isles. The Australian and neotropical regions have an extensive fauna, including many primitive forms. A few fossils are known from the Upper Jurassic in Europe and the Lower Permian of Kansas.

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PLECTRUM, a small contrivance, made of metal, wood or some other suitable material, and used as a substitute for the finger in plucking the strings of musical instruments. In ancient times the strings of the lyre were sometimes so plucked, while later the lute was similarly played, as are the mandolin and zither to-day; the same term being applied also to the quills and bristles of the harpsichord and spinet.

PLEDGE or **PAWN,** in law, a "bailment of goods by a debtor to his creditor to be kept till the debt is discharged" (Jones on *Bailments*). The term is also used to denote the property which constitutes the security. Pledge is the *pignus* of Roman law from which most of the modern law on the subject is derived. It differs from hypothecation and from the more usual kind of mortgage in being confined to personal property, and also in that the pledge is in the possession of the pledgee. A mortgage of personal property, in the majority of instances, takes the name and form of a bill of sale (*q.v.*). In the case of a pledge, it is held that a special property passes to the pledgee, sufficient to enable him to maintain an action against a wrongdoer, but the general property, *i.e.,* the property subject to the pledge, remains in the pledgor. As the pledge is for the benefit of both parties, the pledgee is bound to exercise only ordinary care over the pledge. He must, however, insure against loss by fire (35/36 Vict. ch. 93, s.36). The pledgee has the right of selling the pledge if the pledgor makes default in payment at the stipulated time.

The law of Scotland as to pledge generally agrees with that of England, as does also that of the United States. The main difference is that in Scotland and in Louisiana a pledge cannot be sold unless with judicial authority. Chattel mortgages, which differ from pledges in that the owner retains possession of the article, are uniformly required to be recorded in order to be valid against third parties, but except for a few States and aside from the Factors acts, a pledge, for the validity of which possession must be transferred to the pledgee, will be enforcible against third parties without being recorded. (*See* also FACTORS and PAWNBROKING.)

PLEHVE, VIATSCHESLAF KONSTANTINOVICH (1846–1904), Russian statesman, was born of Lithuanian stock in 1846. He was educated at Warsaw and at the university of St. Petersburg (Leningrad) before he entered the department of justice, in which he rose rapidly to be assistant solicitor-general in Warsaw, then solicitor-general in St. Petersburg, and in 1881 director of the state police. As assistant to the minister of the interior he attracted the attention of Alexander III. by the skill he showed in investigating the circumstances of the assassination of Alexander II. He received the title of secretary of state in 1894, became a member of the council of the empire, and in 1902 succeeded Sipiaguine as minister of the interior. Plehve carried out the "russification" of the alien provinces within the Russian Empire, and earned bitter hatred in Poland, in Lithuania and especially in Finland. He despoiled the Armenian Church, and oppressed the Armenians of the Caucasus. He certainly did nothing to discourage pogroms against the Jews, and he was credited with being accessory to the Kishinev massacres. His logical mind and determined support of the autocratic principle gained the tsar's entire confidence. He opposed commercial development on ordinary European lines on the ground that it involved the existence both of a dangerous proletariat and of a prosperous middle class equally inimical to autocracy. He was a determined and successful opponent of Witte's policy. An attempt was made on his life early in 1904, and he was assassinated on July 28 of the same year by a bomb thrown under his carriage as he was on his way to Peterhof to make his report to the tsar; the assassin, Sasonov, was a member of the socialist revolutionary party.

PLEIAD, in Greek literature, the name given (by analogy from PLEIADES) by the Alexandrian critics to seven tragic poets who flourished during the reign of Ptolemy Philadelphus (285–247 B.C.). In French literature, in addition to the Pleiad of Charlemagne, there were two famous groups of the kind. The first, during the reign of Henri III. (1574–89), the chief member of which was Pierre de Ronsard, sought to improve the French language and literature by enthusiastic imitation of the classics; the second, under Louis XIII. (1610–43), consisted of authors who excelled in the composition of Latin verse.

PLEIADES, the constellation so called is in mythology the seven daughters of Atlas and Pleïone, and sisters of the Hyades. Owing to their grief at the death of their sisters or at the sufferings of their father, they were changed into stars. In another account, the Pleiades and their mother met the amorous hunter Orion (*q.v.*) in Boeotia; for five years he pursued them through the woods, until Zeus translated them all—Pleïone and her daughters, Orion and his dog—to the sky. This is one of the few myths really astronomical in origin, for it is based on the relative positions of the constellations in the sky. The names of the sisters are Alcyone, Asterope, Electra, Kelaine, Maia, Merope, and Taygete (Hesiod fr. 275 Rzach); one is always dim or invisible, because she is Electra mourning for Troy, or Merope, who is ashamed of having wedded a mortal, Sisyphus. All the Pleiades became the ancestresses of divine or heroic families. The early winter rising and spring setting of the Pleiades (Lat. *Vergiliae*) are important dates to the farmer.

See H. J. Rose, *Handbook of Greek Mythology* (1928).

The stars are situated in the constellation Taurus. They are supposed to be referred to in the Old Testament (Job ix. o. xxxviii. 31). The brightest star is Alcyone (*η* Tauri), of the 3rd magnitude. This group is physically connected, being distinguished from the background stars by community of proper motion. Photographs show a faint nebulosity filling the whole region; there is little doubt that this is rarefied matter made luminous by stimulation of the radiation of the hot stars comprised in it. The distance of the Pleiades is estimated at 100 parsecs (300 light-years), but is not very certainly known.

Alcyone and the other bright stars are of the hottest type of spectrum (Type B), and give out several hundred times as much light as the sun.

PLEISTOCENE (Gr. *πλεῖστον,* most, and *καινός,* recent), in geology the epoch which succeeded the Pliocene. The Pliocene is now usually considered the last of the Tertiary period and hence the Pleistocene forms the lower subdivision of the Quaternary era. The period saw the arrival of the great Ice age (*see* GLACIAL

EPOCH) and the Pleistocene and Glacial period are sometimes used as if synonymous. The general geology of the period is considered under QUATERNARY.

PLEKHANOV, GEORGY VALENTINOVITCH (N. BELTMAN) (1857–1918), the founder and for many years the chief exponent of Russian philosophic Marxism, was born on Nov. 26, 1857, in the province of Tambov, of an old noble family. His father wished him to enter the army, but while a student he joined the Narodnist (populist) revolutionary movement. In 1876 he led the first great popular demonstration at St. Petersburg (Leningrad) in the Kazansky square. When the majority section of the Narodnists adopted terrorist methods in 1879, Plekhanov seceded, and with Deutsch, Axelrod, Vera Sassulitch and Ignatov, formed the Marxist "Liberation of Labour" group in Geneva (1883). He spent 40 years in exile, chiefly at Geneva, from which town he became the intellectual leader of the Russian Social-Democratic movement, in particular playing a large part in Lenin's early mental development. In the '90s and the early years of the 20th century the two men were closely associated. In Dec. 1900 was founded the S.D. journal *Iskra* (The Spark) of which Plekhanov was joint editor with Lenin, Martov, and others. In the first split of the Russian S.D. Party in 1903 Plekhanov was largely on the side of the Bolsheviks, holding views closely akin to those of Lenin.

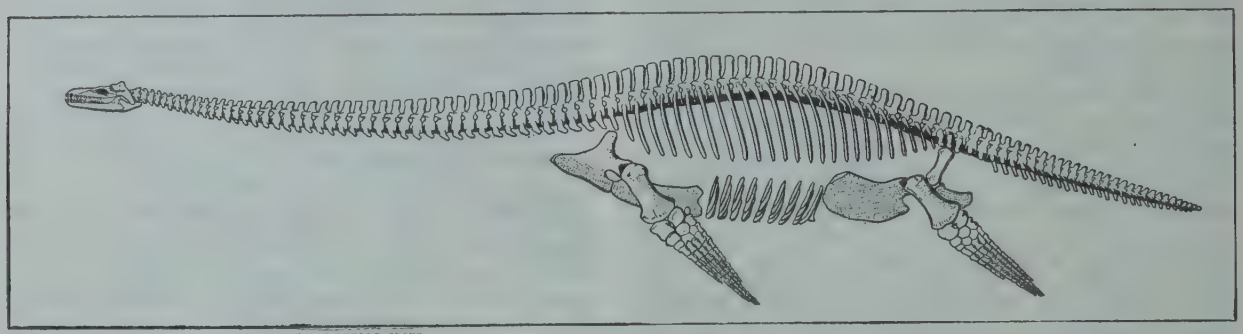
After the resignation of the Mensheviks from editorship of the *Iskra* Plekhanov and Lenin were joint editors, but some months later differences arose between them on the question of collaboration with the Mensheviks, and Lenin resigned. Thenceforth for several years Plekhanov worked with the Menshevik section of the party, but after 1907, while remaining a Menshevik, he took up an attitude on many issues, particularly on the question of participation in the State Duma and also on illegal activities, in agreement with that of the Bolsheviks. At the end of 1910 he again co-operated with the latter in contributing to the Bolshevik *Zviezda* (The Star) but the alliance did not last long, and when the war broke out in 1914 Plekhanov was foremost in advocacy of the principle of "revolutionary defence" of the country against the Bolshevik policy of working for the defeat of the Government. After the March revolution he returned to Russia and was invited to join the Provisional Government. He refused, but actively supported the Government against the Bolsheviks, and remained an opponent of the Bolshevik revolution until his death in Finland on May 30, 1918.

Plekhanov had an enormous influence on the development of the Socialist movement in Russia. The Moscow Marx-Engels Institute has published a complete edition of his works in 26 volumes. His biggest work is available in German: *Beiträge zur Geschichte des Materialismus.*

PLENER, ERNST, FREIHERR VON (1841–1923), Austrian politician, was born on Oct. 18, 1841, at Cheb in Bohemia, the son of the Austrian statesman Ignaz von Plener (1810–1908). From 1888 onwards he was the acknowledged head of the German Liberals in their struggles against the Slav-Conservative majority in the Chamber. Consequently he represented Germanism on the nationalities question, but was not averse to concessions compatible with the maintenance throughout the whole monarchy of the position due to the German Austrians. He sought to compromise the quarrel between Germans and Czechs, and the so-called "points" of 1890, a summary of the bases for a German-Czech understanding, were essentially his work. In the Windischgrätz Coalition Ministry (1893–5), Plener took over the portfolio of Finance. Soon after his retirement from the Finance Ministry, Plener was appointed president of the Supreme Audit Department (*Oberster Rechnungshof*). He entered the Upper House in 1900, and died on May 1, 1923.

Plener wrote a series of economic and political works, among others *Die englische Fabriksgesetzgebung* (1871); *Englische Baugenossenschaften* (1873). He published *Erinnerungen,* 3 vol. (1911–21).

PLESIOSAURUS, technically the name of a genus of extinct reptiles of the group Sauropterygia; it is commonly used to apply to all the later members of that group. The typical plesiosaurs are completely adapted for a marine existence in the open sea. They first appear in the Rhaetic and are last seen in the Upper Cretaceous.



FROM THE "CATALOGUE OF MARINE REPTILES OF THE OXFORD CLAY"

SKELETON OF MURAENOSAURUS, A LONG NECKED PLESIOSAUR, FROM THE OXFORD CLAY OF PETERBOROUGH, ENGLAND

A typical plesiosaur has a small head with a large mouth and slender pointed teeth adapted to the catching of fish. The neck is long, often four times as long as the head. The body is relatively short, as is the tail. All four limbs are converted into paddles, no external trace of the fingers being visible.

From these forms two main evolutionary lines appeared. In one, the animals adopted the habit of living on large prey which they captured by their superior speed; in this line the head grew bigger and the neck shorter until it became no longer than the head. The body is comparatively long, the tail little more than the pointed hinder extremity of the body. The paddles become very large indeed, the hinder pair being bigger than the front ones. There are large members of this line in the European Jurassic, with skulls 5 or 6 ft. long and a body length of 16 ft. or more. The giant of the tribe was *Kronosaurus* of the Cretaceous of Australia, with dimensions nearly twice as great.

The other line consists of animals which fed on small quick-moving prey which they seem to have captured by sudden lateral movements of the head and neck. Its most recent member, *Elasmosaurus,* is found in the Upper Cretaceous of Kansas, England, Queensland and New Zealand. In it the head is about 18 in. in length, the neck with as many as 76 vertebrae may reach a length of 19 ft., and the total length of the animal about 30 ft. The paddles of such an animal were about 3 ft. in length. Some plesiosaurs had the habit of eating pebbles which were kept in the stomach to assist in grinding up food. Although the majority of plesiosaurs were marine, some few are always found in estuaries or fresh-water deposits. *See* REPTILES. (D. M. S. W.; X.)

PLEURISY or PLEURITIS. Strictly speaking, "pleurisy" is a medical term which refers to inflammation of the pleura with or without accumulation of fluid in the pleural cavity; but it is customary to include in the definition certain types of pleurisy with effusion of fluid which are not inflammatory in origin. The pleura is a particularly vulnerable tissue and may be involved in disease processes via the blood stream from either the greater or lesser circulation, via the lymphatics, or by direct extension from the

lung, mediastinum or chest wall.

Dry Pleurisy or Acute Fibrinous Pleuritis.—This may be associated with almost any type of major disease affecting the lung and commonly accompanies the acute pneumonias. The pleura becomes congested and loses its normal glistening appearance, and deposits of fibrin produce roughening of the pleural surfaces. The inflammatory process may subside or may be followed by an outpouring of fluid, producing pleurisy with effusion. Pain localized to the area of pleural involvement is typical of dry pleurisy and is aggravated by coughing or taking a deep breath. Severe pain disappears if the pleural surfaces are separated by the accumulation of fluid.

Wet Pleurisy or Pleurisy with Effusion.—The type of fluid which accumulates in the pleural cavity is determined by the primary disease process producing the effusion. Fluid containing little protein and few blood cells is termed a transudate (hydrothorax), and is not inflammatory in origin. The commonest cause of hydrothorax is heart failure, but pleural transudates may accumulate as the result of a reduced level of plasma proteins or from obstruction to venous and lymphatic channels by tumours. Pleural fluids with higher protein content and more cells are called serous or serofibrinous effusions, and occur in a variety of diseases including tuberculosis, pulmonary infarction, cancer and rheumatic fever. If a pleural effusion becomes grossly purulent, it is termed an empyema.

A pleural effusion is commonly the first sign of pulmonary tuberculosis. The fluid is reabsorbed spontaneously, and the small subpleural tubercle which produced the effusion may not be visible in X-rays following the resolution of the effusion. Tuberculosis initiated clinically by pleuritis is likely to flare up during the subsequent five years if untreated.

A large number of serous pleural effusions remain undiagnosed even after extensive study, and are termed primary or idiopathic effusions. Since early tuberculosis is such a common cause of serous effusion (it is estimated that 40%–60% are tuberculous), it must be assumed that all effusions of unknown cause are tuberculous unless proved otherwise. This means that a patient with a primary pleural effusion should be treated as though he had minimal pulmonary tuberculosis, and should have follow-up chest X-ray examinations for five years. Pleural effusion may be the first sign of cancer of the lung, although it is a late sign and signifies that the cancer is probably inoperable.

Pleuritic Residuals.—Pleuritis usually produces scarring, and the pleural space may be partially or completely obliterated by adhesions. If pleural scarring is extensive the efficiency of the underlying lung as an organ of ventilation is reduced.

Treatment.—Most important is treatment of the underlying disease which produced the effusion. Treatment of the pleurisy is symptomatic. In dry pleurisy the chest may be strapped and analgesics used for the relief of pain. In wet pleurisy fluid may be removed to relieve respiratory distress.

BIBLIOGRAPHY.—E. H. Rubin, *Diseases of the Chest*, p. 546, with bibl. (1947); R. L. Cecil and R. F. Loeb (eds.), *Textbook of Medicine*, p. 881, with bibl. (1951). (R. H. E.)

PLEURONECTIDAE, the family of fishes to which the name "flat fish" is popularly applied. It includes the flounder and plaice (*qq.v.*). (*See* FISHES.)

PLEUROPNEUMONIA (LUNG PLAGUE). A specific contagious disease of bovine animals usually terminating in a characteristic inflammation of the lungs and pleura (lining of the chest cavity), pleuropneumonia is caused by a minute, many-shaped organism so small that it will pass through bacteriological filters. By magnifying at least 1,500 diameters, the organism can be seen as small dots or coccoid bodies, spiral forms, branching and star-shaped figures, from which the name *Asterococcus mycoides* was given to the organism by Pierre Borrel. Although extremely small, it probably should not be classed as a truly ultramicroscopic virus.

In earlier times the disease was prevalent over much of Europe, having been recognized by Claude Bourgelat in 1769 in France and known even earlier in Switzerland and Germany. It spread rapidly because of the traffic in breeding cattle, especially from Holland and Switzerland, and caused such great losses that energetic steps of eradication had to be developed, including slaughter of diseased animals, quarantine and veterinary sanitation measures. It is reported that in Great Britain alone 187,000 cattle died of the disease in one year, 1860.

In the United States, contagious pleuropneumonia first appeared in Brooklyn in 1843, in New Jersey in 1847, in Massachusetts in 1850 and then spread over most of the important cattle-raising states east of the Mississippi, causing the deaths of thousands of animals, particularly in Illinois.

The presence of the disease was such a serious problem that the federal government finally intervened to set up an eradication program to supplement the efforts of the several states; this was a major factor in the establishment of the U.S. bureau of animal industry. The ultimate eradication of contagious pleuropneumonia in 1892 was the bureau's first great accomplishment; it did not appear afterward in the United States.

The disease was also eradicated or greatly reduced in most countries, but still occurred at mid-20th century in parts of Asia, Africa, Australia and the U.S.S.R.

Natural infection usually takes place by contact of diseased animals with susceptible cattle, probably by inhalation of infective material. The incubation period is about two weeks and the symptoms manifested are fever, loss of appetite, dry painful cough, accelerated pulse and respiration and the usual signs of acute pneumonia. Depending on the extent and severity of the infection, the disease may terminate fatally in a few days or run a more chronic course with apparent recovery. However, the disease may become active again because of foci remaining in the affected lung tissues and death often follows.

No effective treatment had been discovered by mid-20th century, although immunization methods had had some success. Materials used for vaccination by inoculation in the tip of the tail include pleural exudate from naturally occurring cases and culture preparations made from the causative organism. However, neither is entirely satisfactory because a small percentage of vaccinates may die and many more lose their tails. The only effective method of dealing with the disease is by eradication, quarantine and other veterinary sanitation measures. Institution of such measures is preceded by a veterinarian's diagnosis through use of the complement-fixation test. A simple slide flocculation test also has been used with success by British workers, particularly in areas where it is not practical to employ the complement-fixation technique.

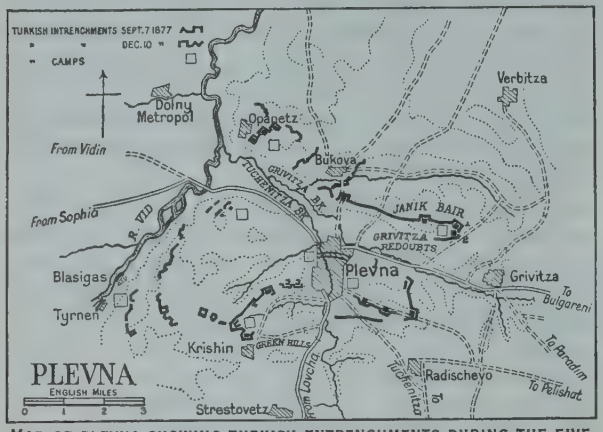
A sidelight of possible public health interest is the recently expressed view of University of Pennsylvania physicians that bovine pleuropneumonia-like organisms may be responsible for some of the obscure human illnesses of respiratory origin seen in the United States. (J. G. HE.)

PLEVNA (Bulgarian *Pleven*), a city in Bulgaria; on the Tutchinitza, and Sofia-Varna railway (opened in 1899). Pop. (1946) 38,997. A branch line, 25 mi. long, connects Plevna with Samovit on the Danube, where a port has been formed. After the events of 1877, it was almost entirely forsaken by the Turks, and most of the mosques have gone to ruin; but, peopled now mainly by Bulgarians, it has quite recovered its prosperity, and has a large commerce in cattle and wine (*see* RUSSO-TURKISH WARS).

Plevna, a small and unknown town without fortifications, became celebrated as the scene of Osman Pasha's exploits. He left Widin on July 13 with a column consisting of some 12,000 men and 54 guns. Hearing that he was too late to relieve Nikopol, he pushed on to Plevna, where there was a small garrison, and on July 19 he took up a position on the bare hills to the north and east. He was none too soon. General Schilder-Schuldner, commanding the 5th division of the 9th corps, which had just captured Nikopol, had been ordered to occupy Plevna, and his guns were already in action. On July 20, having made no preliminary reconnaissance, the Russian commander advanced his infantry in four separate columns. On the north flank they pressed into Bukova, and also succeeded in driving back the Turkish right wing; but in both cases Turkish counterattacks pressed back the Russians, with the result that by noon they were in full retreat, having lost 2,800 men out of a total of 8,000. The Turks lost 2,000. Osman at once drew up plans for the fortification of the position, and the

troops were employed night and day constructing redoubts and entrenchments. In order to secure his line of communications, he occupied Lovcha (Lovatz). The Plevna garrison had now been reinforced to 20,000. Trenches were 4 ft. deep and the redoubts had a command of 10 to 16 ft., with parapets about 14 ft. thick. There were in some cases two lines of trench to the front, thus giving three tiers of fire.

Second Battle of Plevna.—In accordance with orders from the Russian headquarters at Tirnova, a fresh attack was made by



MAP OF PLEVNA SHOWING TURKISH ENTRENCHMENTS DURING THE FIVE-MONTHS DEFENCE OF THE TOWN BY OSMAN PASHA AGAINST THE RUSSIANS IN 1877

Krüdener on July 30. He had been reinforced and his force numbered nearly 40,000 with 176 guns. After a preliminary cannonade the infantry advanced at 3 P.M., as before in widely spread columns. The columns attacking from the north and north-east were repulsed with heavy loss. Shakovskoi temporarily occupied two redoubts, but a counter-stroke by the Turkish reserves forced him back. The Russians retreated, their losses amounting to 7,300, while the Turkish losses exceeded 2,000. The victory was decisive, but Osman again failed to pursue. His troops were elated by success, the *moral* of the enemy severely shaken, the undefended Russian bridge over the Danubé was within 40 m. of him, but he lost his opportunity, and contented himself with strengthening his defensive works. It is said that he was tied down to Plevna by orders from Constantinople.

The Russians now concentrated all their available forces against Plevna and called in the aid of the Rumanians. By the end of August they had assembled a force of 74,000 infantry, 10,000 cavalry and 440 guns. On August 30 Osman moved out of Plevna, and on the 31st attacked the Russians about Pelishat. He returned to Plevna the same evening. The Turks lost 1,300 and the Russians 1,000 men. The Russians determined to occupy Lovcha, and so cut Osman's communications before again attacking Plevna. After three days' fighting this was accomplished by Skobelev, acting under Imeretinski, with a force of 20,000 men, on September 3. Osman moved out to the relief of the garrison that day with a strong column, but, finding he was too late, returned to Plevna on the 6th. The survivors from Lovcha were re-formed into 3 battalions, including which Osman had been reinforced to a strength of over 30,000, with 72 guns.

Third Battle of Plevna.—The Russians moved to their preliminary positions on the night of September 6–7. Their plan was to attack the north-east, south-east and south fronts simultaneously. An artillery bombardment began at 6 A.M. on September 7, and was carried on till 3 P.M. on the 11th, when the infantry advanced. The Rumanians took one Grivitza redoubt; Skobelev occupied two redoubts on the south front, but the centre attack on the Radischevo front failed. On the 12th the Turks recaptured the southern redoubts, the Rumanians remained in possession of the Grivitza redoubt, but the Russian losses already amounted to 18,000 and they withdrew, and entrenched themselves on a line Verbitza-Radischevo, with cavalry on either flank to the Vid. The Turkish losses totalled 5,000, of which only a few hundred were caused by the artillery fire of the first few days. There was no question of pursuit. The Russians were greatly superior in numbers and the Turks were completely exhausted.

Investment and Fall of Plevna.—This was the last open-force attack on Osman's lines. General Todleben, the defender of Sevastopol, was now entrusted with the conduct of the siege, and he determined to complete the investment, which was accomplished by October 24, Osman's request to retire from Plevna having been refused by Constantinople. Supplies eventually gave out and a sortie on the night of Dec. 9–10 failed, with the result that he and his army capitulated.

Plevna is a striking example of the futility of the purely passive defence, which is doomed to failure however tenaciously carried out. Osman Pasha repelled three Russian attacks and practically held the whole Russian army. It remained for the other Turkish forces in the field to take the offensive and by a vigorous counter-stroke to reap the fruits of his successes. Victories which are not followed up are useless. (J. H. V. C.)

See W. V. Herbert, *The Defence of Plevna, 1877* (London, 1895); F. V. Greene, *The Russian Army and its Campaign in Turkey* (London, 1880); General Kuropatkin (Ger. trans. by Krahmer), *Kritische Rückblicke auf den russisch-türkischen Krieg;* Mouzaffer Pacha and Talaat Bey, *Défense de Plevna;* Krahmer's German translation of the Russian Official History; General H. Langlois, *Lessons of Two Recent Wars* (Eng. trans., War Office, 1910); Th. von Trotha, *Kampf um Plewna* (Berlin, 1878); Vacaresco (Ger. trans.), *Rumäniens Antheil am Kriege, 1877–1878* (Leipzig, 1888).

PLEYEL, IGNAZ JOSEPH (1757–1831), Austrian musician, was born at Ruppersthal, near Vienna, on June 1, 1757, the 24th son of a poor village schoolmaster. He studied the pianoforte under Van Hal (known in England as Vanhall), and in 1772 learned composition from Haydn, who became his dearest friend. He was appointed temporary *maître de chapelle* at Strasbourg in 1783, receiving a permanent appointment to the office in 1789. In 1791 he paid a successful visit to London. He narrowly escaped the guillotine on returning to Strasbourg, and was only saved by the existence of a cantata which he had written, and in which the inspiration could fairly be claimed to be on the side of liberty; so that he was permitted to remain until 1795, when he migrated to Paris. Here he opened a large music shop, published the first complete edition of Haydn's quartets, and founded, in 1807, the pianoforte manufactory which still bears his name. The latter years of his life were spent in agricultural pursuits. He died on Nov. 14, 1831, in Paris.

PLIEKSANS, JAN (1865–1929), Latvian poet and dramatist, was born on Sept. 12, 1865, at Tadenava in the district of Illukst, Courland. He adopted the pen name of József Rainis. He was educated at the Riga gymnasium, and from 1884 to 1888 studied law at St. Petersburg (Leningrad). He then practised as a barrister at Mitau, Courland. From 1891 to 1895 he edited in Riga a democratic Latvian paper, *Dienas Lapa* (Daily Paper). He was arrested by the Russian Government on political grounds and remained in exile, first at Pskov and then at Viatka, until 1903. He may be considered the chief exponent of democracy in Latvian poetry. He translated plays from Shakespeare, Goethe and Schiller. His principal historical tragedies are *Uguns un nakts* (*Fire and night*), *Put vejini* (*Blow breeze*) and *Daugava* (*The Dvina*). *The Sons of Jacob* has been translated into English, and was produced on May 22, 1925, at the New Scala theatre, London, by the International Theatre Society. For several years he was director of the Latvian National Theatre, and in 1920 became member of the Latvian Saeima (parliament).

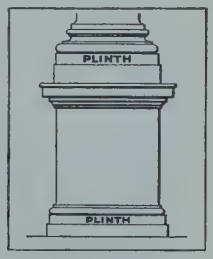
PLIMER, ANDREW (*c.* 1763–1837), English miniature painter, was the son of a clock-maker at Wellington. With his brother Nathaniel (1757–*c.* 1822) he joined a party of gipsies and wandered about with them, eventually reaching London, where in 1781 he was engaged by Mrs. Cosway as studio boy. Cosway sent him to a friend to learn drawing, and then received him into his own studio. In 1785 he set up for himself in Great Maddox Street. He exhibited many times in the Royal Academy, resided for a while in Exeter and travelled a good deal through England. He died at Brighton in 1837 and was buried at Hove. His miniatures are of great brilliance and are in considerable

demand among collectors. They are to be distinguished by the peculiar wiry-treatment of the hair and by the large full expressive eyes which Plimer invariably gave to his female sitters, eyes resembling those of his own wife and daughters. *See* G. C. Williamson, *Andrew and Nathaniel Plimer* (1903). (G. C. W.)

PLIMSOLL, SAMUEL (1824–1898), British politician and social reformer, was born at Bristol on Feb. 10, 1824. His efforts for reform were directed more especially against "coffinships" —unseaworthy and overloaded vessels, often heavily insured, in which unscrupulous owners risked the lives of their crews. Plimsoll entered parliament as Liberal member for Derby in 1868, and failing to pass a bill dealing with the subject, he published a work entitled *Our Seamen* (1872), which made a great impression throughout the country. On Plimsoll's motion in 1873, a royal commission was appointed, and in 1875 a government bill was introduced, which Plimsoll, though regarding it as inadequate, resolved to accept. On July 22, when Disraeli, announced that the bill would be dropped, Plimsoll lost his self-control, applied the term "villains" to members of the house, and shook his fist in the Speaker's face.

Eventually Plimsoll apologised, but the country shared his view that the bill had been stifled by the pressure of the shipowners, and the popular agitation forced the government to pass a bill, which in the following year was amended into the Merchant Shipping Act. This gave stringent powers of inspection to the Board of Trade. The mark that indicates the limit to which a ship may be loaded is generally known as Plimsoll's mark. Plimsoll was re-elected for Derby at the general election of 1880, but gave up his seat to Sir W. Harcourt, in the belief that the latter, as home secretary, could advance the sailors' interests more effectively than any private member. Later on Plimsoll was estranged from the Liberal leaders by what he regarded as their breach of faith in neglecting the question of shipping reform. He became president of the Sailors' and Firemen's Union, and raised a further agitation about the horrors of the cattle-ships. Later he visited the United States with the object, in which he did good service, of securing the adoption of a less bitter tone towards England in the historical textbooks used in American schools. He died at Folkestone on June 3, 1898.

PLINTH, in architecture, the lowest member of a classic base, also any rectangular block on which a statue or vase is placed. In a pedestal or podium the plinth is the lowest member, and usually consists of a projecting, continuous block above which are the base mouldings. (*See* ORDER.)



PLINY THE ELDER (GAIUS PLINIUS SECUNDUS) (*c.* A.D. 23–79), Roman polymath, was born at Novum Comum (Como), in Transpadane Gaul, on which ground he claims Catullus, a native of Verona in the same region, as a fellow countryman (*N.H. praef.* 1., *Catullum conterraneum meum*). The date of his birth is fixed as A.D. 23 or 24 (Plin. *Epp. III.* 5,7). He must have come to Rome at an early age (*N.H. XXXVII.* 81). He practised for some time as an advocate (Plin. *Epp. III.* 5, 7, *aliquamdiu causas actitasse*). He saw military service in various parts of the world, Germany, Spain, Gaul. Under Vespasian, with whom he was on the most intimate terms (Plin. *Epp. III.*, 5, 9), he served as *procurator* in Gallia Narbonensis (A.D. 70) and Hispania Tarraconensis (A.D. 73). At some time—the date is not known—he was in Africa (*N.H. VII.* 36. "I myself saw in Africa," etc., *cf. XVII.*, 41, *XXV.* 123). Finally Vespasian appointed him praefect of the Roman fleet at Misenum, in Campania, which Augustus had made one of the principal Roman naval stations (Sueton. *Aug.* 49). He was stationed at Misenum when on Aug. 24, A.D. 79 there occurred the great eruption of Vesuvius which overwhelmed Herculaneum and Pompeii and incidentally cost Pliny his life. The circumstances are vividly told in a letter of the younger Pliny to the historian Tacitus (Plin. *Epp. VI.* 16). Surveying the eruption from a ship, Pliny took refuge with his friend Pompeianus at Stabiae (Castellamare) on the southern shore of the Bay of Naples. There, in order to allay the fears of his friends, he dined, as his nephew says "cheerfully, or what was equally splendid, with a pretence of cheerfulness," and then retired to rest. In the middle of the night, when stones and ashes were already falling about the house and the house itself was rocking alarmingly, he was roused by his friends and the party determined to seek safety in the open, binding pillows about their heads as a protection against falling debris. "Now it was day elsewhere," to use his nephew's words, "but there night darker and denser than any night, alleviated a little by numerous torches and lights of various sorts. It was decided to go out upon the shore and see at close quarters whether the sea now offered any prospect of safety; it still continued wild and adverse. There Pliny lay down upon a cast-off linen cloth, and once and again he asked for cold water, which he drank. Then flames and a smell of sulphur announcing the approach of flames, caused the others to take to flight and roused him. Supported by two slaves he got upon his feet, but immediately collapsed, his breathing, I gather, being obstructed by the thickening vapour which closed up his throat—naturally weak and narrow and frequently inflamed. When day returned—the third (in English reckoning the second, *i.e.*, Aug. 26) after the last day (Aug. 24) that he had seen—his body was found intact and uninjured, covered as he had been dressed. The appearance of the body suggested one sleeping rather than dead."

A list of Pliny's writings is given in a letter by his nephew, (Plin. *Epp. III.* 5) as follows: 1. *De iaculatione equestri* (On throwing the javelin from horse-back), "written while he was serving as commander of a cavalry regiment with equal ability and care." 2. *De vita Pomponi Secundi duo* (Life of Pomponius Secundus, in 2 books), "the discharge, as it were, of a debt due to the memory of a friend who had entertained a singular affection for him." This Pomponius, who is described by Tacitus (*Ann. V.* 8) as a man "of refined character and conspicuous ability" was a tragic poet who had also a military career of some distinction, *cf.* Plin. *N.H. XIV.* 56. 3. *Bellorum Germaniae viginti* (German Wars, in 20 books), "in which he brought together all the wars waged between us and Germany. He began the work while he was serving in Germany, being admonished by a dream. The ghost of Drusus Nero (stepson of Augustus who died in Germany in 9 B.C.) who, having carried his conquest of Germany to the widest extent, died there, stood by him as he slept and commended to him his memory and entreated him to vindicate him from the injustice of oblivion." This work is cited by Tacitus, *Ann. I.* 69; Sueton. *Calig.* 8 and *Vita Plinii,* and was probably used by Tacitus in his *Germania.* 4. *Studiosi tres* (The Student, in 3 books) "in which he instructs and perfects the orator from the cradle up" (*cf.* Aul. Gell. *IX.* 16. *Plinius Secundus . . . libros reliquit quos studiosorum inscripsit,* Quintil *III.* 1.21). 5. *Dubii sermonis octo* (Dubious Language, in 8 books) "written in the last years of the reign of Nero when slavery had rendered dangerous every study of a free and elevated character," *cf.* Plin. *N.H.* praef. 22. Fragments of the treatise were edited by Beck, Leipzig 1894. 6. *A fine Aufidi Bassi triginta unus* (Continuation of the History of Aufidius Bassus, in 31 books). The History of Bassus seems to have ended with the reign of Claudius (*cf.* Quintil *X.* 1. 103, Tac. *Dial* 23, Seneca Epp. 30), and Pliny continued the story down to his own times. *Cf. N.H.* praef. 20. 7. *Historiae Naturalis* 37 (Natural History in 37 books). This work alone is extant (for fragments of Pliny's lost works cf. *Historicorum Romanorum Reliquiae,* coll. H. Peter, 2,109 ff.).

Pliny, the Younger, has given a description of the uncle's studious habits. He would call upon the Emperor Vespasian before daybreak and then after performing his official duties, return home and devote what time remained to study. After a light luncheon, if it were summer and he had leisure, he would lie in the sun while a book was read, annotated and extracts made: he never read a book without making extracts, holding that no book was so bad as not to contain something good. Next he had a cold bath, a snack, and a short siesta, after which, "as if it were another day," he studied till dinner-time. During dinner a book was read and notes made. He rose from the dinner

table in summer before night-fall, in winter within the first hour of night. Thus at Rome; but in vacations no time was exempt from study, save bath-time, nay, even then, he had something read to him or he dictated something, while he dressed. When travelling he was accompanied by a shorthand writer armed with book and notebook and in winter provided with gloves. To procure time for study he generally drove even in Rome and his nephew tells how he was once reproved by him for wasting valuable time in walking. When he died he bequeathed to his nephew 160 volumes of annotated selections (*electorum commentarios*) "written on both sides and in the minutest hand," for which, when he was procurator in Spain (A.D. 73) and when the number of volumes was rather less, he had declined an offer from Largius Licinus of 400,000 sesterces.

The *Natural History*, which was dedicated to Titus, son of Vespasian and his successor as emperor, and of which the first ten books were probably published in A.D. 77, is, as we have seen, in 37 books. Bk. I. has a general preface and contains a table of contents of the other books, to each being appended a list of the authors consulted, the order of enumeration corresponding to the order in which they are utilised. These lists contain the names of 146 Latin and 327 foreign authors. Bk. II. is devoted to a mathematico-physical description of the world and deals with the heavenly bodies—sun, moon, planets, fixed stars; various meteorological phenomena; the succession of the seasons, the earth's shape and surface phenomena; seas, rivers, springs, and the like. The subject matter of this book affords Pliny an opportunity, of which he readily avails himself, to expound his own philosophic creed, which is a modified Stoicism. His view of nature is pantheistic (*N.H.* II. 1). Bks. III.–VI. are devoted to geography and ethnography. This is unscientific and uncritical but extremely valuable from the incidental facts which it presents. There is an interesting mention of a map of Armenia (*N.H.* VI. 40).

Books VII.–XI. are occupied with zoology and are the most generally interesting section. The seventh book deals with man and is occupied less with the normal than with the marvellous and portentous, which the scientific creed of the author and his belief in the infinite power of *ingeniosa natura* enabled him to accept or at least not forthwith to reject. Thus we have tales such as would have charmed the ear of Desdemona—of men whose feet were turned the wrong way, of the Mouthless Men (*Astomi*) who subsisted upon the mere fragrance of flower and fruit, of the Umbrella-foots (*Sciapodae*) who used their extensive feet by way of parasol to protect them from the sun; monstrous births; precocity or exceptional development of physical strength or speed, of sight or hearing, of mental powers; of men who were unconscionably long of dying. Incidently (*c.* 55) he declares his disbelief in immortality. The eighth book treats of terrestrial animals other than man. Here again, amid much that is interesting in detail, there is an unfortunate absence of scientific arrangement and an excessive proneness to accept the marvellous of which he was so unconscious that he expresses surprise at the credulity of the Greeks (*N.H.* VIII. c. 22 *mirum est quo procedat Graeca credulitas*). Hence side by side with sound science, mostly taken from Aristotle and, so far as concerns Africa, from Iuba, we have a host of imaginary animals—winged horses, unicorns, and the like monstrosities. Book IX. deals with aquatic animals and scientifically is the soundest of all the zoological books, which is no doubt due to the fact that his information is mainly derived from the *History of Animals* of Aristotle, who treats of aquatic animals with unusual fullness. The marvellous in this book is chiefly represented by his belief in Nereids and Tritons and the usual stories of the human sympathies of the dolphin. The tenth book treats of birds, commencing, according to Pliny's practice of beginning with the largest, with the ostrich. Such classifications as he makes of birds is of an empirical kind and based on very superficial observations. The first part of the eleventh book is occupied with insects—the bee being treated with some fullness—and the latter part with what may be called comparative anatomy. Books XII.–XIX. deal, generally speaking, with botany, including forestry and agriculture, the subject of Book XVIII., which is one of the most interesting in this section. Books XX.–XXVII. treat of medical botany or the medicines derived from plants. Books XXVIII.–XXXII. deal with other than botanical *materia medica, i.e.*, of medicines derived from the bodies of man and other land animals (XXXII.). The remaining books are occupied with what may be described roughly as mineralogy, *i.e.*, with metals and metallic products, the precious metals, gold and silver, being discussed in bk. XXXIII., bronze and bronze statuary in bk. XXXIV., painting in bk. XXXV., stone as used in building and sculpture in bk. XXXVI., gems and precious stones in bk. XXXVII.

The style of the *Natural History* gives an impression at once of affectation and of slovenliness which may in some degree be attributable to the condition of the text. On the *Natural History* was based the *Collectanea rerum memorabilium* of Julius Colinus (3rd cent. A.D.) and on Bks. XX.–XXXII. the *Medicina Plinii*, a compilation of the 4th century.

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PLINY THE YOUNGER (GAIUS PLINIUS CAECILIUS SECUNDUS) (A.D. 61 or 62–*c.* 113), Latin prose author, was born at Novum Comum (Como) in Cisalpine Gaul. The second son of L. Caecilius Cilo and Plinia, sister of the elder Pliny, he bore the name P. Caecilius Secundus until the death of his uncle (A.D. 79), who by his will made him his adopted son, when he assumed the name C. Plinius Caecilius Secundus. He was then in his 18th year (*Epp.* VI. 20. 5). Educated in rhetoric under Quintilian (*Epp.* II. 14. 9, VI. 6. 3), he made his debut as an advocate at the age of 18 (*Epp.* V. 8. 8).

Pliny was fortunate in having as guardian—doubtless under his father's will (*Epp.* II. 1. 8)—L. Verginius Rufus (A.D. 14–97), who had three times declined to become emperor (in Nero's lifetime, Dio 63. 25, after Nero's death, Plut. *Galb.* 10. Dio 64. 4, after the death of Otho, Plut. *Oth.* 18). He thus commenced his public career under the most favourable auspices. He became a *quaestor* in 89 and in 91 a tribune of the *plebs*, withdrawing during his year of office from practice at the bar (*Epp.* i. 23, vii. 16. 2, *Paneg.* 95). In 93 he became *praetor* (*Epp.* III. 11. 2; VII. 11. 4; 16. 2, Tac. *Agric.* 6, 45; Juv. x. 36) and during his year of office was one of the counsel for the impeachment of Baebius Massa, procurator of Hispania Baetica (*Epp.* III. 4, VI. 29, VII. 33). In 94 or 95 he was appointed *praefectus aerarii militaris*. Under Nerva in 98 he became *praefectus aerarii Saturni* (*i.e.*, commissioner of the public treasury in the temple of Saturn). In September 100 he became consul, holding office for two months. His oration of thanks to Trajan for his nomination (*Epp.* III. 13. 1; 18. 1) is what is called in the mss. *Panegyricus Traiano dictus*. After acting as counsel for the defence of two ex-governors of Bithynia—Iulius Bassus and Varenus Rufus—he was himself appointed by Trajan, *circ.* 111 A.D., governor of that province. Whether he died in that office is not known, but the probable date of his death is 113, since in the Comum inscription Trajan is mentioned without the titles, conferred in 114, of *Optimus* and *Parthicus*. The inscription referred to was inscribed on a marble slab in the wall of the baths (thermae) presented by Pliny to Comum and commemorated that and other benefactions, including a library. The stone was removed to Milan and broken into six pieces. Four of these were built into a tomb in the church of St. Ambrose, and from the only one of these now known Mommsen, with the aid of other records, restored the inscription.

The extant works of Pliny are the *Panegyric on Trajan* already referred to (cf. *Epp.* III. 18), which is of some historical importance, the *Letters* in nine books, and a tenth book comprising his *Correspondence with Trajan*. Mommsen (*Zur Lebensgeschichte des jüngeren Plinius*, in *Hermes* 3, 1868), suggests as

dates: Bk. I., A.D. 97; II., early in 100; III., 101 or 102; IV., early in 105; V., 106; VI., 106 or 107; VII., 107; VIII., 109; IX., perhaps at same time as VIII.; and *Correspondence with Trajan*, 111–113. Merrill has modified Mommsen's theory by the suggestion that the *Letters* were published in groups: I.–II. in 97 or 98, III.–VI. in 106, VII.–IX. in 108 or 109.

The interest attaching to letters selected and edited for publication, like those of Pliny, is wholly different from that of such a frank and unguarded correspondence as the letters of Cicero. There is in Pliny always a suggestion of pose, of self-consciousness and self-complacency. But the *Letters* are admirable examples of polished and pointed Latinity, while the range of subject and the quality of the persons to whom some of them are addressed render them of singular interest and attraction. As an example of his manner may be taken the letter (I. 21) which he writes on hearing of the death of the poet Martial, who had some time before retired from Rome to his native Bilbilis: "I hear that Valerius Martialis has gone, and I am sorry. He was a man able, acute, and keen: one in whose writing there was wit and pungency, yet not less candour. When he was leaving Rome I provided his travelling expenses, a tribute to friendship, a tribute also to the lines which he wrote about me. It was an old custom to reward with honours or money those who had written the praises of individuals or of cities: in our times, like other fair and excellent things, this also among the first has become obsolete: for since we ceased to do things worthy of praise, praise itself we account foolishness. You ask what are the lines for which I showed my gratitude? I would have referred you to the book itself [Martial, X., 19], were it not that I remember certain of them. He addresses the Muse, bids her seek my house on the Esquiline, approach it reverently:

> But beware nor in season unpropitious,
> Tipsy reveller, knock upon the door of
> Him who dedicates all his days to Pallas,
> While he cons for the hearing of the Hundred
> What posterity and the after ages
> May compare to the writings of Arpinum:
> Safer go when the lamps of eve are lighted:
> Thine the hour when the ruddy wine is flowing,
> On locks perfume-bedewed the roses glowing—
> Then stern Catos themselves might read my verses.

Did not he who wrote thus of me deserve that I should both speed him then, as I did, in friendliest fashion, and mourn him now, which I do, as a dear friend departed? For he gave me the best that he had to give and would have given me more had be been able. Yet what greater gift can be given to any man than glory and praise and immortality? But his writings will not be immortal? Perhaps not: but he wrote them as if they would be." Other letters of special interest are VI. 16, one of several addressed to the historian Tacitus which gives a vivid account of the death of the elder Pliny (*q.v.* for citations from the letter) through the eruption of Vesuvius; VI. 20, also to Tacitus, narrating the experiences of Pliny and his mother; those (I. 18, III. 8, V. 10, IX. 34) written to Suetonius, the biographer of the twelve Caesars; II. 17 which gives a description of Pliny's Laurentine villa; VII. 27 which recounts a couple of ghost stories.

The *Correspondence with Trajan* which consists, apart from the first 15 letters, wholly of letters written during Pliny's governorship of Bithynia, contains much that is of value regarding provincial administration under the empire. But the interest of the modern reader centres chiefly in the two letters (96 and 97) relating to the Christians. In the first Pliny writes to the emperor:

> Sire, It is my custom to refer to you all matters about which I am doubtful: for who is better able to direct my hesitation or instruct my ignorance? At trials of Christians I have never been present and I am therefore ignorant of the usual practice in regard to the matter and the limits of punishment or inquiry. I have had also no little difficulty as to whether some distinction of age should be made, or if persons of the most tender age stand on the same footing as the more adult; whether the penitent is to be pardoned or if a person who has once been a Christian shall have no benefit of ceasing to be one. Whether the mere name of Christian, apart from crime, is punishable, or only trime coupled with the name. Meanwhile in the case of those reported to me as Christians I have followed this procedure. I asked themselves whether they were Christians. If they admitted it, I put the question a second time and a third, with threats of punishment. If they persisted in their confession, I ordered them to be led to execution; for I had no doubt that whatever the nature of that which they confessed, in any case their pertinacity and inflexible obstinacy deserved to be punished. There were others of a similar delusion whom, as they were Roman citizens, I noted for remission to Rome.
>
> Presently the mere handling of the matter produced the usual result of spreading the crime, and more varieties occurred. There was published an anonymous pamphlet containing many names. Those who denied that they were Christians or ever had been, when, after me, they invoked the gods and worshipped with incense and wine your statue which I had ordered to be brought for that purpose along with the images of the gods, and, further, reviled Christ—things which it is said that no real Christian will do under any compulsion—I considered should be dismissed. Others who were named by the informer admitted that they were Christians and presently denied it, admitting indeed that they had been, but saying that they had ceased to be, some several years before, some even twenty. All these likewise did homage to your statue and to the images of the gods and reviled Christ. They affirmed moreover that the sum of their crime or error was that they had been wont to meet together on a fixed day before day-break and to repeat among themselves in turn a hymn to Christ as to a god and to bind themselves by an oath (*sacramentum*), not for some wickedness but not to commit theft, not to commit robbery, not to commit adultery, not to break their word, not to deny a deposit when demanded; these things duly done, it had been their custom to disperse and to meet again to take food—of an ordinary and harmless kind. Even this they had ceased to do after my edict by which, in accordance with your instructions, I had forbidden the existence of societies (*hetaeriae*). For these reasons I deemed it all the more necessary to find out the truth by the examination—even with torture—of two maids who were called deaconesses (ministrae=διακόνοι). I found nothing but a perverse and extravagant superstition.
>
> I have therefore adjourned the inquiry and have had recourse to consulting you. For the matter seemed to me one deserving a consultation, especially in view of the number of those imperilled. For many persons of every age, of every rank, of both sexes even, are daily involved and will be, since not in the cities only, but in villages and country districts as well, has spread the contagion of that superstition—which it seems possible to check and correct. At any rate it is certain that temples which were already almost deserted have begun to be frequented; the customary religious rites, long intermitted, are being restored; and fodder for sacrificial victims—for which hitherto it was rare to find a purchaser—now finds a market. Whence it is easy to infer what a mass of men might be reformed, if penitence were recognized.

The reply of the emperor briefly approves of the procedure adopted by Pliny:

> No formula capable of universal application can be laid down. The Christians are not to be sought out; if reported and convicted, they are to be punished, with this reservation that any person who denies that he is a Christian and confirms his testimony by overt act, that is, by worshipping our gods, however suspect he may have been in the past, shall obtain pardon by penitence. Anonymous publications ought to have no place in a criminal charge. It is a thing of the worst example and unworthy of our age (*et pessimi exempli nec nostri saeculi est*).

The full discussion of the questions raised by the correspondence on the matter of the Christians belongs to the province of Church history, but no one can fail to be interested in the account which Pliny gives of the practice of the early Christians: the meeting on a fixed day before day-break (if the "fixed day" means Sunday, the early hour points to a desire for secrecy perhaps rather than to the rest of the day being occupied with other avocations); the singing or reciting of a hymn or psalm of an antiphonal character (*rf.* O.T. Psalm lxxxvii. 7); the recital of the ten commandments; the love feast (ἀγάπη) with its innocuous elements; the existence of women office-bearers or deaconesses.

When a person selects for publication from his private letters, or when he writes a private letter with an eye to its eventual publication, he is necessarily confronted by a dilemma. The self-revelation, the candour of motive, the frankness of prejudice or predilection, which are not merely appropriate to the private letters but are its chief charm, are incompatible with the reserve which is proper to a public document, and while suppression and excision inevitably produce an air of unreality, unreserved publication is almost certain to expose the writer to a charge of priggishness or self-conceit. Those who care to attack Pliny on this ground

will find a store of arrows ready-winged for their satire in his letters, even without mistranslating or misunderstanding his words (e.g., *"Maxime imitabilis"* used quite innocently of Tacitus in VII, 20).

It is a kinder and more pleasing occupation to recognize the amiability and culture of the character which the *Letters* everywhere reveal and, what at least no competent judge will seek to controvert, the many admirable qualities—conciseness combined with lucidity, precision united with the picturesque—of the style in which they are written.

It need only be added that though Pliny on occasion courted the Muses (*Epp.* IV, 27, *Ego interdum versibus ludo, cf.* Mart. X, 19, *Non Musis vacat aut suis vacaret*) and wrote a Greek tragedy at the age of 14 (*Epp.* VII, 4), the specimens of his verses which he quotes (*Epp.* VII, 4 and 9) do not suggest that his talent lay in that direction.

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PLIOCENE (πλεῖον, more, and καινός, recent) is the geological epoch succeeding the Miocene and just preceding the great glacial epoch (Pleistocene) and the rise of man. The name was introduced by Sir Charles Lyell (in 1830, published in 1833) for the youngest of his three divisions of the Tertiary period of time. He placed in the Pliocene the Tertiary beds at Tuscany, those at the sub-Apennine hills in Italy and the beds of English crag. Because a more nearly complete succession of contemporaneous formations was subsequently discovered in America and elsewhere, the problem of Pliocene boundaries became complex; the correlation table is a tentative summary based on time-tested evidences.

Physical Conditions.—The Pliocene was initiated by wide emergence of land, accompanied by its breaking by orogenies into a more diversified topography and climate than in the Miocene. A connection of North and South America was finally established. North America and Europe continued to be connected in the north throughout the Tertiary and early Pleistocene.

In the old world the emergence was followed by a transgression of the great Mediterranean sea (Tethys) over the lowlands of southern Europe, causing equable climate with an average 18°–21° F. annual temperature. But in the medial Pliocene this sea retreated again and land acquired its present borders and its climate became more nearly continental.

The Sarmatian sea, that stretched from the mid-Danubian region to the Aral sea, contracted in Pliocene time and was divided into numerous basins. At the end of Miocene time the northern and southern parts of the Caucasus were united and became the Asiatic peninsula, separated from the southern Russian plain by a strait. Land connection occurred there in Cimmerian time, but at the end of the Pliocene a new transgression connected the Black and Caspian seas; and at the end of Tertiary time they became separated again. Crimea was connected with Anatolia, making the northern peninsula of Pontian (Asia Minor) a land mass, from the early Miocene till the end of Cimmerian time.

In England the London basin was occupied by a large bay of the North sea; but late in Pliocene time the sea became contracted, halting a little longer at parts of East Anglia. In California the sea withdrew at the close of the Miocene but returned again, spreading especially in middle Pliocene. At the close of the Pliocene many basins became isolated and freshened, as the climate gradually grew cooler.

The Pliocene was terminated by widespread withdrawal of the sea because of local ocean floor sinking that accompanied continental uplift and mountain rising. Sufficiently large areas, including ice-covered mountain peaks, had come so close to the snow line that ice spread over them, thus starting Pleistocene glaciation of the earth.

Marine Life.—Molluscs and other invertebrates of the sea were mostly the same as recent, but provincialism is noticeable in some marine faunas such as those of California and the Black sea area. Many aberrant and highly specialized porpoises lived in Pliocene time; but gradually the modernized dolphins, which have changed but little since the end of the Miocene, crowded the ancient rivals from the seas. Modernized types of whales made their appearance at the close of Miocene time; and the specialized *Balaenula balaenopsis,* the precursor of living genera of the family Balaenidae, in middle Pliocene time. The extinct killer whale, *Orcinus citoniensis,* of the dolphin family is known from Astian beds.

Continental Deposits and Life.—Sandy continental deposits of the high plains, called Ogallala, occupy a belt about 200,000 sq.mi. east of the Rocky mountains. In them are buried widespread remains of seeds of *Stipidium* (related to spear grass *Stipa*), *Nassella,* wild millet, many borages, sedges and other herbs. Forests of poplar, willow, hackberry, elm and other trees grew only along the larger valleys.

Abundant remains of grazing mammals indicate also that in this region grassland predominated over the forest. The Miocene forest horse, *Hypohippus,* continued into the Pliocene, but prairie horses became dominant and widespread. Such was *Hipparion* (an important grazer common to America and Eurasia), the advent of which marks the beginning of the Pliocene. Typical are also the grazers *Pliohippus* and *Protohippus.* Other common extinct mammals comprise camels, *Procamelus* and *Paracamelus,* hornless rhinoceros, *Peraceras* and *Aphelops,* and horned *Teleoceras,* the grotesque three-horned *Synthetoceras tricornutus,* beaver *Dipoides,* and many others.

Correlation Chart for Pliocene and the Directly Preceding and Succeeding Geological Epochs

North American		China	Northern India	Southern U.S.S.R.	Rumania, Austria	England	France	Mediterranean	Epochs
Standard continental (high plains)	Marine in California							Continental Standard in western Europe marine	
								Orogenies:	
Nebraskan glacial stage BLANCAN	Tulare	Nihowan (Sanmenian)	Lower boulder beds	Kujalnic	Upper Levantin	Red Crag		Gunz glacial stage SICILIAN VILLAFRANCHIAN	Early PLEISTOCENE
(Kimball) KIMBALLIAN (includes Sidney gravel)	San Joaquin		Pinjor	CIMMERIAN (warmer Pontian)	Lower Levantin	Coralline Crag	Trevoux Montpellier	*paleo-Wallachian* Montpellier ASTIAN	Late Pliocene
(Ash Hollow) "HEMPHILLIAN" (includes Burge channel)	Etchegoin	Ertemte (Dalai-nor)	Tatrot	PONTIAN (restricted)	Freshened Dacian (*Paludina* beds)	Marine Lenham beds or Diestian	St. Amand Mollon	*Neo-Rhodanic* Casino PLAISANCIAN	Medial Pliocene
(Valentine) "CLARENDONIAN"	Jacalitos	Lutzekou (*Hipparion* red clays)	Dhoc Pathan and Nagri	MEOTIAN (Lower Pontian)	Meotian (*Congeria* beds)		Mount Léberon	*Paleo-Rhodanic* Pikermi MESSINIAN	Early Pliocene
(Sheep Creek)	Delmontian (Upper Monterey)	Tung Gur	Chinji	SARMATIAN				*Attic* VINDOBONIAN	Late MIOCENE

Note: the recommended terms are capitalized. Fossil names and orogenies (mountain-building processes) are in italics.

Grassland and its inhabitants disappeared from this region in the late Pliocene, when a desert, with swamps and shallow lakes, developed. Next came a gentle eastward tilting of the land that drained it and started its Pleistocene erosion, which is still continued.

In Europe, in early Pliocene time lived *Rhinoceros* and *Aceratherium,* giraffes, *Camelopardalis* and others, *Mastodon* and *Dinotherium,* also the ostrich and other birds. In eastern Asia the "Hipparion fauna" includes tapir and primates, *Macacus* and *Procinocephalus;* and in India there were more highly specialized primates, proboscidean *Stegodon* and *Archidiskodon, Camelus* and others.

Undoubtedly grassland existed not only east of the Rockies but also in other places of the world, and certainly there were some desert floras during the Pliocene. However, forest floras predominated. Along the stream borders in western North America grew *Ulmus, Persea, Alnus, Platanus, Populus, Salix* and evergreen oak, while giant *Sequoia* grew only close to the Pacific. Next to this vegetation, particularly in the south, grew a chaparral flora made of *Arctostaphylos, Ceanothus, Cercocarpus, Garrya* and *Heteromeles,* while the higher altitudes were covered by *Cupressus, Libocedrus,* nut pine, oak and *Robinia.*

The Mediterranean flora was much the same as it is today: *Laurus, Persea, Fraxinus, Populus, Quercus, Juglans, Buxus* and dwarfed palm *Chamaerops.* Quite different was the flora of England, which was dominated by Japanese and North American elements, plus some mixture of Himalayan and Indo-Malayan types; but at the end of the Pliocene, west Asiatic and European forms became equally prominent.

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PLOCK or PLOTSK, a town of Poland in the province of Warszawa, on the Vistula, 67 mi. by the Vistula W.N.W. of Warszawa. Pop. (1931) 32,777; (1946) 28,508. It has a cathedral, dating from the 12th century, but restored in 1903, which contains tombs of Polish dukes and of Kings Wladyslaw and Boleslav (of the 11th and 12th centuries).

There is considerable navigation at this point on the Vistula. German troops took Plock soon after the start of World War II in 1939. It was returned to Poland in 1945.

PLOËRMEL, a town of western France in the department of Morbihan, 36 mi. N.N.E. of Vannes by rail. Pop. (1946) 3,871. Ploërmel (*Plou Armel,* people of Armel) owes its name to Armel, a hermit who lived in the district in the 6th century. The Renaissance church of St. Armel (16th century) is remarkable for the delicate carving of the north façade and for fine stained glass. It also possesses effigies of John II and John III, dukes of Brittany, brought from their tomb in an ancient Carmelite monastery founded in 1273 and destroyed by the Protestants in 1592 and again at the Revolution.

The lower ecclesiastical seminary has a room in which the Estates of Brittany held several meetings.

PLOEŞTI, the capital of the department of Prahova, Rumania; at the southern entrance of a valley among the Carpathian foothills, through which flows the river Prahova; and at the junction of railways to Buzau, Bucharest and the Transylvanian system. Pop. (1948) 95,632. As the name Ploeşti (*pluviena,* rainy) implies, the climate is moist. The surrounding hills are rich in petroleum, salt and lignite.

Ploeşti is the greatest centre of the Rumanian oil industry, and as such was severely bombed by British, Americans and Russians in World War II. There are cardboard factories, roperies, tanneries and oil mills. Ploeşti possesses schools of commerce and of arts and crafts, several banks, and many churches, including the Orthodox church of St. Mary, built in 1640 by Matthew Bassarab.

PLOMBIÈRES, a town of eastern France, in the department of Vosges, on a branch line of the Eastern railway, 17 mi. S. of Epinal by road. Pop. (1946) 1,452. The town stands at a height of 1,410 ft. in the picturesque valley of the Augrogne. It is famous for its mineral springs, containing sodium sulphate and silicic acid, varying from 66° to 166° F. The waters have been used since Roman times.

PLOTINUS (A.D. 204 or 205–270) was a native of Egypt, but it is not known from what race he sprang. As a young man he studied philosophy at Alexandria, and at last found a congenial teacher in Ammonius Saccas, under whom he worked till he was 39. Then he accompanied the expedition of the emperor Gordian against Persia, hoping to have an opportunity of studying the wisdom of the east. Gordian was assassinated in Mesopotamia and Plotinus escaped to Antioch with difficulty. In 244 he went to Rome, where he lived for the rest of his life. There he opened a school and gathered round him an enthusiastic band of disciples.

For many years the instruction was purely oral, and Plotinus took but little pains to perpetuate his teachings. We owe the preservation of it mainly to his pupil Porphyry, who edited his scattered lectures and tried to reduce them to order. The philosopher died after a long illness at the age of 66. His biographer Porphyry described him as a man of saintly character and very attractive personality.

In Plotinus philosophy and personal religion were closely connected; the apex of the dialectical pyramid was also the beatific vision in which the mystical life culminates. He made no enemies and was loved and reverenced by all who knew him. The later members of the school spoke of him as "the most divine Plotinus."

The importance of Plotinus in the history of thought can hardly be exaggerated. Among the philosophers of mysticism he holds an undisputed pre-eminence, since no other writer unites in the same measure metaphysical genius with intimate personal experience.

On the theoretical side he draws mainly from Plato, but on Plato as interpreted by a long series of scholars, and buttressed by Aristotle and (to a less extent) by the Stoa. The rival schools of Greek philosophy were in fact beginning to coalesce into a theocentric system, at once universal and individual, of religious discipline. Plotinus gave an impetus to this fusion; for the victory of his philosophy was so rapid and overwhelming that it absorbed the other schools, and when Neoplatonism captured the Platonic academy at Athens, the seat of the official Diadochus, it reigned almost without a rival until Justinian closed the Athenian schools in 529.

Neoplatonism remained attached to the classical tradition, and Porphyry wrote against Christianity. But even Augustine recognized that the differences between Platonists and Christians were slight, and the church gradually absorbed Neoplatonism almost entire. The Christian Platonists of Alexandria led the way; then came Augustine himself, the Cappadocian fathers and the Pseudo-Dionysius, a disciple of Proclus, whose writings, popularly ascribed to St. Paul's Athenian convert, introduced the whole scheme of Plotinian mysticism into the church. It is no paradox to say with Eucken that the pagan Plotinus has left a deeper mark upon Christian thought than any other single man. In reading the *Enneads* we can realize the truth of Troeltsch's famous dictum, that the Catholic Church does not belong to the middle ages but is rather the last creative effort of classical antiquity, which may be said to have died in giving birth to it. Troeltsch adds that in a new synthesis of Neoplatonism and Christianity lies "the only possible solution of the religious problem at the present day," and "does not doubt that this synthesis will once more be dominant in modern thought." Such a judgment, from the foremost thinker of his day in Germany, is enough to show that the philosophy of Plotinus, so far from

being extinct, is still a factor in modern civilization. As Eunapius said, "the altars of Plotinus are still warm."

His Philosophy.—Whatever English equivalents we choose for the Plotinian technical terms must be misleading. The "Matter" of Plotinus is immaterial, being the all-but nothing which remains when we have deprived an object of contemplation of the form and meaning which make it a possible object of contemplation. "Soul" is often nearer "life," the word usually translated "intelligence" is much nearer to "Spirit"; "God" is not the deity of personal theism, and the Absolute is "beyond existence." It is mainly mistranslation of technical terms that has caused many to ascribe metaphysical dualism to Plotinus, for which there is no ground whatever. There are no hard and fast dividing lines in this philosophy, but a graduated hierarchy of existence and value, in every grade of which the soul finds affinities.

The soul is a stranger among the things of sense, into which it has "come down." From the desire of Soul to create after the pattern of Spirit, "the whole world which we know arose and took its shapes." The universal soul is the creator and providence of the visible world, which is in it, rather than the soul being in the world. "There is nothing between soul and spirit except that spirit imparts and soul receives. But even the Matter of Spirit is beautiful and of spiritual form." "There is nothing Yonder that is not also Here." Plotinus therefore blames the half-Christian Gnostics, who despise the visible world and are blind to its beauties. Souls cannot be divided quantitatively; "all souls are one." In the spiritual world there is distinction without separation; individuality is preserved, but all spirits are transparent to each other. Even on earth there is a "faint sympathy" which connects all beings together, a pale reflection of the complete unity in plurality which prevails Yonder. The character of the soul depends on the sphere in which it voluntarily moves. If it chooses to live among the shadows of the true, it forfeits its birthright, and is "lost," so far as a divine being can be lost. There is a higher soul which never consents to sin, and remains in the eternal world. (Here the school was to differ. Later Neoplatonists asked, "If the will sins, how can the soul be impeccable?")

The soul neither comes into existence nor perishes; "nothing that possesses real being can ever perish." But souls that have lived unrighteously will be punished by being reincarnated in the bodies of lower animals; the soul will also be chastened by its daemon or guardian angel. It is not quite clear whether every soul must at last find deliverance from its chains. The world Yonder is the heaven of Neoplatonism. It is the realm of spiritual existence, in which the ultimate and eternal values—Truth, Goodness and Beauty—are fully realized and fully operative. It consists in the unity of *Nous, Noësis* and *Noëta,* in which the whole nature of the Absolute is manifested. It is essentially a kingdom of values, but of values which are fully realized. It is eternal, not as existing through an infinite series of moments, but as belonging to the divine life, of which indestructibility is an attribute. The world reflects in its everlastingness the eternity of its archetype. There is no change or progress Yonder, since the perfect cannot receive augmentation; but there is unceasing life and movement, which on the lower side is manifested in perpetual creativeness. The lower orders of being proceed from the higher in a constant stream, though the higher loses nothing in the process of creation. The lower is immanent in the higher, not the higher in the lower. Nothing that takes place in time can affect the essential nature of eternity.

The duality in unity of the spiritual world points to an absolute unity behind it. This unity, though the necessary culmination of the dialectic, is beyond knowledge and existence, and is revealed to experience only in the mystical trance. The "soul become spirit" cannot rest even in this state of blessedness; it is impelled by its inner nature to aspire still further, "always attaining and always striving upward." Plotinus is convinced that in the mystical state we have actually an experience of formless intuition. This is, it is needless to say, the testimony of all the mystics, of every age, country and creed. The mystical ascent seems to those who pass through it to be a progressive stripping off of everything that is alien to the purest nature of the soul, which cannot enter into the Holy of Holies while any trace of earthliness still clings to it. Hence the constant reiteration of such symbols as nakedness, nothingness and darkness. Plotinus in the well-known sentence with which the *Enneads* as arranged by Porphyry end, defines it as "a flight of the alone to the Alone." He gives us several eloquent descriptions of the mystical trance, drawn evidently from intimate personal experience; but like other mystics he knows that it is impossible to utter the ineffable, and repeats cautions like "The vision is for him who will see it"; "he who has seen it knows what I say."

It is part of the fundamental sanity of Plotinus that he always speaks of the vision of the One as an exceedingly rare experience. It is the consummation of a life-long quest of the highest, to be earned only by intense contemplation and unceasing self-discipline. He says nothing of supernatural favours granted for their encouragement to young aspirants. Nor are there any traces of those attempts to force the pace which in many mystics produce the terrible reactions which are described as the dark night of the soul. This sense of dereliction, which fills so large a place in the records of the mysticism of the cloister, may have some connection with a deeper sense of guilt and sinfulness than the Neoplatonists ever felt; but it is partly the effect of nervous overstrain and of severe mortification of the body, which Platonism has never encouraged. Plotinus, as we have seen, lived the active and sociable life of a professor among his pupils; his habits were austerely simple, but neither he nor his disciples tortured themselves like Heinrich Suso and many other Catholic saints. The combination of healthy asceticism with humanism is the hall-mark of Platonists in all times.

The ethical scheme of Plotinus falls, like everything else in his philosophy, under three heads—purification, enlightenment and unification. The "political virtues," which include all the conduct expected of a good citizen, are the preliminary but indispensable prelude to the course. It was not to be expected that any writer in the 3rd century of our era should show much interest in what we call social questions, which occupied the attention of Plato and Aristotle. The special task of philosophy in that distracted age was to isolate religion in its purity, detaching it from all that was local and temporal, and bringing to light its innermost essence. To have done this is an achievement of permanent value, and we must not blame Plotinus for his apparent indifference to the misfortunes which were threatening his country. But, like all the ancients, he does not sufficiently emphasize our need of our fellow-men to develop the best in human nature. The bravest of the Greeks could never renounce the hope of making himself invulnerable.

Neoplatonism culminates in Plotinus. Of his successors, Proclus alone was a thinker of the first rank, and in Proclus the system is intellectualized and scholasticized. The later history of this type of religious thought and practice is mainly within Christianity. As a philosophy, it was restated with acumen by Scotus, Erigena and Meister Eckhart; but many of the post-Kantians are deeply indebted to Plotinus, and Troeltsch is probably right in thinking that even in the future Christian philosophy must continue to be largely Plotinian. The Church carried off this Hymettian honey to its hive just at the time when the intellectual formulation of the victorious creed was taking its permanent shape.

(W. R. I.)

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On Plotinus generally *see* article in Suidas; Eunapius, *Vitae sophistarum;* and above all the *Vita Plotini* by his pupil Porphyry. Among modern works, *see* the treatises on the school of Alexandria by J. F. Simon, 1. (1845), and R. Vacherot (1846); A. Richter, *Ueber Leben und Geistesentwicklung des Plotin* (Halle, 1864–67); T. Whittaker, *The Neoplatonists* (1901); A. Drews, *Plotin und der Untergang der antiken Weltanschauung* (1907); E. Caird, *Evolution of Theology in*

the Greek Philosophers (1904), ii, 210–257; W. R. Inge, *The Philosophy of Plotinus* (2 vols., 1918; 3rd ed. revised, 1928); F. Heinemann, *Plotin* (1921). A detailed account of Plotinus' philosophical system and an estimate of its importance will be found in the article NEOPLATONISM, the works above referred to and the histories of philosophy.

(*See* also LOGOS; MYSTICISM; MAGIC.)

PLOUGH, PLOW: *see* TILLAGE MACHINERY.

PLOVER, the name given to an indefinite group of birds which, with the snipes and sandpipers, form the group *Limicolae* or "waders," although the plovers themselves rarely enter water. Perhaps the best entitled to the name are the golden plover (*Charadrius pluvialis*) and the gray plover (*Squatarola helvetica*). The latter is the larger and lacks the hind toe; otherwise the two forms are similar. The gray plover breeds in the far north of America, Asia and Europe, migrating south in the winter, when it reaches the Cape, Australia and Ceylon. The golden plover is more local but ranges from Iceland to Siberia, including the British Isles, as a breeding species. It also migrates south in winter. Both forms are exceedingly wary. In America occur two further golden plovers, breeding in the far north, where, in Alaska, their ranges are scarcely 100 mi. apart. But whereas the eastern form winters in Patagonia, which it reaches via Labrador, Newfoundland and the Antilles, returning by way of Panamá, the Pacific bird winters in the Low Archipelago (*see* Coward's *Migration of Birds*). Plovers are gregarious but monogamous birds, partial to mud flats and marshes and eating worms and small arthropods and molluscs. The legs are long, the bill shorter than in most waders.

The ringed plovers include the shore-haunting British bird of that name; killdeer (*q.v.*); zick-zack (*Hoplopterus spinosus*), celebrated for its connection with the crocodile, from the mouth of which it picks leeches and other parasites, besides, from its wariness, acting as a sentinel to the reptile. The coursers, *Cursorius* and allied genera, to which the last belongs, are mainly desert forms from Africa and India. Other allies of the plovers are the stone curlews (*see* CURLEW), lapwings (*q.v.*), oyster catchers (*q.v.*), turnstones (*q.v.*) and avocets (*q.v.*). (For "plovers' eggs" *see* LAPWING.)

PLÜCKER, JULIUS (1801–1868), German mathematician and physicist, was born at Elberfeld on June 16, 1801. After studying at the universities of Bonn, Heidelberg and Berlin he went in 1823 to Paris, where he came under the influence of the great school of French geometers, whose founder, Gaspard Monge, had only recently died. In 1825 he was received as *Privatdozent* at Bonn, and after three years he was made professor extraordinary. He then held the following posts: professor of mathematics at Friedrich Wilhelm's Gymnasium, Berlin (1833–34), professor of mathematics at Halle (1834–36), professor of mathematics (1836–47) and finally professor of physics at Bonn. He died on May 22, 1868.

From his lectures at Bonn sprang his first great work, *Analytisch-geometrische Entwickelungen* (vol. i, 1828; vol. ii, 1831), in which he introduced the abridged notation which has since characterized modern analytical geometry. (*See* ANALYTIC GEOMETRY.) He applied this notation to the straight line, circle and conic sections, and he used it in his theory of cubic curves. Also he established the great principle of duality. Plücker discovered the six equations known as "Plücker's equations" connecting the numbers of singularities in algebraical curves. (*See* CURVE.) Plücker communicated his formulae in the first place to *Crelle's Journal,* vol. xii (1834) and gave a further extension and complete account of his theory in his *Theorie der algebraischen Curven* (1839). In his *System der analytischen Geometrie* (1835) he introduced the use of linear functions in place of the ordinary co-ordinates; he also made the fullest use of the principles of collineation and reciprocity. He discussed curves of the third order and gave a complete enumeration of them, including 219 species. In 1846 Plücker published his *System der Geometrie des Raumes in neuer analytischer Behandlungsweise,* but this contains merely a more systematic and polished rendering of his earlier results.

After his appointment as professor of physics at Bonn, Plücker began a series of researches in physics. His first physical memoir, published in *Poggendorfs Annalen* (1847), deals with the behaviour of crystals in a magnetic field. Then followed a long series of researches, mostly published in the same journal, on the properties of magnetic and diamagnetic bodies, establishing results which are now part and parcel of our magnetic knowledge. This was followed by researches on the discharge tube; he investigated the deflection of the discharge by a magnet and the behaviour of the negative glow in a magnetic field. Plücker, first by himself and afterward in conjunction with J. W. Hittorf, made many important discoveries in the spectroscopy of gases. He anticipated R. Bunsen and G. R. Kirchhoff in announcing that the lines of the spectrum were characteristic of the chemical substance which emitted them and in indicating the value of this discovery in chemical analysis. According to Hittorf he was the first who saw the three lines of the hydrogen spectrum, which a few months after his death were recognized in the spectrum of the solar protuberances, and thus solved one of the mysteries of modern astronomy. Induced by his mathematical friends in England, Plücker in 1865 returned to "line geometry." His first memoir on the subject was published in the *Philosophical Transactions* of the Royal Society of London in 1865. Plücker worked out the theory of complexes of the first and second order, introducing in his investigation of the latter the famous complex surfaces of which he caused those models to be constructed which are now well known to the student of higher mathematics. He left an uncompleted work on the subject which was so far advanced that his pupil and assistant, Felix Klein, was able to complete and publish it. (*See* LINE GEOMETRY.)

See R. F. A. Clebsch's obituary notice (*Abh. d. kön. Ges. d. Wiss. z. Göttingen,* vol. xvi, 1871), to which is appended an appreciation of Plücker's physical researches by Hittorf and a list of Plücker's works by F. Klein. *See* also C. I. Gerhardt, *Geschichte der Mathematik in Deutschland,* p. 282, and Plücker's life by A. Dronke (Bonn, 1871).

PLUM, the name of a fruit tree which belongs to the genus *Prunus* in the Rosaceae family. Like the peach and cherry, also members of the same genus and family, it is called a stone or drupe fruit. The fruit of the plum develops from a single ovary. As the fruit grows to maturity, the outer part of the ovary ripens into a fleshy, juicy exterior making up the edible part of the fruit and a hard interior called the stone or pit. The seed is enclosed within the stone. The fruits show a wide range of size, flavour, colour and texture.

The trees of some plum species are vigorous in growth with upright branches reaching a height of 20–30 ft., while others are much smaller; some are small shrubs with drooping branches, and some have great beauty as ornamental plants. The flower buds on most varieties and species are borne on short spurs or along the terminal shoots of the main branches. Each bud may contain from one to five flowers, two to three being most common; and where the buds are close together, they give an appearance of densely packed, showy flower clusters when the trees are in full bloom. Characteristic of the genus *Prunus,* the individual flower is made up of a receptacle forming a hollow cup bearing sepals, petals and stamens on the outer rim surrounding a single pistil attached at the bottom of the cup. After fertilization of the flower, the receptacle and attachments fall off and the style withers and drops off, leaving the enlarged basal portion of the pistil, the ovary, which develops into the fruit.

Native Habitat of Plum Species.—The common European plum, known botanically as *Prunus domestica,* appears to have originated somewhere in southeastern Europe or western Asia, probably in the region around the Caucasus and the Caspian sea. Although it is called the European plum, some botanists who have summarized the history of these stone fruits are doubtful that *P. domestica* is indigenous to Europe. According to the earliest writings in which this plum is mentioned, the species dates back about 2,000 years.

Another old world plum species, probably of European or Asiatic origin, is the damson plum (*P. insititia*). This species seems to antedate *P. domestica,* as is suggested by the finding of damson plum pits in ancient ruins. The ancient writings connect the early cultivation of these plums with the region around Damascus.

An important species native to China is the plum (*P. salicina*), which was domesticated in Japan and was introduced into the United States about 1870.

Two less important species are the myrobalan plum (*P. cerasifera*), a native of Europe, and the Simon or apricot plum (*P. simoni*), a native of China. The myrobalan plum has been used a great deal in the United States as a rootstock. Varieties of *P. cerasifera* and *P. simoni* are noted for their ornamental foliage.

Botanists have divided the native American plums into a number of species and subspecies. Many of them have numerous characteristics in common, so that they overlap somewhat in horticultural groups and classifications. *P. americana*, the most important of the native species, has a wide range of adaptation in the United States, extending from Maine to Florida, westward to Utah, and northwestward into Manitoba. The tree is small, not so vigorous as the European, and it has rough, shaggy, grayish bark. The fruit is red, reddish-yellow, or reddish-orange, possesses a pleasant flavour and is of good quality, but it has a thick, tough skin and the flesh clings to the pit. Desoto and Weaver are among the typical cultivated varieties of americanas.

PLUM (PRUNUS DOMESTICA) A. LONGITUDINAL SECTION THROUGH FLOWER SHOWING RECEPTACLE AND FLOWER PARTS WITH ENLARGED BASAL PORTION OF THE PISTIL THAT DEVELOPS INTO THE FRUIT. B. TWIG WITH BLOSSOMS, AND C. FRUITS (DRUPES).

Other American species of minor importance from a commercial standpoint but of interest to the fruit breeder are the native varieties of *P. hortulana*, the chickasaw plum (*P. angustifolia*), and the wildgoose plum (*P. munsoniana*) of the southeastern and south central United States, of which Wildgoose and Robinson are important varieties.

Still other species of plums growing in North America are the Canada plum (*P. nigra*), which is adapted to the north central United States and Canada; the small beach plum (*P. maritima*), which grows along the eastern seacoast; and the western or Pacific plum (*P. subcordata*), which grows east of the Coast range in southern Oregon and northern California.

Plum Culture in the United States.—Cultivated varieties of at least 12 species of plums are to be found in U.S. orchards or growing in the wild, but most of the important commercial varieties are confined to four of the species already mentioned, namely, *domestica, insititia, salicina* and *americana*.

It is not known just when European plums were introduced into North America, but probably pits were brought over by the first colonists. It is reported that plums were planted by the Pilgrims in Massachusetts and importations were made by the French into Canada. These European plums have done remarkably well in the new world, and they constitute the most important group grown commercially for canning and drying.

The best known and most important of these groups are varieties of *Prunus domestica*, the European plums and prunes. These are vigorous-growing trees, upright spreading in habit. Unfortunately, they are not well adapted to regions with hot, dry summers or dry, cold winters. They are at home in the northeastern United States and in sheltered sections along the Great Lakes; but they are at their best in the irrigated regions of the intermountain and Pacific coast states, as is evidenced by the extensive production of fresh fruit and dried prunes in this region. The trees do well on medium heavy soils that are well drained. They blossom later than peaches and thus escape spring frosts. The European plums have been under domestication longest, and the fruits are notable for large size and attractive appearance. They vary in colour from the green and golden yellow of the Reine Claude (greengage) and Yellow Egg groups to the red and dark purple of the Lombard and Italian prune.

The damsons (*P. insititia*) of the old world are quite different from the domesticas. The trees are more upright, compact and dwarfish; the leaves and flowers are smaller; and the fruits are small, round and quite tart, so that they are especially suitable for preserves and jams. Varieties of this group are hardy, vigorous and productive, and the trees make good stocks for other species, being adapted to a wide range of conditions and thriving even when they are neglected. The Shropshire and the French are important blue damsons in the United States, while the yellow Mirabelles are popular in France. The demand for varieties of plums of this type is limited, and they are not planted as extensively as those varieties that can be consumed fresh, dried or canned.

The Oriental plums (*P. salicina*) are relatively new to North America, but in the short time since their introduction they have been widely planted and in 1944 ranked second to the domesticas in commercial production. The trees are more spreading in habit than the domesticas or damsons, and in leaf and fruit characters they are very different, resembling the native American plums. The fruits are very attractive and are characterized by a yellow ground colour overlaid by various shades of red. In some varieties the flesh colour is striking red, whereas fruit of the domesticas and damsons is green or yellow. Some newer hybrids of the salicina group show distinct superiority in flavour and in commercial possibilities over the early importations. Varieties of this group appear to be widely adapted in the United States except in the very coldest climates. While the quality is not equal to that of the best domesticas, and the commercial varieties are not so satisfactory for canning and drying, the fresh fruit is delicious in its blend of flavours. The varieties cross readily with one another and with the native americanas. Among the first so-called Japanese plums grown in the United States, Kelsey, Burbank, Abundance and Satsuma are typical. The trees are hardy and productive, and they tolerate a variety of soils as well as climatic conditions. The blossoms open earlier, however, than those of the domesticas and damsons and are frequently killed by spring frosts in the eastern part of the United States.

The native American plums were doubtless used for food by the Indians long before the white man set foot on the shores of North America. Reports of early explorers mention the finding of plums growing in abundance. According to the descriptions of the early settlers, these plums were inferior to the domesticas of the old world in quality, so that the colonists soon began importing varieties from Europe. As a result, European plums soon became predominant in home fruit gardens as well as commercial orchards in the northeastern United States. Varieties of native species, however, while not grown in commercial orchards, do fill a need in supplying fruit for the home garden in regions where the domesticas are not well adapted, as for example in the southwestern and south central United States. American varieties also have been selected for planting in the northern Great Plains where only cold hardy sorts can survive. Varieties like Assiniboin and Cheney of the *P. nigra* group, and Wyant and Desoto of the americanas, survive in this region.

Hybrids produced by crossing American and oriental varieties have given larger fruited varieties of better quality, also adapted to the colder climates. Waneta and Underwood are two varieties that have been planted in home gardens. Furthermore, American species hybridize with the sand cherry (*P. pumila*), and plant breeders have produced new varieties adapted to cold and dry conditions in the northern Great Plains. Important varieties are Opata, Sapa and Zumbra.

In the United States, as well as in Europe, the plum has long been recognized as one of the most delicious of fruits, and among the stone fruits it ranks next to the peach in commercial production. Many of the varieties of plums cultivated in the United States have been introduced from elsewhere, and when these are added to the native varieties they give plums the largest number

and greatest diversity of kinds and species among the stone fruits.

Fortunately varieties can be selected that are adapted to a wide variety of soils and climatic conditions. Plums respond to good soil management practices. When the trees come into bearing they do not require a large amount of pruning and in the home fruit garden can be grown satisfactorily provided insects and diseases are controlled.

Insects and Diseases.—The fruit and tree of the plum are attacked by a number of troublesome insects and diseases that seriously limit production if not controlled by spraying. One of the most serious of the insect pests is the plum curculio, a small beetle that deposits its eggs in the fruit. As the larvae hatch and feed on the fruit, the affected fruits drop prematurely. Sometimes all of the fruits will drop off before harvest. This insect can be controlled by timely spraying with arsenate of lead. Brown rot caused by a fungus that gains entrance through breaks in the skin or through punctures caused by the curculio may also be a serious menace. Fortunately this disease can be controlled by the timely application of fungicides of sulphur or copper. A bacterial leaf disease called bacterial spot, or shot hole, is serious in the more southern latitudes of the United States. Some varieties are quite resistant to this disease while others are susceptible. For the successful production of plums in any region a timely spray program must be followed to protect the fruit and foliage against these insect and disease pests.

Prunes.—Prune is a name given to a plum that can be dried without removing the pit into a firm long-keeping product. This term is frequently applied as a group name to plum varieties that have a sufficiently high sugar content and firm flesh so that they can be preserved by drying. The dried plum of commerce is, therefore, called a prune and only certain varieties have the qualities to make a good dried product. In California most of the plums are dried in the sun, while in Oregon and Washington drying is done in specially built dehydrators, where the drying is done with artificial heat. The growing of plums for the production of prunes in the United States is confined largely to the states of California, Oregon, Washington and Idaho. Agen or French, Italian, Sugar and Imperial Epineuse, all of the European group, are the principal varieties.

In the period 1938–42 the average annual production of prunes on a fresh basis totalled 639,120 tons. Of this amount 48,622 tons produced in the states of Washington, Oregon and Idaho were consumed as fresh prunes. Prunes also make a delectable product when canned, and in the states of Washington and Oregon, where most of the commercial pack of canned prunes is put up, an average of 26,140 tons of prunes were marketed. During this same period, also, an average of 202,080 tons of dried prunes were produced in the four western states.

A large quantity of prunes has been exported in the fresh, canned and dried form. In the years just prior to 1940, before shipping was interfered with by World War II, the total exports on a fresh basis amounted to 275,000 tons. Of this amount 107,000 tons were in the form of dried prunes.

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PLUMBAGO: *see* GRAPHITE.

PLUMBING is the system of piping, fixtures and equipment installed in a building for the purpose of: (1) supplying water in desired quantities at points of usage, and (2) removing water and water-borne wastes from fixtures, equipment, areas and appliances. Health and safety require that the foregoing be done under the following conditions: (a) without contamination of the supply water through back siphonage or cross connections, and (b) without permitting air, gases, bacteria or vermin inside the soil and waste system to enter the interior of the building. The word "plumbing" is derived from the Latin *plumbum,* meaning the art of working in lead. It originated from the extensive use of lead in the construction of water supply and disposal systems in buildings.

Plumbing systems generally are considered as starting at the supply of water. In municipalities, this is where the supply branch from the municipal main crosses the property line. The municipal water main customarily is located in a street, highway or easement adjacent to or near the land on which the plumbing is installed. In areas not served by municipal supplies, the plumbing starts at a shallow or deep well, a cistern, a spring or other source of potable water. In municipalities, water is supplied at the main under pressure sufficient to distribute the water to all points of usage in the building served. Where tall buildings or long pipe lines and special usages require a greater-than-normal pressure, this is produced by house pumps or booster pumps. In the case of private water supplies, mechanical pumps deliver water through the plumbing system in the required quantity and at the desired pressure.

Water Supply.—Pumps for supplying water are classified broadly as shallow-well types having a practical working depth of 28 ft. or less, and deep-well pumps which are designed to raise water from a depth of more than 28 ft. A shallow-well pump is connected to its water supply by means of a suction pipe, one end of which is submerged in the water. The pump operates on the principle of reducing the pressure in the suction line. The atmospheric pressure on the surface of the water, as a result, forces the water into the suction line and up to the pump mechanism which in turn delivers the water under pressure to a pneumatic storage tank, to an overhead storage tank or directly into the plumbing system.

Deep-well pumps operate on the principle of lifting water either by a valve mechanism generally submerged in the water or by jet propulsion. As in the case of shallow-well pumps, after the water is raised to the level of the pump, it is forced under pressure by the pump to the plumbing system. Hydraulic rams which depend upon the energy of falling water for their motive power also are used for pumping water.

Plumbing Classified.—Plumbing systems are classified broadly as to the type of service rendered. This includes residential plumbing, commercial plumbing, industrial or process plumbing, laboratory plumbing and institutional plumbing.

Individual plumbing systems are divided into the following: (1) the water supply portion, (2) the sewage and waste disposal portion and (3) the venting portion. The functions of the first two divisions of a plumbing system are self-evident. The third or venting portion is necessary in connection with the sewage and waste disposal system.

The reason is that all fixtures and appliances connected to soil and waste lines must be protected by a water seal to prevent the passage of sewer air, gases, bacteria or vermin from the sewer system into the interior of the building. This sealing is accomplished by means of a trap which is a section of the waste line shaped in the form of an "S" or a "P." This trap is located as close to the discharge outlet of the fixture as possible. When water is discharged from the fixture, an amount remains in the trap sufficient to fill a portion of it and thus close off the waste piping. Unless precautions are taken, the flow of water in the soil and waste piping, the discharge from other fixtures in the system or the discharge of the fixture itself may siphon the water contents of the trap and thus break the water seal. This is avoided by designing the system so that the pressure within the soil and waste lines will always be equal to the atmospheric pressure outside the soil and waste lines.

Venting System.—The venting system accomplishes this by making outside air available at points where negative pressures otherwise would be induced and by allowing air to be exhausted from the system at points where pressures above atmospheric otherwise would be built up. The venting system, like the soil and waste piping, is concealed within the walls of the building. Its outlets are through the roof. In cold climates, the section of the vent stack which extends through the roof is increased in diameter so that accumulations of frost caused by the condensation and freezing of water from the vapour in the drainage system do not close the opening.

Lead, galvanized iron or copper flashings are formed over the vent stack and around the opening to prevent the leaking of rain water through the roof at that point. Cleanout plugs are located at strategic points in the soil and waste system so that stoppages may be removed if they occur. These plugs usually are placed at points where vertical soil, waste or vent stacks converge with horizontal mains or branches.

Plumbing and Health.—There are very definite health aspects in connection with plumbing. The first consideration is that of maintaining the purity of the water in the supply system up to and including the point where it is discharged or used. There are on record instances of cross connections between potable and non-potable water supplies and between potable water supplies and actual sewage and waste piping. When such cross connections are made, usually there are provisions for separating the two systems by means of valves. In practice, inevitably danger arises from neglect, carelessness or ultimate deterioration of the barriers to contamination, with the result that through cross connections, pure water supplies are mixed with impure water and delivered to points of discharge for human consumption. Accordingly, modern plumbing practice is unalterably opposed to cross connections in plumbing systems.

A second source of contamination of pure water supplies occurs through what is known as back siphonage due to submerged or nearly submerged inlets at fixtures or equipment where water is used. This is based upon the fact that under certain conditions it is possible to induce in water supply lines pressures which are less than atmospheric pressure, otherwise known as partial vacuums.

Back Siphonage.—Unless specific precautions are taken this can occur in plumbing systems under various conditions. For instance, when a fire occurs, the fighting of it requires the pumping of water by a fire engine from a street main. The excessively rapid draw may reduce pressures in the lines in adjacent buildings to such an extent that partial vacuums actually occur in those lines. In other instances, in tall buildings, unless specifically designed and maintained to avoid it, an excessively heavy draw at fixtures on lower floors has been known to cause sub-atmospheric pressures in the water supply lines at upper floor levels. In such instances, if there are submerged or nearly submerged inlets, the flow of water to a fixture is reversed and the water in the fixture is drawn back into the water supply piping where it is redistributed to other fixtures for human consumption or use. Properly designed and installed plumbing systems take into account these possibilities and are definitely planned with modern safeguards to prevent such occurrences. Outbreaks of widespread and fatal epidemics due to contamination through cross connections and back siphonage have been authenticated by the United States Public Health service and other authorities and are a matter of public record.

Piping.—The piping for plumbing is in effect a transportation system hidden inside the walls of buildings. It supplies water where water is wanted and it removes water and wastes at the will of the user. The piping for plumbing systems is made of various materials depending upon local practice, water conditions and the selection of those who design and control the installation. These materials include lead, galvanized wrought iron, galvanized steel, galvanized iron, cast iron, copper tubing, brass, block tin and chemical stoneware. Industrial, commercial and process piping may and frequently does include other metals and alloys selected for their corrosion-resistant and corrosion-proof qualities. Depending upon the material used, piping connections are made by means of threaded and screwed joints, compression fittings, soldered or sweat fittings, wiped joints, brazed, burned or welded connections and calked and leaded joints.

Softeners and Filters.—Plumbing systems include provisions for removing hardness from water. Such equipment is known as a water softener and is connected in the water supply line. Essentially it consists of a tank filled with a substance which removes from the water the dissolved minerals causing the so-called hardness. The ordinary softener is equipped with valves and accessories which permit the recharging and backwashing of the water-softening substance as required.

Another item of equipment associated with plumbing systems and the purification of the water supply is the water filter, which is designed to remove foreign substances and to purify the water.

All complete plumbing systems include both hot and cold water lines to points where variations in temperatures are desired by the user. In institutions such as hotels, where refrigerated drinking water is distributed to all bathrooms, a third water supply line is installed with a faucet at the lavatory. In homes where water is softened, hot and cold soft water lines are provided with a third line carrying untreated cold water for drinking and cooking purposes.

Water Heating.—Equipment for the heating of water is included in plumbing systems. Various types are used, designated partially by the type of fuel burned, such as gas-fired, oil-burning, electric and coal-burning. These water heaters are further classified as direct, indirect, storage, instantaneous, submerged and immersion types. In warm climates, solar water heaters sometimes are used, employing the principle of absorbing heat by exposing a bank of coils to the direct rays of the sun. An important part of water heating is control of the equipment to provide predetermined temperatures and to relieve the temperature and pressure inside the water heater in the event they become excessive. Mixing valves, either thermostatic or manual, are designed and installed to control further the discharge temperature of the water at points of usage. Under certain conditions, vacuum relief valves are provided to prevent the collapse of certain types of hot water storage tanks. In some installations, hot water is circulated continuously to outlets so that hot water is available instantly upon opening a faucet.

Wastes from sinks and equipment used in the preparation of food and in the washing of dishes and utensils are discharged through lines separate from the soil system. This is because of the grease content of the waste which is run through a grease trap and thence to a catch basin before it is discharged into the main sewer. Removing the grease from the water prevents the solidification and accumulation of the grease in the drainage system, with subsequent stoppages.

Scope of Plumbing.—Plumbing systems include roof drains, area drains, swimming pools, sprinkling systems, stand pipes and hose connections for fire protection, sprinkling systems and hose connections for watering gardens and lawns, and water meters where water is purchased from a municipality or utility. Plumbing also includes sewage disposal systems consisting of septic tanks and distribution lines to disposal fields in installations where municipal sewer mains are not available. Plumbing also includes the insulation of pipes and tanks to prevent the loss of heat from hot water or other liquids carried, to prevent the gain of heat by refrigerated water and to prevent the condensation of water vapour on the surfaces of cold pipes and tanks.

Special applications include plumbing for steamships, railroad cars, automobile trailers and airplanes. (W. W. Gd.)

PLUM CURCULIO, a North American curculionid beetle, or weevil (*Conotrachelus nenuphar*). This insect is confined to North America east of the Rocky mountains. It ranges as far north as Manitoba and Quebec, and as far south as Victoria, Texas and northern Florida. In this territory it is a serious enemy to stone fruits and also attacks the apple and other pomaceous fruits. It is especially injurious to all varieties of plums, and to peaches and cherries. Its original food was probably the fruit of native *Crataegus,* and wild plum.

The adult curculio is small (about $\frac{1}{4}$ in. long), dark brown in colour, with whitish markings on the thorax and the hinder part of the wing covers. It lays its eggs in holes next to a crescent-shaped cut made in the skin by the beetle's beak. The function of the crescent-shaped cut is to kill the spot in the fruit containing the egg, so that the latter will not be crushed by the rapidly growing fruit. The larvae penetrate the flesh of the fruit, and a number of them may occur in the same plum or peach. On reaching full growth, the larva leaves the fruit and enters the soil, forming a cell in which it transforms successively to the pupa and adult. It rests in the pupal stage for two or three weeks. The resulting beetles feed upon the fruit and foliage until the approach of cold weather, when they enter hibernating quarters in protected places such as under trash in the orchards or in near-by woods. In its more northern range the insect has but one generation annually. In the far south some individuals develop a second generation.

The plum curculio is a great enemy to orchards. In 1947 it was estimated that the annual loss through its work in the United States was continuing to be from $7,800,000 to $10,000,000. It has several natural enemies among the hymenopterous and dipterous parasites, and it is destroyed by a few species of predatory insects. The fruit attacked by it often falls to the ground, and under such conditions poultry destroy many of the pests.

Fruit growers rely chiefly on spraying with lead arsenate for the control of the plum curculio. The foliage of the peach is particularly susceptible to injury by arsenicals, although most of this can be overcome by the addition of lime or of zinc sulphate and lime. The sprays on peach are usually combined with a self-boiled lime sulphur or one of the so-called wettable sulphurs to control various diseases, especially brown rot, which often gains entrance into the fruit at points injured by the curculio.

In areas in which a second brood of the curculio develops and where the insect becomes especially abundant, spraying is supplemented by a number of other practices, including the jarring of the trees and the capturing of the beetles on sheets placed underneath, the picking up and destruction of infested wormy drop peaches, and cultivation during the period when the insect is transforming in the ground and when it is readily injured by any disturbance of the soil. Information on the control of the insect may be obtained from state agricultural experiment stations or from the U.S. department of agriculture. (L. O. H.)

PLUMER, HERBERT CHARLES ONSLOW PLUMER, 1st Viscount, of Messines, cr. 1929 (1857–1932), British field marshal, was born on March 13, 1857, and entered the army in 1876. He served on the Red sea littoral in 1884, and in 1896 commanded a mounted regiment in the Matabele campaign. Before the outbreak of the South African War (1899) he raised the Rhodesian field force, which he commanded during the early months of the contest. He was promoted major general on the

conclusion of hostilities.

In May 1915 Sir Herbert Plumer was selected to lead the II. Army on the Western Front. His army was not very actively engaged during the remainder of 1915, nor yet in 1916, but on June 7, 1917, Plumer gained a signal victory at Messines. (*See* YPRES, BATTLES OF.) In November he took charge of the British troops sent to the basin of the Po after the Italian defeat at Caporetto, and in the following March was recalled to Flanders to resume the leadership of the II. Army just before the great German offensive started. In the general advance in August, his army took part in the operations for the recovery of Belgian Flanders. At the peace he received a peerage, promotion to field-marshal and a grant of £30,000. He subsequently commanded the British forces on the Rhine for a short time. From 1919 to 1925 he was governor of Malta, and from 1925 to 1928 high commissioner for Palestine. He died July 16, 1932.

PLUMPTRE, EDWARD HAYES (1821–1891), English divine and scholar, was born in London on Aug. 6, 1821. A scholar of University college, Oxford, and a fellow of Brasenose, he was ordained in 1847, and became professor of pastoral theology at King's college, London. In 1863 he was given a prebendal stall at St. Paul's, and from 1869 to 1874 he was a member of the committee appointed by Convocation to revise the authorized version of the Old Testament. He was Boyle lecturer in 1866–67 ("Christ and Christendom"), and Grinfield lecturer on the Septuagint at Oxford 1872–74. After successively holding the livings of Pluckley and Brickley in Kent, he was installed in 1881 as dean of Wells. He died on Feb. 1, 1891.

Plumptre translated the plays of Sophocles (1865) and Aeschylus (1868), and the *Divina commedia* of Dante (1886). In verse his main achievements were *Lazarus* (1864), and *Master and Scholar* (1866). Among his many theological works may be mentioned *An Exposition of the Epistles to the Seven Churches of Asia* (1877), *The Spirits in Prison* (1884), "The Book of Proverbs" (which he annotated in the Speaker's *Commentary*), the "Synoptic Gospels, Acts, and II. Corinthians," in Bishop Ellicott's *New Testament Commentary*, and *Life of Bishop Ken* (1888).

PLUNKET, OLIVER (1629–1681), Irish Roman Catholic divine, was born at Loughcrew, Co. Meath. He was appointed archbishop of Armagh and primate of Ireland in July 1669 and in November he was consecrated at Ghent, reaching Ireland in March 1670. The measures following on the Test Act bore hardly upon him, and in Dec. 1678 he was imprisoned in Dublin Castle for six weeks. Accused of a share in the Irish branch of the "Popish Plot," he was brought to London, and in June 1681 arraigned in the King's Bench, charged with conspiring to bring a French army to Carlingford. He made a good defence, but on the most absurd of evidence the jury convicted him of treason, and on July 1, he was hanged, drawn and quartered at Tyburn.

PLUNKET, WILLIAM CONYNGHAM PLUNKET, 1ST BARON (1764–1854), Irish lawyer, orator and statesman, was born in the county of Fermanagh in July 1764, the son of a Presbyterian minister, and studied at Trinity college, Dublin. Having entered Lincoln's Inn in 1784, Plunket was called to the Irish bar in 1787. He gradually obtained a considerable practice in equity and was made a king's counsel in 1797.

In 1798 he entered the Irish parliament as member for Charlemont. He was an anti-Jacobin Whig of the school of Burke, and a fervent Irish patriot. But he was a sincere admirer of the constitutional government of England as established in 1688; he even justified the ascendancy it had given to the Established Church, although he thought that the time had arrived for extending toleration to Roman Catholics and dissenters. To transfer it to Ireland as thus modified, and under an independent legislature, was the only reform he sought for his country; he opposed the union because he thought in incompatible with this object.

When Plunket entered the Irish parliament, the Irish Whig party was almost extinct, and Pitt was feeling his way to accomplish the union. In this he was seconded ably by Lord Castlereagh, by the panic caused by a wild insurrection, and by the secession of Grattan from politics. When, however, the measure was brought forward, among the ablest and fiercest of its adversaries was Plunket, whose powers as a great orator were now universally recognized. His speeches raised him immediately to the front rank of his party; and when Grattan re-entered the moribund senate he took his seat next to Plunket, thus significantly recognizing the place the latter had attained.

After the union Plunket returned to the practice of his profession, and became at once a leader of the equity bar. In 1803 he was selected as one of the Crown lawyers to prosecute Emmet. For his speech on this occasion he was exposed to much obloquy, and more especially to the abuse of Cobbett, against whom he brought a successful action for damages. In 1803, in Pitt's second administration, he became solicitor-general, and in 1805 attorney-general for Ireland; and he continued in office when Lord Grenville came into power in 1806. Plunket held a seat in the Imperial parliament during this period, and there made several able speeches in favour of Catholic emancipation, and of continuing the war with France; but when the Grenville cabinet was dissolved he returned once more to professional life.

In 1812 he re-entered parliament as member for Trinity college, and identified himself with the Grenville or anti-Gallican Whigs. He was soon acknowledged as one of the first orators, if not the first, of the House of Commons. In 1822 Plunket was once more attorney-general for Ireland, with Lord Wellesley as lord-lieutenant. One of his first official acts was to prosecute for the "bottle riot," an attempt on his part to put down the Orange faction in Ireland. He strenuously opposed the Catholic Association, which about this time, under the guidance of O'Connell, began its agitation. In 1825 he made a powerful speech against it; thus the curious spectacle was seen of the ablest champion of an oppressed church doing all in his power to check its efforts to emancipate itself. In 1827 Plunket was made master of the rolls in England; but, owing to the professional jealousy of the bar, who regarded an Irishman as an intruder, he resigned in a few days. Soon afterwards he became chief justice of the common pleas in Ireland, and was then created a peer of the United Kingdom. In 1830 he was appointed lord chancellor of Ireland, and held the office, with an interval of a few months only, until 1841, when he finally retired from public life. He died on Jan. 4, 1854, and was succeeded by his eldest son, Thomas Spen Plunket (1792–1866), bishop of Tuam, as 2nd baron. *See* the *Life of the First Lord Plunket* (1869), by his grandson, David Robert Plunket.

PLUNKETT, SIR HORACE (CURZON) (1854-1932), K.C.V.O. (1903), son of the 13th Baron Dunsany, was born on Oct. 24, 1854, and educated at Eton and Oxford. After engaging in cattle ranching for ten years, his interest in agriculture led him to devote himself to the promotion of agricultural co-operation, and in 1894 he founded the Irish Agricultural Organization Society. As a member of parliament from 1892 to 1900, he strongly advocated the cause of agriculture, and in 1899 he was appointed vice-president of the department of agriculture and technical instruction for Ireland. Two years later he became commissioner of the Congested Districts Board in Ireland. He was elected F.R.S. in 1902, and in 1919 endowed a trust, known by his name, for the development of agriculture. He presided over the Irish Convention of 1917–18, and was a Senator (1922–23) of the Irish Free State. He died March 26, 1932.

His works include, *Ireland in the New Century* (1904); *The Rural Life Problem of U.S.* (1910); *Some Tendencies of Modern Medicine* (1913); and *A Better Way* (1914).

PLURALISM. The term describes certain schools of philosophical thought. It is, indeed, distinctive of one of the two groups into which metaphysical theories may be divided by what is perhaps the profoundest of the many differences apparent between the various directions taken by the speculations of eminent philosophers. In short, every philosophical system is either singularistic or pluralistic; that is, it takes for its starting point, and for the guiding principle which directs its development, the idea of the essential unity of reality; or, on the other hand, it regards as fundamental the characters of diversity and plurality which are everywhere in evidence in the realms open to observation.

Nevertheless, the term "pluralism" is by no means definite in meaning. On the contrary it is ambiguous and capable philosoph-

ically of a number of different meanings, each of which, however, refers to some peculiarly radical distinction in philosophic thought. But, as so frequently happens in such cases, the word has tended more and more to become restricted in meaning to one particular type of theory. This is perhaps an example of the survival of the fittest, for it is probable that what is nowadays generally meant by "pluralism" is capable of giving a better account of itself and of putting up a stronger defence than any of the other kinds of theory which may be included within the scope of the term as literally interpreted.

QUALITATIVE PLURALISM

In the first place the term "pluralism" may have a *qualitative* meaning. One of the oldest problems of philosophy is that which concerns itself with the question whether the ultimate fundamental stuff, which is the ground of reality, is a single substance or includes a number of substances with differing attributes. Theories founded on the supposition that there are many ultimate substances, or at any rate more than one, are "pluralistic" in the qualitative sense of the term.

As a matter of fact only one theory of this type has ever been seriously propounded and effectively defended. This is the theory of "dualism," which holds that there are two kinds of fundamental substance. The two substances of dualism are commonly termed "mind" and "matter," and the distinctive attributes assigned to them are not merely different but are strictly incomparable with one another. The essential property of "mind" is thought; that of "matter" is extension. Dualism, which probably approximates more nearly than any other metaphysic to the practical, if unformulated, belief of the ordinary man who does not concern himself with philosophical analysis, recurs at intervals, in one form or another, throughout the history of speculative thought. But the clearest statement and the most able defence of it are to be found in the writings of Descartes (1596–1650), with whom modern philosophy is generally regarded as beginning. Descartes starts from the existence of the self. The fact of consciousness is, he holds, quite undeniable. He then proceeds to deduce the existence of God from the presence in our minds of an idea of God which embraces attributes so exalted as to make it inconceivable that the idea could have originated in anything so limited as the human mind. Accordingly its presence can only, he thinks, be explained by an external cause, namely, God himself. From this it is an easy step to the existence of matter. For God, being perfect, would not falsify our clearest perceptions; and among these is the perception of matter. Moreover, the attribute of matter which is most distinctly apparent to us is its extension, or occupancy of space, and this must accordingly be regarded as the essentially distinctive property of material substance.

We need not stop to consider in detail the defects of this argument which Descartes elaborated with remarkable thoroughness and ingenuity. It is sufficient to point out that the essential feature of his analysis, namely, the division of reality into mind and matter, was at fault. Matter as he conceived it, so far from being a substance and therefore concrete in the most complete sense, was altogether abstract. The same is true, though to a lesser extent, of his conception of mind. In fact the dualistic division of the universe into mind and matter, though it starts, as all philosophical theories must start, from the elements given in immediate experience, proceeds by abstracting some of these elements and elevating them to the position of concrete entities in their own right. This process, useful and indeed necessary for the purposes of such bodies of knowledge as the special sciences, is too artificial to yield anything of metaphysical value. Metaphysics, to achieve its end, must keep in constant touch with the concrete, that is, with experience. But a process of reasoning like that adopted by Descartes inevitably tends further and further away from the concrete to the abstract. The practical consequences of this for dualism are seen in its inability to attack with any success such problems as those concerned with the relation of body and mind, the nature of the external world, and the question as to how knowledge is possible at all.

Dualism is the only form of qualitative pluralism which has ever been seriously developed. (But it should perhaps be pointed out that the cosmology of Empedocles [490–430 B.C.], with its four elements, earth, air, fire, water, together with the qualitative atomism of his follower Anaxagoras, who regarded the universe as made up of a countless number of qualitatively simple elements, are really forms of qualitative pluralism.) It is true that some of the doctrines of theosophy and allied systems appear to tend to a pluralism of more than two kinds of substance, but these doctrines are essentially speculative and have never been developed in a form sufficiently definite, nor defended by arguments sufficiently logical, to affect at all seriously the development of philosophical thought. We may therefore conclude this brief survey of qualitative pluralism and pass on to consider quantitative pluralism.

QUANTITATIVE PLURALISM

Quantitative pluralism includes all those theories which hold reality to be made up of a number of relatively independent substantial entities, each of which exists, at any rate to some extent, in its own right. Quantitative pluralism is thus sharply contrasted with those forms of singularism or absolutism which regard reality as ultimately consisting of a single individual being, of which the many and diverse elements which seem to exist in the world are no more than mere appearances, qualities, or modes, having no real existence in themselves. This contrast has sometimes been expressed by saying that whereas, according to pluralism, the multitude of entities which appear to find a place in the universe have a "substantival" existence, according to singularism their existence is merely "adjectival" as attributes or aspects of the one real being.

We may classify types of quantitative pluralism according to their doctrine regarding the substance composing the real entities which they postulate. This substance may be material, spiritual (or mental), or it may be neutral in the sense that its essential character is unknown, or, if known in part, cannot be placed definitely in any particular category.

Neutral Pluralism.—The first kind of neutral pluralism, where the nature of the ultimate substance of which individual entities are composed is taken as unknown, though not altogether untenable, is philosophically barren and need not detain us. Its best known exponent is Herbart, who contended that reality is ultimately made up of a number of independent entities, of the inner nature of which we could know nothing, although they were the ground of all the facts of which knowledge was possible. Herbart's theory did not seriously affect the course of metaphysical speculation. It was largely a reaction against the philosophy of Hegel (1770–1831).

The second kind of neutral pluralism, in which the nature of the ultimate reals is regarded as known, at least in part, but as not definitely classifiable, has been developed only in comparatively recent years. William James (1842–1910), foremost and most original of American philosophers, seems to have been the first to have given it clear expression, though he was probably influenced to some extent by the speculations of the German physicist Ernst Mach. James based his belief on what he himself described as a "radical empiricism." He held essentially that the world of which we have knowledge is made up of a number of fundamental elements which may be taken as arranged in different types of patterns or sequences. If the elements are set out in one way we get the kind of structures or series which make up the contents of what we call "minds." Another method of selecting the elements will give the type of arrangements which constitute those entities which we know as material objects or physical events. Yet the elements of a pluralistic universe of this kind are not to be regarded as themselves essentially mental or material—they are of "neutral" stuff. Incidentally James was the first thinker to give the term "pluralism" currency among English-speaking philosophers, though in Germany we find it even as early as Wolff, the disciple of the great Leibniz (1646), to whom we shall refer later.

More recently still, a neutral pluralism which in some respects

exhibits a strong family likeness to that of William James has been developed in England by Bertrand Russell, who describes his own theory by the name "logical atomism." Russell's procedure consists essentially of an exceptionally detailed analysis of the material open to immediate observation, especially the particulars given in sensation and in imagery, followed by an attempt to build up from this material alone constructions corresponding to the fundamental concepts characteristic of physics and of philosophy, or to such among these concepts as analysis may show to be valid within their limits. Russell has applied his method to the analysis both of "mind" and of "matter." Current developments in the theories of some of the American neo-realists seem also to be moving along rather similar lines.

There can be no doubt that a neutral pluralism of the type we have outlined is in many respects an extremely powerful theory. Not only does it establish a metaphysical position which calls for serious consideration, but it introduces into the philosophical world an analytic technique the value of which it would be difficult to overestimate. It is not possible to undertake a detailed criticism here; but it is probable that the chief objections to current expositions of the theory are to be found in the fact that they dispose of some of the traditionally pressing questions of metaphysics with arguments which may be regarded as unduly facile, to say the least; while many will feel that most of the really ultimate problems are left untouched. No doubt the supporters would retort that these problems are insoluble, and no more time should be wasted on them.

Material Pluralism.—There remain for consideration material pluralism and spiritual pluralism. For the material pluralist the world consists, in the last analysis, entirely of particles or bodies, the properties of which are among those commonly associated with the concept of matter, in particular mass (or, perhaps, electric charge); position and (perhaps) extension in space; and position and (perhaps) extension in time.

The earliest philosophers to give coherent expression to a theory of this kind were the Greeks, Leucippus and Democritus (about 460–350 B.C.). We owe to Leucippus the first clear statement of philosophic materialism, namely, the reduction of all reality to the primary qualities of matter. The denial of qualitative differences between the elements was combined with an atomic theory of matter which was conceived as split up into an infinite number of minute reproductions of itself, these "atoms" being invisible to the eye, eternal and unchangeable, and differing from one another only in shape and size. The scientific development of this point of view by Democritus was an outstanding philosophical achievement which marked a definite stage in the progress of the speculative thought of antiquity.

Although material pluralism, or atomistic materialism, suffered long periods of eclipse during the middle ages and the Renaissance, it has been revived at intervals and was finally given complete and powerful expression as a result of the great advances made during the last century in physical and biological science. Twentieth century materialism is chiefly associated with the name of Herbert Spencer (1820–1903), who developed an extremely comprehensive system based on three current doctrines which were just then achieving remarkable triumphs in the respective realms of chemistry, physics and biology. These doctrines were the atomic theory, the principles governing the distribution and conservation of energy, and the Darwinian theory of evolution by natural selection. In a swift and temporarily overwhelming advance, philosophic materialism reached its zenith. But its success was a transient one. Before the end of the century it was already beginning to stagger under the powerful blows of its opponents, and during the years that have since elapsed it has ceased to be regarded as a tenable metaphysical theory. It can probably be safely stated that it will never again be revived unless it be in so changed a form as to be unrecognizable. Briefly, its downfall may be said to be due to three inherent defects. In the first place the concepts and principles on which it is based are merely descriptive in character, that is, they do no more than give an account of what actually occurs, or is presumed to occur, in the world, and do not even begin to provide any kind of genuine explanation of reality. Not only this, but secondly, modern analysis has shown that most of the conceptions of conventional materialism, so far from corresponding to anything really concrete, are most probably no more than abstractions from, or constructions made up of, the content perceived by minds in sense-experience or perception. Thirdly, materialism has never yet been able to give an account of the origin of mind which could possibly be accepted as a satisfying one, while its consequent attempts to dismiss mind as unreal or at most real but ineffective, have been extremely facile and altogether unconvincing.

Spiritual Pluralism.—There remains spiritual pluralism, and it is to this type of theory that the name "pluralism" is most commonly understood to apply at the present time. It is the belief that the world consists ultimately of an indefinite number of beings, essentially spiritual in character. Its origin can be traced back, albeit in a vague form, even to the obscure hylozoism of the ancients, who regarded all nature as alive and informed with a countless number of animate beings, to whose activities all her manifestations were due. But at this epoch the distinction between the physical and the mental had not begun to emerge clearly, and only when this occurred was it possible for the development of spiritual pluralism to take place.

But it was not till the coming of Leibniz (1646) that spiritual pluralism at last received definite and coherent statement, together with logical development. Leibniz started from a conception of mind directly opposed to that which had been given currency by Locke and the English empiricists. The latter regarded the mind as a passive receiver of impressions from objects external to it. But Leibniz realized that it is the essence of mind to be active. In his famous work, the *Monadology*, he elaborated the theory that reality consists of an infinite number of individual forces or agents, psychic in nature, which he termed "monads." These individual minds or spirits exhibited every degree of mental development and complexity, from that of beings even higher than man (the "angels") right down to that of psychic entities of so low an order that Leibniz described their being as a *mens momentanea* or mere flash of conscious awareness. In this hierarchy of mind a complete continuity from one level of development to another was postulated.

Leibniz conceived each monad as reflecting within itself the rest of the universe from its own particular "standpoint." The perceptions of each monad were partly conditioned by its particular level of development, and constituted the appearance to it of all the other monads. But Leibniz met with great difficulty at this point. He had conceived the monads as absolutely independent reals with no ground of connection between them. But how could the appearance of beings other than itself arise in such an isolated entity as a monad, which, being "windowless" (as Leibniz put it), was impervious to external influence? Leibniz tried to solve this difficulty by his doctrine of "Pre-established Harmony," which involved the introduction of the idea of God into his system. According to this doctrine the development of the universe is the working out of a plan conceived by God when he created the monads. Each monad contains the principle of its own development, but the course of that development is so arranged that, at any instant, the unfolding order of phenomena within each monad is an accurate representation of the rest of the universe at that instant. This may be illustrated by the analogy of a number of clocks set going by the watchmaker so as always to keep time with one another, though actually there is no connection between them.

The spiritual pluralism of Leibniz, though it continued to exert a dominant influence in Germany until the time of Kant (1724–1804), did not find much vogue among English-speaking philosophers until comparatively recent times. During the last years of the 19th and the early years of the present century, however, it was adopted and developed, in the reaction against crude materialism, by one or two influential thinkers, including Howison in America and the late James Ward in England. Though his system is founded on that of Leibniz, Ward introduced very considerable modifications, exposing the weaknesses of the orig-

inal theory and endeavouring to eliminate them. He pointed out that pluralism has to explain away three difficulties. Two of these are concerned with what he calls respectively "the upper limit" and "the lower limit" of pluralism. If we are to make reality at all intelligible we must, with Leibniz, postulate continuous development of the monads. But from what did this development originate and how was it set going? We can trace it downwards to ever lower levels, but we cannot find within it the principle and the explanation of its own origin. On the other hand, whither is it tending? A mere plurality of independently developing beings cannot contain any indication of a satisfying explanation which shall harmonize, and give point to, the manifold separate developments. Thirdly, there is the old difficulty, encountered by Leibniz, as to the impossibility of interaction between the monads if these are really independent individuals.

Ward comes to the conclusion that a thoroughgoing pluralism is untenable. It must be supplemented by a principle of unity which, while it does not destroy the conception of the monads as real individuals having a "substantival" and not a merely "adjectival" existence, at the same time enables us to get rid of the difficulties raised by a pure pluralism. Ward finds his unifying principle in a theistic theory, conceiving God as a supreme being transcending the world of the many and yet immanent in it. On the one hand God, as creator, originates monadic development; on the other, He stands as the supreme unity to a harmonious co-existence with whom that development is for ever more nearly approaching. Moreover, as immanent in the world, He mediates the interaction between the monads.

It is impossible to enlarge here upon the metaphysical theory thus outlined. It must suffice to point out that it has many important possibilities and merits serious consideration. Moreover, it is a healthy corrective to the cruder forms of materialism, for while the latter are ultimately based on conceptions which can be shown to represent pure abstractions, spiritual pluralism starts from a fact of which each of us is certain from his own immediate experience, namely, the concrete existence of such a thing as an individual "mind," or better, perhaps, "spirit."

A form of spiritual pluralism is being developed in America by the Personal Idealists; while in England Wildon Carr has propounded an interesting monadism with especial reference to the philosophical importance of Einstein's principle of relativity and its apparent implication of the reality and profound significance of the existence of individual observing minds.

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PLURALITY, a term applied particularly to the holding of two or more offices by the same person (called then a *pluralist*). In ecclesiastical law, plurality, or the holding of more than one benefice or preferment, was always discountenanced, and is now prohibited in England by the Pluralities Act, 1838, as amended by the Pluralities Act, 1850, and the Pluralities Acts Amendment Act 1885. By the latter act a provision was made that two benefices might be held together, by dispensation of the archbishop on the recommendation of the bishop, if the churches be within four miles of each other, and if the annual value of one does not exceed £200. (*See* Benefice.)

In the United States, the term is used in election law to denote the number of votes which a candidate has received for a public office in excess of the number received by any one of two or more other candidates.

PLURALITY OF CAUSES, in logic, is the view that one and the same kind of effect can be produced in different cases by different causes. This is quite distinct from the question whether the cause of an effect is as a rule a complex or multiplicity of several or many constituent or contributory factors or conditions. Assuming the complexity of each cause, there still remains the further question whether any one of several separate causes can produce the same kind of effect as another. In other words can one cause ever act vicariously for another? (Hence the alternative, and less ambiguous name, "vicarious causes.") J. S. Mill is the best known advocate of the doctrine of plurality of causes. Examples taken from daily experience seem to support the view. Many different causes can produce death for example. For most practical purposes the doctrine holds good. The whole system of substitutes, in peace and in war, is based on it. But for practical purposes many effects are sufficiently similar, although they are really very different when closely scrutinised. The *total* state called death is very different according as one cause or another led to it. The holding of coroner's inquests is based on the assumption that a close examination of the state of a dead body can help to determine the precise cause of death in each case. Similarly with all cases in which details matter. The total effect produced by one kind of cause is never precisely the same as that produced by any other. So that strictly speaking the doctrine of plurality of causes is not true. But where the interest is centred in broad kinds of effect, and differences of detail do not matter much, there the doctrine holds good for all practical purposes.

See J. S. Mill, *System of Logic* (1875 etc.); J. Venn, *Empirical Logic* (1889); J. Welton, *Manual of Logic* (1896).

PLUSH. Plush fabrics are characterized by a fur-like or velvet pile surface somewhat typical of the short hairy pelts of certain animals as, for example, the seal and otter. A plush pile surface is developed in woven fabrics by causing a series of tufts of pile to project more or less vertically from a foundation texture. The tufts of pile virtually consist of short lengths of warp threads usually of silk, artificial silk or mohair yarn interwoven with the foundation fabric in such a manner that the tufts of pile are looped under the picks of weft by which they are securely retained in the fabric.

PLUTARCH (Gr. Πλούταρχος) (*c.* A.D. 46–120), Greek biographer and miscellaneous writer, was born at Chaeronea in Boeotia. After having been trained in philosophy at Athens he travelled and stayed some time at Rome, where he lectured on philosophy and undertook the education of Hadrian. (There seems no authority for this statement earlier than the middle ages.) Trajan bestowed consular rank upon him, and Hadrian appointed him procurator of Greece. He died in his native town, where he was archon and priest of the Pythian Apollo. In the *Consolation to his Wife* on the loss of his young daughter, he tells us (§ 2) that they had brought up four sons besides, one of whom was called by the name of Plutarch's brother, Lamprias. We learn incidentally from this treatise (§ 10) that the writer had been initiated in the secret mysteries of Dionysus, which held that the soul was imperishable. He seems to have been an independent thinker rather than an adherent of any particular school of philosophy. His vast acquaintance with the literature of his time is everywhere apparent.

The celebrity of Plutarch, or at least his popularity, is mainly founded on his 46 *Parallel Lives*. He is thought to have written this work in his later years after his return to Chaeronea. His knowledge of Latin and of Roman history he must have partly derived from some years' residence in Rome and other parts of Italy (*Demosth.* § 2), though he says he was too much engaged in lecturing (doubtless in Greek, on philosophy) to turn his attention much to Roman literature during that period.

Plutarch's design in writing the *Parallel Lives*—for this is the title which he gives them in dedicating *Theseus* and *Romulus* to Sosius Senecio—appears to have been the publication, in successive books, of authentic biographies in pairs, taking together a Greek and a Roman. In the introduction to the *Theseus* he speaks of having already issued his *Lycurgus* and *Numa*, viewing them, no doubt, as bearing a resemblance to each other in their legislative character. Theseus and Romulus are compared as the legendary founders of States. In the opening sentence of the life of Alexander he says that "*in this book* he has written the lives of Alexander and Caesar" (Julius), and in his *Demosthenes*, where he again (§ 1) mentions his friend Sosius, he calls the life of this orator and Cicero the fifth book. (It is quite evident that the

original order of the books has been altered in the series of *Lives* as we now have them.) It may, therefore, fairly be inferred that Plutarch's original idea was simply to set a Greek warrior, statesman, orator or legislator side by side with some noted Roman celebrated for the same qualities, or working under similar conditions. Nearly all the lives are in pairs; but the series concluded with single biographies of Artaxerxes, Aratus (of Sicyon), Galba and Otho. In the life of Aratus, not Sosius Senecio, but one Polycrates, is addressed.

The *Lives* are works of great learning and research, long lists of authorities are given, and they must for this very reason, as well as from their considerable length, have taken many years in compilation. It is true that many of the lives, especially of Romans, do not show such an extent of research. But Plutarch must have had access to a great store of books, and his diligence as an historian cannot be questioned, if his accuracy is in some points impeached. From the historian's point of view the weakness of the biographies is that their interest is primarily ethical. The author's sympathy with Doric characters and institutions is very evident; he delights to record the exploits, the maxims and virtues of Spartan kings and generals. This feeling is the key to his apparently unfair and virulent attack on Herodotus, who, as an Ionian, seemed to him to have exaggerated the prowess and the foresight of the Athenian leaders.

The voluminous and varied writings of Plutarch exclusive of the *Lives* are known under the common term *Opera moralia*. These consist of above 60 essays, some of them long and many of them rather difficult, some too of very doubtful genuineness. Their literary value is greatly enhanced by the large number of citations from lost Greek poems, especially verses of the dramatists, among whom Euripides holds by far the first place. The principal treatises in the *Opera moralia* are the following:—

On the Education of Children; How a Young Man Ought to Hear Poetry, on the moral aspect of Homer and the tragedians, with quotations *On the Right Way of Hearing* (Περὶ τοῦ ἀκούειν) is another educational essay. Among the moral essays may be included: *How a Flatterer may be Distinguished from a Friend, How One May be Conscious of Progress in Goodness,* addressed to Sosius Senecio, consul under Nerva and Trajan; three short essays, *On Having many Friends, On Chance* and *On Virtue and Vice,* mainly valuable for quotations from poets otherwise lost; *Advice to the Married, On the Late Vengeance of the Deity, On the Genius of Socrates, On Superstition, On Exile,* a fine essay plentifully illustrated with quotations; *The Amorous Man,* and the *Gryllus,* an entertaining dialogue proving the moral superiority of many animals over man. The speakers are Circe, Odysseus, and a pig; the pig wins.

Another group includes some physical treatises such as *Precepts about Health,* which do not often coincide with modern ideas; *On the Face of the Moon's Disk,* which throws light on ancient astronomical theory; *Whether Land or Water Animals are the Cleverer; Whether Water or Fire is the More Useful; On Primary Cold; Questiones Naturales* and *On Flesh Eating.* The historical treatises include: *On the Fortune of the Romans,* two essays on the career of Alexander, *Whether the Athenians were More Renowned for War or for Wisdom,* and the famous *De Malignitate Herodoti,* charging Herodotus with unfair treatment of the non-Ionic States. There are also a purely metaphysical work, the *Platonic Questions,* and two political treatises, *Should a Man Engage in Politics when No Longer Young?* and *Political Precepts.* There are also two *Consolations,* one to Apollonius for his son, and one to his own wife for their daughter. There remains a group of his most valuable and interesting works, on archaeological questions generally, and especially religious history. These include *On Isis and Osiris, On the Cessation of Oracles, On the Pythian Responses* (an appendix to the last), and *On the E at Delphi,* of the exclusively ritual discussions; and two miscellaneous works, which contain a vast collection of information and discussions on points of almost every kind, the *Symposiaca* (9 books), and the *Quaestiones Romanae* and *Graecae,* which is of considerable importance to classical archaeology. There is also the collection of *Short Sayings,* divided into (1) of kings and commanders. (2) of Spartans, and (3) of Spartan women. Doubt is thrown on the validity of *The Banquet of the Seven Wise Men, On Fate; Parallels; On Accepted Opinions and the Lives of the Ten Orators.*

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PLUTARCH, of Athens (350?–430), Greek philosopher, head of the Neoplatonist school at Athens, was the son of Nestorius. His main principle was that the study of Aristotle must precede that of Plato, and that the student should be shown the fundamental points of agreement between them. With this object he wrote a commentary on the *De anima* which was the most important contribution to Aristotelian literature since the time of Alexander of Aphrodisias. This critical spirit reached its greatest height in Proclus, the ablest exponent of this latter-day syncretism. Plutarch was versed in all the theurgic traditions of the school, and believed in the possibility of attaining to communion with the Deity by the medium of the theurgic rites. Unlike the Alexandrists and the early Renaissance writers, he maintained that the soul which is bound up in the body by the ties of imagination and sensation does not perish with the corporeal media of sensation. He interposed between sensation and thought the faculty of Imagination, which is the activity of the soul under the stimulus of unceasing sensation, and provides the raw material for Reason. Reason is present in children as an inoperative potentiality; in its pure activity, it is the transcendental or pure intelligence of God. *See* Marinus, *Vita Procli,* 6, 12; Zeller's *History of Greek Philosophy.*

PLUTO, a euphemistic name for the Greek god of the lower world (Gr. Πλούτων), properly Hades, Aïdes or Aïdoneus, "the Unseen." He was the son of Cronus and Rhea, and brother of Zeus and Poseidon. Having deposed Cronus, the brothers cast lots for the kingdoms of the heaven, the sea, and the infernal regions. The last, "the house of Hades," sometimes loosely called Hades, fell to Pluto. Here he ruled with his wife, Persephone, over the other powers below and over the dead. He is stern and pitiless, deaf to prayer or flattery, and sacrifice to him is of no avail; only the music of Orpheus prevailed upon him to restore his wife Eurydice. His helmet, given him by the Cyclopes after their release from Tartarus, rendered him invisible (like the Tarn—or Nebelkappe of German mythology). Being feared, he is usually alluded to by euphemistic epithets: Polydectes (the receiver of many), Clymenus (the Illustrious), Eubulus (the giver of good counsel). But, perhaps by contamination with a god of the fertility of the earth, he is also Pluto, the "giver of wealth" (a name that first occurs in the Attic poets of the fifth century), and at most of the centres of his cult he was so worshipped; At Elis alone he was Hades, the god of the dead. The plants sacred to him were the cypress and narcissus; black victims were sacrificed to him, as to all underworld powers. In art he was represented like Zeus and Poseidon, but sterner; his attributes are a sceptre and Cerberus: he carries the key of the world below

and is frequently in company with Persephone.

PLUTO is the outermost known planet of the solar system, ninth in order of distance from the sun. Its mean distance from the sun is 39.5 times that of the earth; its period of revolution 248 years. Its orbit is so eccentric (e=0.25), that at perihelion passage, as in 1989, Pluto is closer than Neptune to the sun. The inclination of its orbit (17°) and the orientation (longitude of ascending node=110°) are such, however, that the orbits of Neptune and Pluto do not intersect. Pluto is so faint, about 15th magnitude, that a telescope of 20-in. aperture is necessary to see it easily. Because it is so small and so faint its diameter has not been measured, nor has its spectrum been obtained except on a very small scale. The measures of its colour show that Pluto is yellower than Neptune. From the brightness and an assumed albedo (reflecting power) it is inferred that Pluto is probably smaller than the earth, possibly even smaller than Mars. The mass of Pluto, which has been determined from its disturbing effect on Neptune, is about 0.9 that of the earth.

Pluto was discovered as a result of a systematic search instituted by Percival Lowell who thought that the motion of Uranus gave evidence of a trans-Neptunian planet (*Memoirs of the Lowell Observatory,* vol. i, 1915). The discovery was made on Feb. 18, 1930, by Clyde William Tombaugh of the Lowell observatory, while systematically comparing photographs taken on Jan. 23 and 29, 1930, in the search for the planet (*Scientific Monthly,* vol. 34, Jan. 1932). He recognized the new planet by its motion which, near opposition, is much slower than that of the numerous asteroids also recorded on the photographs. When discovered, Pluto was close to the star δ Geminorum, near the position predicted by Lowell.

Other investigators had also predicted the position of a trans-Neptunian planet on the basis of its gravitational effects. Such a prediction by William Henry Pickering based on the motion of Neptune (*Harvard Annals,* 82, No. 3, 1919) also gave a position quite close to the correct one. In spite of the fact that the planet was found near the position indicated by these computations, many astronomers think that the finding of Pluto was due to the thoroughness of the observational search rather than to the theoretical prediction of its position. Considering the small mass of Pluto and the probable errors in the observed and computed positions of Uranus and Neptune, they believe that the discrepancies prior to 1915 were so small that the direct solution of the problem would be indeterminate. (S. B. N.)

PLUTO MONKEY, a guenon, *Cercopithecus mitis,* which takes its name from the black fur of the under parts, passing into blackish gray on the head and back. The violet-coloured face is fringed by large bushy whiskers and surmounted by a white band above the brows. The typical form extends from the Congo to Nyasaland and Angola.

PLUTONIUM. The element plutonium has the chemical symbol Pu and the atomic number 94. It was given its name after the planet Pluto to follow the convention which was used in the naming of uranium and neptunium. Since all of the isotopes are produced synthetically, the atomic weight depends on the particular isotopic composition of any given sample, which in turn depends on the source of the sample. Plutonium occupies a position in the periodic system of the elements as the fifth member of a transition series, the actinide series, which includes the heaviest known elements and in which an inner electronic shell (the 5f shell) is being filled. The electronic structure of the gaseous atom is probably that of the element radon (atomic number 86) plus five 5f, one 6d and two 7s electrons although it may possibly contain six 5f and no 6d electrons. All of the isotopes are radioactive.

History.—The element plutonium was discovered late in 1940 at the University of California in Berkeley, Calif., by G. T. Seaborg, E. M. McMillan, A. C. Wahl and J. W. Kennedy. The first isotope to be discovered was the one of mass 238 formed by the bombardment of natural uranium with 15-Mev deuterons in the 60-in. cyclotron. This led to the production of an isotope, Np^{238}, of the element with atomic number 93 which decays with a 2.0-day half-life by the emission of beta particles to the isotope Pu^{238}. The latter decays by the emission of alpha particles with a half-life of about 90 yr.

TABLE I.—*Known Isotopes of Plutonium and Some of Their Radioactive Properties*

Isotope	Half life	Type and energy of radiation (Mev)
Pu^{232}	36 min.	EC* (≥98%); α† (≤2%) 6.58
Pu^{234}	9.0 hr.	EC (≈96%); α (≈4%) 6.19
Pu^{235}	26 min.	EC (99+%); α (≈0.002%) 5.85
Pu^{236}	2.7 yr.	α 5.75
Pu^{237}	≈40 days	EC
Pu^{238}	90 yr.	α 5.49 (71%), 5.45 (29%)
Pu^{239}	24,400 yr.	α 5.147 (70%), 5.134 (20%), 5.097 (10%)
Pu^{240}	6,600 yr.	α 5.16 (74%), 5.12 (26%)
Pu^{241}	14 yr.	β^- (99+%) ≈0.02; α (≈10^{-3}%) 4.91
Pu^{242}	5×10^5 yr.	α 4.88
Pu^{243}	5.0 hr.	β^- 0.5

*EC=orbital electron capture.
†α=alpha particle emission.

The isotope of plutonium which is of greater importance is the one with mass number 239. This isotope, which decays by the emission of alpha particles with a half-life of about 24,000 yr., was discovered at the University of California in the spring of 1941 by J. W. Kennedy, G. T. Seaborg, E. Segrè and A. C. Wahl. Its importance stems from its property of being fissionable with slow neutrons, a property which makes it useful as a nuclear fuel and a source of atomic or nuclear energy.

The first pure chemical compound of plutonium, free from carrier material and all other foreign matter, was isolated by B. B. Cunningham and L. B. Werner at the wartime Metallurgical laboratory in Chicago, Ill., during Aug. 1942. This isolation marks the first sight of a synthetic element and the first isolation of a weighable amount of an artificially produced isotope of any element.

Occurrence and Production.—Plutonium occurs in nature in uranium-containing ores in a very small concentration. Such plutonium was first discovered in Canadian pitchblende by G. T. Seaborg and M. L. Perlman in 1942. The isotope involved is Pu^{239} which is formed continuously as a result of the absorption of neutrons by U^{238}. The neutrons are those emitted during the spontaneous fission of uranium and those resulting from the action of alpha particles on the near-by light elements, and the concentration of Pu^{239} is determined by the equilibrium balance between its rate of formation and its rate of radioactive decay.

TABLE II.—*Concentrations of Plutonium in a Number of Ores*

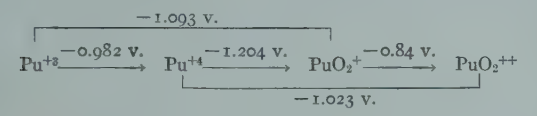
	Pu^{239}/ore
Pitchblendes:	
Canada (13.5% U)	9.1×10^{-13}
Belgian Congo (38% U)	4.8×10^{-12}
Colorado (50% U)	3.8×10^{-12}
Monazites:	
Brazil (0.24% U)	2.1×10^{-14}
North Carolina (1.64% U)	5.9×10^{-14}

By far the most important source of plutonium is that of its production or manufacture in nuclear reactors or chain reacting piles. An example is a nuclear reactor consisting of natural uranium and some neutron-slowing material or moderator such as carbon (graphite) or heavy water (deuterium oxide). In such a reactor a self-sustaining nuclear chain reaction results from the fission of the uranium isotope U^{235} with neutrons, and the excess neutrons are absorbed by U^{238} to form U^{239} which decays by two successive beta-particle emissions to Pu^{239}. After the production of the Pu^{239}, it is separated by chemical means from the highly radioactive fission products and the uranium and other foreign material. The chemical plants for this purpose are massive structures which are engineered to fit the grave problems inherent in handling the extremely high levels of radioactivity caused by the fission products. The manipulations in these plants are carried out entirely by remote control through heavy walls of shielding material.

Uses.—The main use for plutonium, in the form of isotope Pu^{239}, lies in its application for nuclear (or atomic) energy. Nuclear reactors may be built to use the isotope Pu^{239} as fuel. Such reactors, operating in conjunction with the abundant isotope of uranium, U^{238}, can generate energy through the "burning" of the Pu^{239} while they at the same time produce more Pu^{239} as a result of the absorption of neutrons in U^{238}; such a system is known as a "breeder." A fissionable isotope such as Pu^{239} gives rise to an amount of heat energy equivalent of about 10,000,000 kw.hr. per pound when it completely undergoes the fission reaction. In industrial uses the energy may be used in this heat form or, in most cases, converted into the more convenient electrical form by more or less standard turbine equipment. The efficiency with which this heat energy can be turned into electrical power in an industrial nuclear energy reactor would depend on the details of the particular machine, but it seemed likely in the early 1950s that efficiencies of about 20% to 30% might be realized. The isotope Pu^{239} can also be used as an explosive ingredient for nuclear (atomic) weapons. An important use of the by-product radioactive tracers, which may be formed by neutron absorption in various chemical elements inserted into a chain reacting unit, is for fundamental and applied investigations in basic science, agriculture and industry and for fundamental investigations and therapeutic uses in biology and medicine.

Chemical Properties in Aqueous Solution.—The chemistry of plutonium is markedly similar to that of uranium and neptunium, the elements immediately preceding it in the periodic table. The differences in the chemical properties of these elements are due primarily to a progressive increase in the energy required to form their positive ions.

Plutonium exhibits four oxidation states in aqueous solution: +3, +4, +5 and +6. The ionic species corresponding to these oxidation states vary with the acidity of the solution. In moderately strong (one molar) acid the species are Pu^{+3}, Pu^{+4}, PuO_2^+ and PuO_2^{++}. The ions are hydrated but it is not possible at present to assign a definite hydration to each ion. The potential scheme of the ions in one molar acid is the following:



The potentials are in volts relative to the hydrogen-hydrogen ion couple as zero.

The potentials of the various couples are so nearly the same that the intermediate oxidation states are unstable with respect to self-oxidation and reduction:

$$3Pu^{+4} + 2H_2O = 2Pu^{+3} + PuO_2^{++} + 4H^+$$

and,

$$2PuO_2^+ + 4H^+ = Pu^{+4} + PuO_2^{++} + 2H_2O.$$

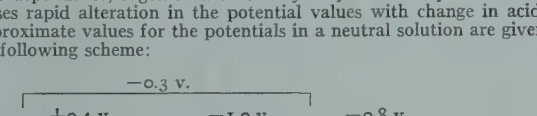
These net changes do not indicate the mechanisms of the reactions, which are more complex. The disproportionation of PuO_2^+ is accompanied by a simultaneous oxidation of PuO_2^+ by Pu^{+4} (with the products PuO_2^{++} and Pu^{+3} formed).

The oxidation-reduction relationships of the plutonium ions in acid solution are among the most intricate to be found in the field of inorganic chemistry.

The values given for the potential scheme in one molar acid may be altered extensively by a change in hydrogen ion concentration or, as a result of the addition of substances capable of forming complex ions, with the plutonium species. Among such substances are sulphate, phosphate, fluoride and oxalate ions, and various organic compounds, especially those known as chelating agents. The tetrapositive and hexapositive ions are complexed appreciably even by nitrate and chloride ions. The stability of the complex formed with a specified anion increases in the order: PuO_2^+, Pu^{+3}, PuO_2^{++}, Pu^{+4}.

The hydrolysis of the ions follows a similar order; Pu^{+4} begins to hydrolyse even in tenth molar acid and in hundredth molar acid forms partly the hydroxide $Pu(OH)_4$ and partly a colloidal polymer of variable but approximate composition $Pu(OH)_{3.85}X_{0.15}$, where X is an anion present in the solution. Further reduction of the acidity results in the hydrolysis of PuO_2^{++} near pH 5, of Pu^{+3} at about pH 7, and of PuO_2^+ at about pH 9.

The potentials of the couples involving either of the two lower states with either of the two upper states have an approximately fourth power hydrogen ion concentration dependence in moderately acid solution. This dependence, together with the hydrolytic effects just mentioned, causes rapid alteration in the potential values with change in acidity. Approximate values for the potentials in a neutral solution are given in the following scheme:



The plutonium ions in aqueous solution possess characteristic colours: blue-lavender for Pu^{+3}, yellow-brown for Pu^{+4} and pink-orange for PuO_2^{++}. Pure solutions of PuO_2^+ had not been prepared at mid-century, and since the ion showed but little absorption of visible light, its appearance in solution was not definitely known. Presumably, concentrated solutions of PuO_2^+ would have a reddish appearance, since the ion absorbs mainly in the shorter and medium wave lengths of the visible spectrum. The colours of the plutonium ions are altered by hydrolysis or complex ion formation. The absorption spectra of plutonium solutions are found to consist of a number of relatively narrow bands. Each oxidation state exhibits a characteristic spectrum that may be used for the quantitative as well as the qualitative analysis for that oxidation state in solution. The most useful bands for this purpose are those at: 9,000, 6,650, 6,030, 6,000 and 5,600 A for Pu^{+3}; at 8,150, 7,300, 7,000, 6,650 and 4,700 A for Pu^{+4}; at 7,750 and 5,690 A for PuO_2^+ and at 9,830, 9,530 and 8,330 A for PuO_2^{++}.

Absorption bands as sharp as those found in plutonium solutions are observed only in solutions of other actinide elements or of the rare earths. It is inferred that in plutonium, as in the rare earths, the bands originate from transitions occurring in protected inner f orbitals.

The aqueous ions of plutonium are strongly paramagnetic and measurements of the magnetism are in agreement with the assignment of five, four, three and two f electrons respectively for the oxidation states from +3 through +6.

Pure solutions of the upper and lower oxidation states may be obtained without difficulty, the former by oxidation with oxidizing agents such as bromate, dichromate or ozone, and the latter by treatment with reducing agents such as sulphur dioxide, hydroxylamine or hydrogen in the presence of platinum black. Because of the disproportionation reactions mentioned previously, the intermediate oxidation states are not stable. However, fairly pure solutions of Pu^{+4} may be obtained by dissolving the hydroxide in warm, concentrated perchloric acid, allowing several days at room temperature for reproportionation and diluting the resulting solution. The disproportionation reaction is rather slow and the concentrations of Pu^{+3} and PuO_2^{++} remain small for several hours.

The pentapositive state is quite unstable in strongly acid solution, but becomes increasingly stable as the hydrogen ion concentration is decreased, down to about ten-thousandth molar. Dilute solutions containing a major proportion of plutonium as PuO_2^+ are stable at this acidity.

The precipitation properties of Pu^{+3} are similar to those of the tripositive rare earth ions, of Pu^{+4} to Ce^{+4}, and of PuO_2^{++} to the corresponding ions of uranium and neptunium.

Tri- and tetrapositive plutonium ions form salts of low solubility with fluoride, oxalate, ferricyanide and hydroxide ions. The tetrapositive ion is precipitated also by iodate and arsenate, even in strongly acid solution.

Pentapositive plutonium may be precipitated as a potassium salt from strong carbonate solutions, but no other solid compounds of this oxidation state are known.

The plutonyl ion, PuO_2^{++}, separates as the beautifully crystalline pink salt $NaPuO_2(CH_3COO)_3$ from solutions containing a high concentration of sodium ions and acetate ions. This salt is analogous to sodium uranyl acetate and sodium neptunyl acetate.

Unlike many of the salts of uranyl uranium, the plutonyl salts are not fluorescent.

Nonaqueous Chemistry.—Many of the most important compounds of plutonium are formed by reactions between solid phases or solid and gas phases, rather than in aqueous mediums. The most interesting and important of these compounds are the oxides, the halides and oxyhalides and the binary compounds with carbon, nitrogen, silicon or sulphur.

TABLE III.—*Known Oxides of Plutonium*

Composition	Colour and appearance	Crystal structure	Density (g./cc.)
$Pu_{1.0-?}$	metallic lustre	cubic; NaCl type	13.89
$PuO_{1.5-1.75}$	silvery, semimetallic	I hexagonal II cubic, modification of rare earth sesquioxides	
PuO_2	greenish-yellow	cubic, CaF_2 type	11.44

Oxides.—The plutonium oxygen system does not present the degree of complexity exhibited by the uranium oxygen system (*see* URANIUM) largely because of the stability of the dioxide. However, analogous behaviour is shown in the variable composition of the so-called sesquioxide ($PuO_{1.5-1.75}$). The monoxide had not been investigated with sufficient care at mid-century to determine whether it also exhibits variable composition.

Plutonium monoxide occasionally appears on the surface of metal exposed to atmospheric oxidation, but is prepared more conveniently by treating the oxychloride with barium vapour at about 1,250° C. The oxide is classified with the interstitial compounds rather than with the typical metal oxides.

The so-called sesquioxide ($PuO_{1.5-1.75}$) is a typical mixed oxidation state oxide, similar to those formed by uranium, praseodymium, terbium, titanium and many other metals. Its composition shows continuous variation with changes in temperature and pressure of oxygen above the oxide. The limits of composition given above are only approximate. Near the lower limit of the oxygen range the structure is hexagonal. A higher proportion of oxygen causes the oxide to assume the cubic C type modification of the rare earth sesquioxides. Plutonium sesquioxide may be formed by the thermal decomposition of the dioxide at about 1,500° C. in high vacuum.

Plutonium dioxide is the most important oxide of the element. Almost all compounds of plutonium are converted to the dioxide upon ignition in air at about 1,000° C. The ignited oxide is chemically inert at ordinary temperatures and has a well-defined composition; for these reasons it is a satisfactory compound for weighing in the gravimetric determination of plutonium.

The dioxide is frequently used as the starting material in the synthesis of other compounds of plutonium. In these cases prolonged high temperature ignition of the oxide is avoided, since this leads to progressive chemical inertness.

Plutonium dioxide was the first compound of the element to be isolated and weighed in pure form and it was in fact the first compound of any synthetic element to be separated in pure form in ponderable amounts. It was also the first compound of a synthetic element to be identified by X-ray diffraction methods (W. H. Zachariasen).

Halides and Oxyhalides.—All of the halides except the tri-iodide may be prepared by the hydrohalogenation of the dioxide or of the oxalate of plutonium (III) at a temperature of about 700° C. With

hydrogen fluoride the reaction product is PuF_4, unless hydrogen is added to the gas stream, in which case the trifluoride is produced. With hydrogen iodide the reaction product is PuOI, and the other oxyhalides may be formed by the addition of appropriate quantities of water vapour to the hydrogen halide gas. Plutonium tri-iodide is produced by the reaction of the metal with hydrogen iodide at about 400° C.

TABLE IV.—*Important Halides and Oxyhalides of Plutonium*

Compound	Colour	Crystal structure	Density (g./cc.)	M.P. (° C.)	B.P. (° C.)
PuF_3	violet	hexagonal, tysonite type	9.32	1,425	2,190*
PuF_4	light brown	monoclinic	7.0	..	..
$PuCl_3$	emerald green	hexagonal, UCl_3 type	5.70	760	1,770*
$PuBr_3$	green	orthorhombic, $PuBr_3$ type	6.69	681	1,510*
PuI_3	bright green	orthorhombic, $PuBr_3$ type	6.9	770*	1,380*
PuOCl	blue green	tetragonal, PbFCl type	8.81	..	..
PuOBr	deep green	tetragonal, PbFCl type	9.07	..	..
PuOI	green	tetragonal, PbFCl type	8.46	..	..

*Estimated value.

The trihalides are appreciably volatile at moderately elevated temperatures and all except the trifluoride may be purified by sublimation in quartz tubes in high vacuum at 800° to 1,000° C.

Except for the trifluoride, the halides are so hygroscopic that they must be handled in an anhydrous atmosphere. The trifluoride shows so little tendency to hydration that the anhydrous salt is obtained directly upon precipitation from aqueous solution.

The crystal chemistry of the halides and oxyhalides of plutonium is closely similar to that of the analogous compounds of the rare earths—a consequence of the fact that these compounds are predominantly ionic and that the cations have nearly the same ionic radii.

Carbides, Nitrides, Silicides and Sulphides of Plutonium.—Plutonium forms several binary compounds which are of interest because of their refractory character and stability at high temperatures. These include the carbide, nitride, silicide and sulphide of the element.

TABLE V.—*Properties of Binary Compounds of Plutonium*

Compound	Colour and appearance	Crystal structure	Density (g./cc.)	Approx. temp. limit for stability in high vacuum (° C.)
PuC	black, semimetallic	cubic, rock salt type	13.99	1,800
PuN	brown	cubic, rock salt type	14.22	1,500
$PuSi_2$	silvery, metallic	tetragonal, $ThSi_2$ type	9.12	1,000
$PuS_{1.33-1.5}$	black	cubic, Ce_3S_4 type	8.41	1,200

The monocarbide is formed by reacting the dioxide in intimate mixture with carbon at about 1,600° C., and the mononitride may be obtained by heating the trichloride in a stream of anhydrous ammonia at 900° C.; it is prepared more easily, however, by reacting finely divided metal with ammonia at 650° C. Although the lower temperatures are favourable to the production of higher nitrides, none are obtained, in contrast with the uranium, nitrogen system in which compositions up to $UN_{1.75}$ are easily realized.

The disilicide is formed when a slight stoichiometric excess of calcium disilicide is heated with plutonium dioxide in vacuum at about 1,550° C. The disilicide is only moderately stable in air and burns slowly to the dioxide when heated to about 700° C.

Plutonium "sesquisulphide" may be prepared by prolonged treatment of the dioxide in a graphite crucible with anhydrous hydrogen sulphide at 1,340°–1,400° C., or by reaction of the trichloride with hydrogen sulphide at 900° C.

Only the most important compounds of plutonium have been mentioned in this article. The number of known compounds is very large. (*See* ATOMIC ENERGY; DEUTERIUM; ISOTOPES; RADIOACTIVITY, ARTIFICIAL.)

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(G. T. SE.)

PLUTUS, properly, the abundant increase of the earth; child of Demeter (*q.v.*) and Iasion; in art, usually shown as a child, alone or in company with Tyche, Eirene, Athena or some other goddess. In popular thought, allegories and comedy, he was represented as Wealth. He was said to be blind.

PLYMOUTH, a city, county borough and seaport of Devonshire, England, 231 mi. W.S.W. of London. Pop. (1951) 208,985. Area 20.5 sq.mi.

Plymouth, the Sutton of Domesday, was afterward divided into the town of Sutton Prior, the hamlet of Sutton Valletort and the tithing of Sutton Ralph. The market, established about 1253, became town property in 1311. In 1292 the town first returned members to parliament. In the 14th century it was often used for armies to and from France and it suffered from French attacks. In 1412 the inhabitants petitioned for a charter, which was granted Nov. 12, 1439, the town being the first in England to be incorporated by act of parliament. In the discovery of the new world it played an important part. Sir John Hawkins was port admiral and (in 1571) M.P. From Plymouth in 1577 Drake set out on his voyage round the world; in 1581 he became mayor and represented the borough in parliament during 1592–93. Sir Humphrey Gilbert (M.P. 1571) sailed on his second colonizing expedition to America in 1583 from the port. Plymouth supplied seven ships against the Armada, and it was in the sound that the English fleet awaited the Spaniards. A stone on a quay at the Barbican records the fact that this was the last port touched by the Pilgrim Fathers on their voyage to America. During the Civil War the town withstood all efforts by the Royalists to take it, and it early declared for William of Orange. Plymouth was created a city in 1928 and the title of lord mayor was granted in 1935. Four years later its area was extended by almost 4,000 ac.

It lies at the head of Plymouth sound, stretching westward from the river Plym toward the mouth of the Tamar, from which it is separated by the township of East Stonehouse and the borough of Devonport, both of which were included in Plymouth in 1914. The water frontage of the "Three Towns" consists of Plymouth sound, with its inlets. The Cattewater and Hamoaze are flanked on the east and west respectively by high ground, on which are built forts. On the western side of the entrance to Cattewater is the Citadel, founded in the reign of Henry VIII and rebuilt by Charles II. It is a specimen of 17th-century military architecture, an irregular bastioned pentagon in trace and during World War II was used as army headquarters and barracks. The adjacent Hoe extends along the northern edge of the sound. To the north is seen the town of Plymouth. In the sound is Drake's (formerly St. Nicholas's) island. The city suffered air raids during World War II, and much of it was destroyed. More than 50,000 houses and buildings had been damaged before the close of 1941. Among churches, St. Andrews, a Perpendicular building of 1480–1520 restored in 1874, was destroyed, only the walls and clock tower remaining.

Plymouth is the seat of a Roman Catholic bishopric founded in 1851, the cathedral, in Wyndham street, being completed in 1858. The building is in the Early English style, and adjoining are the bishop's house and the convent of Notre Dame.

The port of Plymouth in 1311 embraced Plympton, Modbury and Newton Ferrers, and received a customs grant from Richard II. In 1435, 65 cargoes were imported, and in the reign of Elizabeth I it rose to be the foremost port in England. The 18th century saw a great development of trade with Virginia and the West Indies, and this resulted in the establishment of a sugar-refining industry that was maintained into the 20th century.

In 1749 the "town's water" was carried to the Barbican to supply shipping. The port of Plymouth as at present constituted embraces the waters of the Plymouth sound and the Hamoaze. The chief water area within the limits of the port is the sound with its inlets, the Cattewater, Sutton pool, Mill bay, Stonehouse pool and the Hamoaze. The sound itself covers an area of 4,500 ac. and is sheltered from the southwest gales by a breakwater a mile long with a lighthouse at its eastern end. It was constructed in 1841. Cattewater, Sutton pool and Mill bay constitute the three mercantile harbours of Cattewater harbour, Sutton harbour and the Great Western docks, while Hamoaze was set aside for the royal navy. Cattewater harbour has an area of 260 ac. and 8,000 ft. of quayage space. Sutton harbour entered from Cattewater has a quayage space of 4,500 ft. Great Western docks at Mill bay has an outer basin of 35 ac., an inner one of 13.

Steamers sail regularly from Plymouth for Australia, New Zealand, the Cape and North America. The port has productive fisheries. It has also a considerable export and import trade. As a naval station it is second only to Portsmouth. The city is served by the Western Region railway.

The industries of Plymouth include soapmaking, manufacture of chemicals, artificial manure and paper staining. There is some electrical engineering and a clothing factory. Plymouth has returned three members to parliament, from the Drake, Devon-

port and Sutton divisions, since 1918.

Lady Astor, the first woman elected to the house of commons, was returned in 1919.

PLYMOUTH, a town of Massachusetts, U.S., 37 mi. S.E. of Boston, on Plymouth bay; a port of entry and the county seat of Plymouth county. It is served by the New York, New Haven and Hartford railroad and in summer by buses from Boston. Pop. (1950) 13,608 and in 1940 it was 13,100. Visitors to the number of many thousands are brought annually by the historic interest of the town and its attractions as a summer resort. The modern town has important manufacturing industries (notably the largest cordage works in the world, with its own steamers bringing cargoes of sisal fibre from Yucatan). Plymouth has two large woollen mills. Other important industries are cranberry culture, herring fisheries, curtain manufacturing, boat building and repairing and zinc and tack manufacturing. Lobster fishing is also an important industry.

Plymouth was the landing place of the Pilgrims and the first permanent settlement by Europeans in New England. Plymouth Rock, the granite boulder on which the Pilgrims stepped from the shallop of the "Mayflower" on Dec. 21, 1620, was placed in 1920 on the spot it originally occupied, under a protecting portico of granite, presented by the Society of Colonial Dames, and this part of the water front has been made a part of the state park system. Rising behind the Rock is Cole's hill, where during their terrible first winter in America the Pilgrims buried half their number, levelling the graves and sowing them with grain in the spring to conceal their losses from the Indians. Burial hill (the site of the first fort and of a watchtower) contains the graves of William Bradford and others of the original Pilgrims, though the oldest stone is dated 1681. In the Registry building are the original records of Plymouth Colony, the will of Miles Standish, the original patent of Jan. 23, 1630, and many other interesting historical documents. Pilgrim hall, a large stone building erected in 1824, houses a rich collection of relics of the Pilgrims and of early colonial times. The oldest house still standing (the Crowe house) was built in 1664, and many others antedate the Revolution. In the northern part of the town is the National Monument to the Forefathers (of Maine granite), designed by Hammatt Billings, which was dedicated on Aug. 1, 1889, 30 years after the cornerstone was laid. Plymouth dates its founding from the landing of the Pilgrims. It was never incorporated as a town, but in 1633 the general court of the Colony recognized it as such by ordering that "the chiefe government be tyed to the towne of Plymouth."

It remained the seat of government until 1692, when Plymouth Colony was united to Massachusetts Bay Colony.

PLYMOUTH, a borough of Luzerne county, Pennsylvania, U.S., on the west bank of the Susquehanna river, opposite Wilkes-Barre. It is on federal highway 11 and is served by the Lackawanna and the Delaware and Hudson railways. Pop. (1950) 13,021; 1940 federal census 15,507. Plymouth is in the midst of the anthracite fields, and is surrounded by the beautiful scenery of the Wyoming valley. The mining, preparation and handling of anthracite provide the principal occupations, but there are various other industries. Plymouth was settled in 1769 under the auspices of the Susquehanna Company of Connecticut, by colonists from Plymouth, Litchfield county, Conn., and other places in New England, and became a centre of the conflict known as the Pennamite-Yankee war. (*See* WYOMING VALLEY.) The first coal shipped from the anthracite region was sent from Plymouth in 1808 by Abijah and John Smith. The borough was incorporated in 1866.

PLYMOUTH BRETHREN, a community of Christians who received the name in 1830 when Rev. J. N. Darby (1800–1882) induced many of the inhabitants of Plymouth, Eng., to associate themselves with him for the promulgation of his opinions.

Although small Christian communities existed in Ireland and elsewhere calling themselves Brethren, and holding similar views, the accession to their ranks of Darby so increased their numbers and influence that he is usually called the founder of Plymouthism. Darby had been a curate in Wicklow 1825–27, when he felt himself constrained to leave the Anglican communion; going to Dublin, he became associated with several devout people who called themselves Brethren. Among these were A. N. Groves and J. G. Bellett, who rank among the founders of the movement. In 1830 Darby at Plymouth won over many people to his way of thinking, among them the well-known biblical scholar Samuel Prideaux Tregelles. During the next eight years progress was rapid, and communities were founded in many towns of England.

In 1838 Darby went to reside in French Switzerland and made many disciples. French Switzerland remained the stronghold of Plymouthism on the continent, and for his followers there Darby wrote two tracts, *Le Ministère considéré dans sa nature* and *De la Présence et de l'action du S. Esprit dans l'église.* The revolution in the canton Vaud brought persecution to the brethren in the canton and in other parts of French Switzerland.

He returned to England, and his reappearance was followed by divisions among the Brethren at home. These divisions began at Plymouth. Benjamin Wills Newton, head of the community there, who had been a fellow of Exeter college, Oxford, was accused of departing from the testimony of the Brethren by reintroducing the spirit of clericalism. Unable to detach the congregation from the teacher, Darby began a rival assembly. The majority of the Brethren out of Plymouth supported Darby, but a minority remained with Newton. The separation became wider in 1847 on the discovery of supposed heretical teaching by Newton. In 1848 another division took place. The Bethesda congregation at Bristol, where George Müller was the most influential member, received into communion several of Newton's followers and justified their action. Out of this came the separation into Neutral Brethren, led by Müller, and Exclusive Brethren, or Darbyites, who refused to hold communion with the followers of Newton or Müller. The Exclusives, who were the more numerous, suffered further divisions. An Irish clergyman named Samuel O'Malley Cluff had adopted views similar to those of Pearsall Smith, who preached a doctrine of sanctification called "Death to Nature" as an antidote to the supposed prevalent Laodiceanism, and when these were repudiated seceded with his followers. The most important division among the Exclusives came to a crisis in 1881, when William Kelly and Darby became the recognized leaders of two sections who separated on a point of discipline. This was followed (1885) by the disruption of the strict Darbyite section, two communions being formed out of it upon points of doctrine.

The theological views of the Brethren differ considerably from those held by evangelical Protestants. They make the baptism of infants an open question and celebrate the Lord's Supper weekly. Their distinctive doctrines are ecclesiastical. They hold that all official ministry, whether on Episcopalian, Presbyterian or Congregationalist theories, is a denial of the spiritual priesthood of all believers, and sets aside the Holy Spirit's guidance.

See W. B. Neatby, *A History of the Plymouth Brethren,* 2nd ed. (London, 1902).

PLYMPTON ST. MARY and **PLYMPTON ST. MAURICE** or ERLE, two small adjacent towns in Devon, England, 5 mi. E.N.E. of Plymouth, on the Western Region railway route. Pop. (1931), Plympton St. Mary, 5,077, Plympton St. Maurice, 1,075. The earthworks on which in the 12th century Richard de Redvers reared his Norman castle at Plympton St. Maurice were probably of British origin; traces of the castle remain. A Saxon document dated 904 records a grant by Edward the Elder to Asser, bishop of Sherborne, of 12 manors in exchange for the monastery of Plymentun. Plympton St. Mary has a Decorated and Perpendicular church, with a lofty tower of the later period. Near it are remains of the former Augustinian priory of Plympton, founded by William Warelwast, bishop of Exeter (1107–36). They include an Early English refectory with Norman undercroft, the kitchen and other fragments; but there are no remains of the great priory church. There are several old houses in the town, together with a guildhall dated 1696, and a grammar school founded in 1658, of which Sir Joshua Reynolds' father was master.

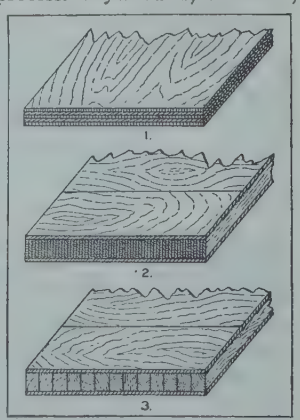
PLYNLYMON (*Plynlimmon, Pumplumon, Pumlumon, Penlumon: pump* means fire: *lumon,* chimney flag or beacon; *pen,* head), a mountain of Wales 2,463 ft. high, about 10 m. from Machynlleth and Llanidloes. It is composed of Bala (Ordovician) grits and stands out above the high plateau of Central Wales. There are three summits with a *carnedd* (stone-pile, probably a military or other landmark, rather than the legendary barrow or tomb) on each. Plynlymon is the source of the Rheidol, the Llyfnant and the Clywedog, the Wye and the Severn.

The morasses of Plynlymon saw many a struggle, notably the war between Owen Cyfeiliog (*fl. c.* 900), prince of Powys, and Hywel ab Cadogan. Here also Owen Glendower unfurled the banner of Welsh independence; from here, in 1401, he harassed the country, sacking Montgomery, burning Welshpool, and destroying Abbey Cwm Hîr. Aberystwyth obtains its water from a reservoir on the mountain slopes. There are slate quarries, also old lead and copper mines in the district. The district west, north and east of Plynlymon is a very wild and lonely moorland, with very few roads. Around the sharp northern and western edges of the moorland are deep-cut ravines with waterfalls.

PLYWOOD. Board made of several plies or *veneers* (*q.v.*) of wood, glued together with the object of obtaining comparatively large sheets free from some of the natural defects and limitations of timber. *Rotary cut* (peeled) or *sliced* veneers are used, if necessary joined edgewise, to form each ply, and thus large sheets with an unbroken surface are obtained; the plies are sorted as to their appearance, and the inferior (knotty, shaky or sappy) material is generally utilized for the interior of the board (*core*), leaving the best plies for the outer surfaces (*face and back*).

The natural tendency of wood to shrink, swell and warp is effectively neutralized, and the comparatively low tensile strength of wood along its grain is greatly improved upon, by carefully cross-graining the plies. In the result, a large flat board of wood is produced, practically unaffected by climatic influences, and possessing considerably higher shearing, braking and bending properties than ordinary wood of similar thickness.

The plies are glued (*cemented*) together under considerable pressure, different adhesives being used, dependent upon whether or not the gluing process is aided by heat, and also varying according to the kind of timber used. The veneers are wet when produced from the log and may be glued together either in their wet state or after a pre-drying process. Plywood is, therefore, grouped into two classes, *wet* and *dry* produce. The drying of veneers before being cemented and pressed into a board prevents their shrinkage during the pressing process and, therefore, helps to make a better plywood board. If the veneers be glued wet the drying process is combined with the glueing operation in the press, and this often produces face checks (cracks) on the surfaces of the finished board.



PLYWOOD CONSTRUCTION
(1) Ordinary plywood, (2) laminated plywood, (3) batten board

In the construction of plywood the different types are shown in the drawing.

The outside plies of the laminated type and of batten boards may be occasionally superimposed on so-called crossbandings (veneers lying crosswise to the outer plies) to ensure still greater rigidity of the boards.

Utilization.—Plywood is used wherever a material is required to cover large unbroken spaces with a light but strong and rigid sheeting, *e.g.*, in *cabinet-making* (for panels, bed-ends, sides of wardrobes, tabletops, etc.); *building* (for doors, wall panelling, ceilings, flooring, etc.); *coach-building* (for coach panels, motor bodies, railway carriage roofs and walls, vans, baby carriages, etc.); *shipbuilding* (for bulkheads, etc.); *boxmaking* (for tea chests, rubber chests, cases, etc.); *engineering* (for aeroplane fuselages, hydroplane hulls, bed plates, etc.); etc.

Although there is evidence that the principle of "plying" thin strips of wood into panels to ensure permanent flatness was known and practised in very early days of civilization and was continued by the cabinet-maker and builder all over the world, mechanical production of plywood originated comparatively recently, *i.e.*, in the eighteen-eighties, when the first factories specializing in the production of plywood were erected in Russia. The industry has since spread to all parts of the world wherever large timber resources are available and where widespread employment of the material makes local manufacture profitable.

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PNEUMATIC CONVEYING is the utilization of the conveying power of air in motion. It will be realized that conveyance of material through a pipe-line, either by suction or blast, is ideal; since there are no mechanical parts in the path of the material there cannot be any contamination by lubrication. Another advantage is the greater flexibility of pneumatic plant; every part of the hold of a vessel, for instance, can be reached by flexible tubes for the purpose of unloading a grain cargo, whereas a more complex mechanical plant is rigidly fettered to straight lines.

BY COURTESY OF MESSRS. HENRY SIMON, MANCHESTER
PNEUMATIC COAL-HANDLING PLANT AT BRIMSDOWN POWER STATION

The *modus operandi* of a pneumatic plant is extremely simple and is as follows:—Into a grain cargo in a vessel, for instance, a hosepipe is lowered, the nozzle at the end of which admits a mixture of air and grain. The other end of the pipeline enters tangentially into the upper part of a cylindrical receiver from which the air is exhausted, while the grain is withdrawn from the cone-shaped lower end by an air-trap, without, however, admitting air into the receiver. When comparing pneumatic with mechanical handling devices the former have but one drawback, viz.: the greater consumption of driving power for handling a given quantity. This, however, is more than compensated for by the greater flexibility and the hygienic value of the system. The first grain handling installation on the Duckham system was known as "Mark Lane No. 1," and was built, under the personal supervision of the inventor, by the East Ferry Road Engineering Co., during the closing years of the 19th century. This was one of the most epoch-making revelations of all systems of handling. The plant is mounted on a pontoon and sucks the grain through a nozzle and pipeline from the ship's hold to an elevated receiver, whence it runs by gravity to a given point, via an air trap; an exhauster furnishes a partial vacuum by pipes connected with the said receiver.

As has been shown, the material in a pneumatic plant floats, so to speak, in a current of air, from which it is separated by its specific gravity when the air expands in the receiver. The heavier the material to be handled the greater must be the speed of travel of the air in the conveying pipes in order to ensure the floating of the material in and with the air. If the air speed is too slow the tendency will be for the material to separate from the air and thus block the pipes, especially such portions as are horizontally disposed, or nearly so. Obviously, therefore, installations for such heavy materials as coal and ash require more powerful pumps. Similar installations in which, however, draught is induced by "steam jets" are successfully employed for handling ash from boilers.

Owing to the advantages accruing from the use of pneumatic handling plants new avenues for their employment are being constantly opened. Such varied materials as grain, small coal,

chemicals, ashes, potatoes, and even red-hot rivets and artillery shells are now successfully handled by pneumatic means. An offshoot of this system is the pneumatic tube, which is largely employed in postal and telegraph offices, as well as in great variety in business offices and stores. (G. F. Z.)

PNEUMATIC DISPATCH, a system of transporting written dispatches through long tubes of small diameter by means of compressed or rarefied air. It was introduced in 1853 by J. Latimer Clark between the Central and Stock Exchange stations of the Electric and International Telegraph company in London, the stations being connected by a tube 1½in. in diameter and 220yd. long, the messages, enclosed in a tight fitting carrier, being drawn through it by the production of a partial vacuum at one end. The system was improved in 1858 by C. F. Varley, who used compressed air to return the carriers in the other direction. By this means it was possible to develop two-way working on single tubes between a central station, equipped with air-compressing plant, and outlying offices.

Pneumatic dispatch tubes are in extensive use in many countries for both telegraphic and postal matter.

Radial System: This system of pneumatic dispatch was developed by R. S. Culley and R. Sabine in connection with the British post office for the transmission of telegrams between local collection and delivery offices and the central telegraph office; it became generally more economical, under normal conditions of traffic and distance, to transmit these messages by tube rather than wire so dispensing with the employment of skilled telegraphists.

Since that time the system has been greatly extended both in London and the large provincial towns until in London alone the street tubes laid measure over 57m., varying in length from 100yd. to nearly 4,000yd. These tubes are either single tubes working in both directions or, where the traffic warrants it, separate "up" and "down" tubes are installed. In a few cases intermediate offices are connected to the tubes, but this practice is not desirable as delay in transmission is caused and direct tubes are installed wherever possible.

A further development is the laying of pressure worked trunk tubes from the central telegraph office to an outlying centre, messages being transmitted between this centre, where a pumping plant is also installed, by radial tubes to offices in the vicinity.

House Tubes and Street Tubes.—Short tubes known as house tubes are in use in a large number of offices and telephone exchanges for carrying messages from the public counter or one room to another. These tubes, which are generally 1½in. in diameter, are made of brass and are operated by hand-worked pumps where the distance is short and the traffic inconsiderable, or by means of small electrically driven centrifugal fans or other form of blower. The pressure or vacuum required is only a few inches as shown by water gauge and the blowers are either run continuously or switched on as required.

Street tubes used by the post office are generally 2¼in. in diameter, but 3in. and 1½in. tubes are also used. These tubes when laid in the street are in all cases made of lead and are protected by cast-iron pipes. Where they are run in buildings or subways brass tubing is used. They are operated by electrically driven compressors.

Carriers.—The carriers, in which the messages are inserted for dispatch, are made of gutta-percha covered with felt, the front of the carrier being provided with a buffer or head formed by several layers of felt fitting the tube closely, the messages being held in place by means of an elastic band. The 3in. carriers hold 50, the 2¼in. carriers 20 and the 1½in. carriers five ordinary forms. The carrier used on house tube systems are generally made of fibre the messages being retained by a clip.

Working.—The air for working the street tubes is supplied by electrically driven compressors, the standard pressure and vacuum used being 10lb. and 6½lb. per sq.in. respectively, which values give approximately the same speed.

The time of transit of a carrier through a tube at the ordinary pressures in use is given approximately by the empirical formula:—

$$t = \cdot 00872 \sqrt{\frac{l^3}{Pd}}$$ where l = length of tube in yards,

d = diam. in inches, P = effective air pressure in pounds per sq. inch,

t = transit time in seconds.

For vacuum working the formula is:—

$$t = \frac{\cdot 00825}{1 - \cdot 234\sqrt{15 \cdot 5 - P_1}} \sqrt{\frac{l^3}{d}}$$ where P_1 = effective vacuum in lb. per sq. inch.

The horse-power required to propel the carrier is approximately

$$\text{for pressure H.P.} = (\cdot 574 + \cdot 0011P)\sqrt{\frac{P^3 d^5}{l}}$$

$$\text{for vacuum H.P.} = (5 \cdot 187 - 1 \cdot 214\sqrt{15 \cdot 5 - P_1})\, P_1 \sqrt{\frac{d^5}{l}}$$

For a given transit time the horse-power required is less in the case of vacuum than in the case of pressure working, owing to the lesser density of the air column moved: thus, for example, the transit time under 10lb. pressure is the same as with a vacuum of 6½lb., but the horse-power required is as 1·83 to 1. A 2¼in. tube 1m. long worked at 10lb. per sq.in. pressure will have a transit time of 2¼min. and will theoretically require 3·35 h.p. to work it. Actually owing to various losses 25% more power must be allowed for the compressor. When working at the same pressure the transit time for a 2¼in. tube is 16% more than that for a corresponding length of 3in. tube, but the power required is 50% less and it is therefore advisable to use the smallest tube compatible with the traffic.

Dispatching and Receiving Apparatus.—On house tube systems, where only low pressures and vacuum are required, simple forms of terminals consisting of cast-iron bodies with flap-doors are used, the doors being opened to insert a carrier, and through which carriers are automatically ejected, the door closing behind them. Dispatching funnels are also used at the open end of tubes.

On the street tubes, however, a more complicated type of apparatus, called a double slide switch, is used at the central office. This consists of two vertical sections of tube secured into top and bottom plates and provided with a handle by which it is rocked between two fixed horizontal plates forming a frame, three holes being provided in each plate, the air supply pipe and dispatch tube being connected to the centre holes and funnels for inserting or removing the carriers to the other holes. The carrier on arriving is received in one of the vertical sections and on the rocker being moved to its second position the carrier drops out through the funnel provided. The second tubular section is now ready to receive a carrier, which is discharged when the rocker is returned to its first position. The process is reversed for dispatching purposes, and where the tube is used for two-way working one position is reserved for sending and one for receiving. The supply of air, and whether under pressure or vacuum for sending or receiving purposes, is controlled by a three-way valve mounted under the switch.

A form of flap terminal, the door being restrained by a spring in view of the higher pressures used, is installed at the outlying offices in place of the receiver originally used and the carrier is automatically ejected.

On tubes where the carrier reaches a high velocity, a by-pass is provided near the terminal by means of which the air pressure behind the carrier is released after it has passed this point so as to reduce the velocity of egress. This terminal is also used for the dispatch of carriers to the central office, the supply of air to the tube being changed from vacuum to pressure at the latter point in response to a bell signal. When used for dispatching the by-pass is cut off by a remote control valve. Carriers may be diverted from one tube to another by means of a moving section of tube directly or remotely controlled.

A further development is the provision of an automatic rotat-

ing pneumatic tube switch by which carriers can be transferred between street and house tubes for both sending and receiving purposes, the terminals used being of the flap type.

Circuit System.—Another system of working is the circuit system, in which stations are arranged in circular or loop lines round which the carriers travel in one direction only, both pressure and vacuum being used. This system is in use in Paris and other Continental cities. In Messrs. Siemens' system a continuous flow of air is maintained in the tube, the carriers being dispatched or removed through a form of rocking switch so designed that the movement of carriers in other parts of the system is not interfered with. More usually carriers, or trains of carriers, are dispatched at intervals, the air supply being cut off when not required. Long tubes may be sectionalized, means being provided at the various stations by which air is only supplied to the working section.

In America, under the Batcheller system, tubes 8in. in diameter are used for postal purposes in New York, Brooklyn, Chicago, Philadelphia, Boston and St. Louis; tubes 6in. and 10in. in diameter are also used. These tubes are essentially cast-iron pipes, carefully bored and equipped with suitable apparatus for introducing and receiving the carriers. The carriers for the 8in. tubes consist of cylindrical steel shells about 7in. in diameter and 21in. long (inside dimensions) with suitable end covers. They are fitted with lubricated soft bearing or packing rings. The working capacity of these tubes may be taken as 8lb. per container and six containers per minute, or 2,880lb. of postal matter per hour in each direction, the average speed being about 25 to 30m. per hour.

The dispatching apparatus is similar to that in the Siemens' system, consisting of two sections of tube supported in a rocking frame so arranged that either section may be brought into line with the main tube, in which a current of air is constantly flowing. One of these sections maintains the continuity of the tube while the other section is loaded. The switch is then swung over by means of a pneumatically operated piston to insert the carrier in the tube. A by-pass is provided to maintain the flow of air in the tube during the operation. As soon as the carrier leaves the switch it trips a lever and the switch automatically returns to the loading position. A time lock is used to prevent carriers being dispatched too frequently. The carrier is received by an air cushion formed by closing the end of the tube with a sluice gate, a by-pass being provided before this point to allow the air to flow away.

In addition to their use for postal and telegraphic purposes pneumatic dispatch tubes are used for internal communication in offices, hotels, etc., also in shops for the transport of money and bills between the counters and the cashiers' desk. Pneumatic tubes are also used for the unloading and transport of grain and other commodities in bulk between warehouses and ships, trains, etc.

BIBLIOGRAPHY.—The system as developed for use in the British post office by Messrs. Culley and Sabine is described in a paper in *Min. Proc. Inst. Civil Eng.*, vol. xliii. The same volume contains a description of the Paris system and of experiments thereon by M. Bontemps, and also a discussion of the theory of pneumatic transmission by Prof. W. C. Unwin. Reference should also be made to a paper by C. Siemens (Min. Proc. Inst. Civ. Eng. vol. xxxiii.), describing the Siemens' circuit system; to *Les Télégraphes*, by M. A. L. Ternant (1881); to the report to Congress of the American joint commission on pneumatic tube mail service, March 1919; General Post Office engineering department's *Technical Instruction No. X* (Pneumatic Tubes); a short paper by J. McGregor on the automatic system in the post office (*P.O. Elec. Eng. Journal*, vol. xix., part 1), and to Kempe's *Engineer's Year Book*. (J. McG.)

PNEUMATIC TOOLS comprise various classes of hand tools which are operated by compressed air power. They are divided in two general classes according to the principle of operation (1) percussion, (2) reciprocating motor-driven. Under percussion tools are grouped rivetting, chipping and sand rammers, pneumatic diggers, rock drills, paving breakers, etc.; each using a piston or plunger for striking a blow. Reciprocating motor-driven tools employ a reciprocating piston air motor to drive a spindle from which power can be used for drilling, grinding, etc. The tools under this classification include pneumatic drills, grinders, motors, hoists, etc. Pneumatic tools usually operate best when supplied with compressed air at 90 lb. gauge pressure.

The principal uses of pneumatic tools occur on those classes of work where it is not possible or not advisable to take the work to a machine. A pneumatic tool, being a self-contained power unit, can be taken to the work and various operations performed rapidly, with a minimum of manual labour. Pneumatically operated tools are suited for a wide variety of uses because of their availability, the adaptability of compressed air power, the absence of danger and because they embody within small confines a great range of power and action. Other advantages are rugged construction, simplicity, and easy operation.

Pneumatic Hammers are made in a variety of sizes and types, and the name for each is governed largely by the work to be performed. This group covers chipping, rivetting, scaling and caulking hammers, diggers, paving breakers, rock drills and similar implements. (*See* BLASTING.) Each class of work requires a hammer of a particular size, weight, speed and strength of blow. In the operation of most rivetting hammers air enters the hammer at the air inlet in the handle, the amount of air being controlled by the throttle valve which is actuated by a trigger. After passing the throttle valve the air is conducted through the passage in the handle to the valve chamber containing the operating valve and valve box. The valve is moved back and forth in the valve box by the action of the air pressure on its differential areas. As the valve moves forward it admits air back of the piston, throwing it forward against the rivet set, which forms the rivet head. The piston, after striking a blow, is returned for another stroke by air admitted to the front of the cylinder, which is covered by the piston in this position. Hammers for chipping, caulking and scaling are very similar in construction to the rivetting hammer. The chipping hammer is used to clean foundry castings, for caulking the seams of boilers and tanks, pipe joints, etc., saving two-thirds the time required by hand work.

Sand Rammers have a long barrel containing a piston having a projecting rod at one end, to which the tamping butt is attached. In action the piston moves rapidly up and down in the barrel lifting the tamping butt from the sand and returning it with considerable impact against the material to be rammed. The ramming of certain classes of moulds in foundry work, a long and arduous task when done by hand, is rapidly accomplished by means of the pneumatic sand rammer. Machine-rammed moulds are harder and more uniform than those rammed by hand, resulting in better castings. Floor rammers are used for working on large moulds on the floor, and the bench rammer on small bench moulds. These tools strike up to 800 blows per minute. The force and number of blows are regulated by the operator with a throttle. The sand rammer is also used to tamp the back-fill in trenches in city streets, where it is desired to pack the sand solidly and by this means avoid the subsequent settling.

Pneumatic Drills.—Portable pneumatic drills are divided into four general types: the reversible drill, the nonreversible drill, the woodborer and the close-quarter drill. The several types are also given certain other minor divisions according to the use to which they are put, such as boring, reaming, tapping, flue rolling and stud-setting. The larger sizes of pneumatic drills use a four-cylinder V-type air motor, with one crank throw provided for each pair of cylinders in the same cross plane. The power from the crankshaft is transmitted to the drilling spindle by gears arranged to give the spindle speed desired. A feed screw with a feed handle is used to feed the drill up to the work. A main valve, of rotary type, controls the supply of air to each of the four cylinders, the air supply reaching this main valve through a throttle handle. At the upper end of the main valve is located a centrifugal speed governor which limits the speed of the drill motor after it has passed the point of maximum horsepower.

Another small class of pneumatic drills employ a three-cylinder radial air motor, the three cylinders being in one plane with one crank provided for all three cylinders. The power from the crank is transmitted through a spindle and gears to the point

where the drill chuck is attached. The main spindle also serves as a valve controlling the air to the three cylinders, greatly simplifying the construction of the tool. These tools are used for light drilling in metal, in the automobile assembly plants for running up nuts, and for running in screws. They are equipped with either feed screw, spade handle or breast plate. The close-quarter type of pneumatic drill uses a two-cylinder, double-acting motor to give a flat and compact construction. The power is transmitted from the crankshaft to the spindle by a train of gears. A feed screw is located at the end of the spindle and can be turned by means of the ratchet handle. This type of drill is used for drilling, reaming and tapping in cramped spaces where the usual drill cannot be employed.

Pneumatic Grinders.—The pneumatic grinder is similar in general construction to the air drill except that a higher speed motor, operating at 3,000 to 6,000 r.p.m. is used. The motor is directly connected to a spindle upon which is mounted the grinding wheel. These tools are used in all kinds of service where a portable grinding tool, buffer or polisher is needed and are widely used in foundries and machine shops, monumental stone shops and automobile body plants.

Pneumatic Diggers.—Pneumatic diggers, of the same operating principle as a rivetter, are made in two styles. A short-handle type is used in tunnel work or in close quarters and an extension-handle type for trench or shaft. Pneumatic diggers are a recent development for work where it is desired to replace the hand pick. The tools are used for loosening up clay, hard ground, etc. The pneumatic digger consists of a hammer having a piston which strikes against a blade or scoop. The blows of the piston drive the blade into the ground, prying it loose. One man with such a tool is the equal of six men using ordinary hand picks.

Rock Drills.—The removal of solid rock in excavation for foundations, trenches, highways, in mining and many other projects calls for the use of a vast number of compressed-air rock drills. These tools are made in a wide variety of sizes for all classes of work, depending on the size and depth of the hole to be drilled, the hardness of the rock and other factors. In the jackhammer type of rock drill, compressed air enters to a throttle valve in the handle and then passes to a flapper type of plate valve, which controls the movement of the piston. On the forward or downward movement of the piston it strikes against the shank of the drill steel, and imparts a cutting action to the points of the steel. On the back stroke of the piston it slides over a fluted rifle bar which turns the piston and causes it to turn the drill steel. Rotation of the drill steel is desired in order that the cutting edges on the end of the drill steel may be put in a new position with regard to the rock being drilled. A ratchet mechanism ensures rotation in one direction. To blow out the cuttings and dust from the hole in the rock, air is passed down through the rifle bar and piston and through the drill steel to the cutting face.

These tools make it possible to drill holes in rock for inserting the explosives which blast out rock. One rock drill bores 100 to 150 ft. of hole in rock in an eight-hour day, while the best a man can do using a hand hammer and steel is not more than 8 to 10 ft. a day. Rock drilling requires the use of pointed drill steels which must be resharpened as the cutting edges become worn and dulled by the rock. This is done by compressed-air-operated drill steel sharpening machines in which after the drill steel is heated and inserted quickly shapes and sharpens the steel by means of dies many times faster than by hand methods.

Paving Breakers.—The paving breaker is a tool somewhat similar in construction to the rock drill and is used in demolition work such as breaking up pavement, tearing out concrete walls, foundations, etc. This tool uses a pointed chisel or steel, but it is not rotated. The absence of the rotation mechanism simplifies the general construction of the paving breaker. Paving breakers are extensively used by public utilities for making openings in the pavement prior to installing or repairing sewer pipes and connections. They are usually operated from a portable air compressor, mounted on a motor truck, which can be quickly taken to the place where the work is to be done. One man operating one tool is able to break out more pavement in a given time than 12 to 15 men using hand sledges and steels.

Air Motor Hoists.—These are made in a range of sizes to handle loads from 500 lb. up to 20,000 lb. This style of hoist is equipped with a high-powered air motor of the four-cylinder type which is geared to a hoisting drum. A feature of these hoists is the automatic brake which acts to hold the load at any point after the air pressure is shut off. When the motor is operating, air passes to the brake through a connecting tube releasing it. When the air is shut off at the throttle, the brake is automatically applied. These air hoists are widely used in industrial plants for handling material too heavy to be easily lifted by one man. In machine shops they lift and place heavy parts on lathes, milling machines and planers. (*See* MECHANICAL HANDLING.) Air hoists are particularly suited for foundry work because the operation is not affected by dust, dirt or fumes, and they are not damaged by overloading. Another type is the portable hoist, which can be mounted wherever convenient; *i.e.*, to a post or timber. It is used for pulling cars, skidding timbers, pulling a scraper on backfill work, and dozens of other applications.

Tools for Railroad Track Work.—Special pneumatic tools have been developed for a number of applications in railroad track construction and maintenance. There are pneumatic tie tampers for tamping ballast under ties, pneumatic spike pullers, spike drivers, rail drills, pneumatic wrenches, rail bonding drills and others. Tamping ballast with pneumatic tampers is much easier than swinging a pick or tamping with a hand bar. The air tampers strike a uniform blow all day long and produce a uniform track. In removing old rail, the old spikes must be pulled. A compressed-air-operated spike puller draws 10 to 15 spikes per minute. One such machine does as much work as eight to ten men using hand claw bars. The pneumatic wrench removes the nuts or runs up nuts on the joint bolts much faster than is possible with a hand wrench. The air-operated spike driver puts down the spikes in a fraction of the time required by a hand hammer. A pneumatic rail drill bores a $\frac{7}{8}$ in. hole through the web of a rail in from 25 to 30 sec. Small holes for signal wires are drilled with pneumatic rail bonding drills at the rate of 60 per hour. (R. A. Lu.)

PNEUMATOLYSIS, in petrology, discharge of vapours from igneous magmas and effects produced by them on rock masses (so called from Gr. πνεῦμα, vapour, and λύειν, to set free). In volcanic eruptions the gases given off by molten lavas are powerful agencies. The slaggy clots of lava thrown out from the crater are so full of gas that when they cool they resemble spongy pieces of bread. The lava streams as they flow down the slopes of the volcano are covered with white steam clouds, while over the orifice of the crater hangs a canopy of vapour which is often darkened by fine particles of ash.

Cause of Volcanic Explosions.—Most authors ascribe volcanic explosions to the liberation of steam from the magma which held it in solution, and the enormous expansive powers which free water vapour possesses at very high temperatures. Of these gases the principal are water and carbonic acid; but by analysis of the discharges from the smaller fumaroles, for the active crater is generally too hot to be approached during an eruption, it has been ascertained that hydrogen, nitrogen, hydrochloric acid, boron, fluorine, sulphuretted hydrogen and sulphurous acid are all emitted by volcanoes. A recent lava flow has been likened to a great fumarole pouring out volatile substances at every crack in its slaggy crust. Many minerals are deposited in these fissures, and among the substances produced in this way are ammonium chloride, ferric chloride and oxide, copper oxide (tenorite and cuprite) and sulphur; by reacting on the minerals of the rock many zeolites and other secondary products are formed. These processes have been described as "juvenile" or "posteruptive," and it is believed that the amygdales which occupy the cavities of many porous lavas are not due really to weathering by surface waters percolating in from above, but to the action of the steam and other gases set free as the lava crystallizes. The zeolites are the principal group of minerals which originate in this way together with chlorite, chalcedony and calcite. The larger

cavities (or geodes) are often lined with beautiful crystal groups of natrolite, scolecite, thomsonite, stilbite and other minerals of this order.

Solfataric Activity.—The active gases were evidently in solution in the magma as it rose to the surface. Geologists now believe they are of subterranean origin like the lava itself, and an essential or original component of the magma. Long after a lava has cooled down and become rigid the vapours continue to ooze out through its fissures, and around many volcanoes which are believed to be extinct there are orifices discharging gas in great quantities. This state of activity is said to be solfataric, and a good example of it is the volcano called the Solfatara near Naples. The numerous "soufrières" of the West Indies are further instances. The prevalent gas is steam with sulphuretted hydrogen and carbonic acid. White crusts of alum, various sulphates, and sulphides such as pyrites, also carbonates of soda and other bases, are formed by the action of the acid vapours on the volcanic rocks. The final manifestation of volcanic activity in a solfataric region may be the discharge of heated waters, which have ascended from the deep-seated magma far below the surface, and make their appearance as groups of hot springs; these springs persist long after the volcanoes which give rise to them have become extinct.

Role of Hot Waters.—It is now believed by a large number of geologists and mining engineers that these ascending hot waters are of paramount importance in the genesis of some of the most important types of ore deposits. Analyses have proved that the igneous rocks often contain distinct though very small quantities of the heavy metals; it is also established beyond doubt that veins of gold, silver, lead, tin and mercury most commonly occur in the vicinity of intrusive igneous masses. At Steamboat, Nev., hot springs, probably of magmatic origin, are forming deposits of cinnabar; at Cripple Creek, Colo., and in many other places gold-bearing veins occur in and around intrusive plugs of igneous rock. Tin ores in all parts of the world are found in association with tourmaline granites, and in all cases the veins bear evidence of having been filled from below by hot waters set free during the cooling of the igneous intrusions. Volcanic rocks are consequently the parent sources of many valuable mineral deposits, and the agency by which they were brought into their present situations is the volatile products discharged as the magma crystallized. The process was no doubt a long one and it is most probable that both steam and water took part in it. In what condition the metallic ores are dissolved and by what reactions they are precipitated depends on many factors only partly understood. The tin ores are so often associated with minerals containing boron and fluorine that it is quite probable that they were combined with these elements in some way, but they were deposited in nearly all cases as oxides. Other gaseous substances, such as sulphuretted hydrogen, carbonic acid and hydrochloric acid, probably have an important part in dissolving certain metals; and the alkaline carbonates, sulphides and chlorides have been shown by experiment to act also as solvents. In these ore deposits not only the heavy metals are found, but often a much larger quantity of minerals such as calcite, barytes, fluorspar, quartz and tourmaline which serve as a matrix or gangue, and have been deposited by the same agencies, and often at the same time as the valuable minerals.

Alteration of Minerals.—In their passage upward and outward through the rocks of the earth's crust, these gases and liquids not only deposit minerals in the fissures along which they ascend, but attack the surrounding rocks and alter them; the granite or other plutonic mass from which the vapours are derived is specially liable to transformation, probably because it is at a high temperature, not having yet completely cooled down. Around the tin-bearing veins in granite there is extensive replacement of feldspar and biotite by quartz, tourmaline and white micas (the last-named often rich in lithia). In this way certain types of altered granite are produced, such as greisen (*q.v.*) and schorl rock (*see* SCHORL).

In the slates adjacent to the tin veins tourmalinization also goes on, converting them into schorl-schists. The alteration of feldspar into kaolin or china clay is also a pneumatolytic process, and is often found along with tin veins or other types of mineral deposit; probably both fluorine and carbonic acid operated in this instance along with water. Equally common and important is the silicification of rocks near mineral veins which carry gold, copper, lead and other metals. Granites and felsites may be converted into hard cherty masses of silica; limestones undergo this transformation very readily; at the same time they are regarded as rocks very favourable to the deposition of ores—probably the great frequency with which they undergo silicification and other types of metasomatic replacement is one of the main causes of the abundance of valuable deposits in them. The process known as propylitization, which has extensively affected the andesites of the Hungarian goldfields, is believed to be also a consequence of the action of pneumatolytic gases. The andesites change to dull, soft, greenish masses, and their original minerals are to a large extent replaced by quartz, epidote, chlorite, sericite and kaolin. Around granites intrusive into serpentine and other rocks containing much magnesia, there is often extensive steatization, or the deposit of talc and steatite in place of the original minerals of the rock. Some of the apatite veins of Canada and Norway accompany basic rocks of the gabbro group; it has been argued that the apatite (which contains phosphorus and chlorine) was laid down by vapours or solutions containing those gases, which may play a similar part in the basic rocks to that taken by fluorine and boron in the pneumatolytic veins around granites. In the country rock around the veins scapolite (*q.v.*), a lime alumina silicate, containing chlorine, often is substituted for lime-feldspar.

These extensive changes attending the formation of mineral veins are by no means common phenomena, but in many plutonic masses pneumatolytic action has contributed to the formation of pegmatites (*q.v.*). (J. S. F.)

PNEUMONIA. An inflammation of the lung, pneumonia was recognized as a disease by the ancients, but no progress was made in knowledge of it until the time of Leopold Auenbrügger (1761) and René Laennec (1819), when order was brought into its classification. From then until the bacteriologic era opened, classification depended on the anatomic or clinical features, and adjectives such as lobar, lobular, broncho-, interstitial, pleural, double, central, croupous and catarrhal were used. Other pneumonias were called aspiration, contusion, hypostatic or terminal pneumonias, depending upon the cause. Although after 1880 various bacteria and viruses were known to cause pneumonia, the modern etiologic classification did not become popular until about 1920. Precise knowledge of the bacterial or other cause permits the use of specific therapeutic or preventive measures and other rational management in the control of the disease. More than 50 different infectious, physical or chemical causes of pneumonia were known by mid-20th century, but of these, relatively few were of common occurrence. Pneumonias may be grouped as follows: (1) Primary; *i.e.*, those caused by pathogenic cocci, bacilli, viruses and fungi which attack the lung primarily; (2) pneumonias which occur in more or less specific forms as part of systemic infections such as tularaemia, psittacosis, tuberculosis, rheumatic fever, rickettsial and protozoal diseases, lupus erythematosus and others; (3) pneumonias caused by mixed infection induced by physical or mechanical injury of the lung such as shock, debility, passive congestion, aspiration of foreign bodies or fluid, obstruction to airway, atelectasis, trauma and others; and (4) pneumonias caused by the aspiration of oil, by chemicals, by roentgen rays, deficiency of vitamin A, by allergic reaction and other causes.

PRIMARY PNEUMONIAS

Pneumococcal Pneumonia.—The modern era of this disease began with the discovery of the pneumococcus in 1880 by G. M. Sternberg and its association with pneumonia by A. Fraenkel and A. Weichselbaum in 1884. F. Neufeld first pointed out serologic differences among strains of pneumococci in 1910, and shortly afterward F. S. Lister and A. R. Dochez independently classified them into types. Much fundamental work on the bacteriology, etiology, pathogenesis, clinical aspects and treatment of pneumococcal pneumonia was done after 1911 at the Hospital of the Rockefeller Institute under the leadership of Rufus Cole and Oswald Avery. Extensive bacteriologic, clinical and epidemiologic

contributions on the subject were also made notably by Russell Cecil and Maxwell Finland in the United States and by Max Gundel in Germany. Specific immune serum for treatment was largely developed in the 1920s when it reached its greatest effectiveness and popularity as the refined, concentrated form, only to be displaced by the sulfonamide compounds after 1935. These in turn were superseded by penicillin in 1942 and by other antibiotics later.

Etiology.—There are about 75 types and subtypes of pneumococci of which only a few are of clinical importance. Types 1, 2, 3, 4, 5, 7, 8 and 14 account for about 80% of all pneumococcal lobar pneumonias. Type 1 pneumococcus causes about 30% of cases; type 2, 20%; type 3, 10%, the remainder are caused by pneumococci of other types which, in contrast with those mentioned, often are present in the pharyngeal secretions of healthy persons.

Pneumococci are rarely primary invaders of the lung. In almost all instances there is evidence of some preceding condition which injures the lung and favours invasion, especially minor infections of the respiratory tract commonly called colds; chilling of the body, and debilitation. The pneumococci which become invasive are acquired by inhalation from outside sources or are already present in the pharynx; the first circumstance indicates that pneumonia may be a contagious disease contracted from other patients or carriers of pneumococci, and the second that it may arise as an autogenous infection. Under certain conditions when the general resistance is lowered by serious conditions, and in old age, the pneumonia is apt to be atypical (Cole) or lobular (bronchopneumonia); that is, it does not behave like the lobar form. The onset is gradual, consolidation may not occur, and the course is irregular. The pneumococci causing this form are usually of the higher numbered types, indicating that they are part of the normal flora of the respiratory tract which have become invasive.

Pathology.—Pneumococci reach the lung by way of the air passages, settle in an area where they find circumstances suitable for growth, and give rise to an area of inflammation conditioned by complex factors, among which partial immunity, allergy and nervous influences seem to play an important role. The inflammation spreads rapidly, and soon involves part or most of a lobe, first as congestion then with an outpouring of fibrin and polymorphonuclear leukocytes into the alveolar spaces. The exudate becomes rather solid and grayish over a period of several days, and finally, when recovery occurs, it softens and is resorbed. During this time pneumococci often enter the blood stream and may localize on the valves of the heart, the meninges or elsewhere. The pleura may be invaded resulting in empyema.

Epidemiology.—Pneumococcal pneumonia is contagious at times, but susceptibility to infection is largely controlled by the resistance of the host. The prevalence of pneumonia usually parallels the incidence of minor respiratory tract infections, and both are most common in cold months, but may occur at any season. Many household epidemics are on record. Pneumonia varies in incidence from year to year and to some extent in its clinical manifestations, depending on the type of pneumococci predominant at the time. It is most prevalent in the temperate climates but may occur anywhere. All races are susceptible. Men are affected more often than women because of greater hazards to exposure. It is commonest in early adult life.

Pneumococcal pneumonia declined steadily in incidence after 1900, and at an increased rate after sulfonamides and antibiotics were introduced. In 1949 pneumonias of all kinds were the sixth most important cause of death in the United States.

Clinical Features.—Lobar pneumonia in its typical form is a strikingly clear-cut disease. It often develops in a person who has a cold and usually begins suddenly with a chill, pain in the chest, high fever, cough and thick rusty sputum, which are present in variable combinations and constitute the chief symptoms of the disease. Other symptoms and signs are headache, vomiting, rapid respiration, cyanosis, dyspnea, tachycardia and herpes. The course in untreated patients may last a week or more, during which severe illness occurs. Characteristic signs in the chest in the early stage are those of congestion which soon become those of consolidation of the lobe or lobes with dullness and other physical signs (bronchial breathing, egophony, pectoriloquy and occasionally friction sounds). Roentgenography is of great aid in observing the location and course of the pulmonary lesion. In patients who develop pleural effusion or empyema, signs of fluid appear. The leukocyte count and sedimentation rate of red cells are usually increased, the blood culture often becomes positive, and the specific polysacchride of the causative pneumococci may appear in the urine.

In certain patients the onset is gradual and the course is not so characteristic, giving a clinical response named "atypical" pneumonia by R. I. Cole.

In those who recover, improvement often begins abruptly as a crisis with rapid fall of temperature and general improvement unless other involvement occurs. Death is caused by toxaemia, overwhelming infection, circulatory collapse or extrapulmonary localization, the chief of which are empyema, meningitis, endocarditis and arthritis. In patients treated with penicillin or sulfadiazine the course usually is terminated promptly within 24 to 48 hr.

The mortality rate of untreated patients is 30%; of those treated with penicillin, aureomycin or sulfadiazine about 5%. Five per cent is probably a minimum rate, since there are certain instances in which therapy is unsuccessful or for various reasons may be delayed or not available. The disease is more fatal to infants, debilitated or senile patients or to those with other chronic disease such as diabetes, hypertension or nephritis, or when treatment is postponed. Overwhelming infection may occur which does not respond to any treatment.

One attack of pneumonia does not necessarily predispose a person to another. There are certain persons who, for unknown reasons, have repeated attacks of pneumonia caused by the same type or by different types of pneumococci, or by other bacteria. There is some evidence of a hereditary tendency to the disease in certain family groups.

Treatment.—Diagnosis should be established by clinical, roentgenologic and bacteriologic methods. Material for tests must be obtained before treatment is begun. Penicillin should be given promptly by injection or by mouth daily until the temperature becomes normal and for several days afterward. Aureomycin, chloramphenicol, terramycin or sulfadiazine may be used if penicillin is unavailable or ineffective. Possible toxic effects of sulfadiazine and antibiotics should be anticipated. Appropriate symptomatic treatment must be given.

Prevention.—The fundamental measures of prophylaxis are the prevention of minor respiratory tract infections and other conditions which predispose to pneumonia and the control of carriers of pneumococci. The maintenance of general health by adequate food, exercise and rest are important. Specific vaccines prepared with killed pneumococci have been used experimentally but are of little practical value. Vaccine consisting of specific pneumococcal polysaccharides is said to be of superior value, but is of practical advantage only among well-controlled groups.

Haemolytic Streptococcal Pneumonia.—This form of pneumonia is less common than the pneumococcal forms and occurs often as a complication of influenza as it did in the pandemic of 1918–19. It is caused by any of the 27 or more types of group A beta haemolytic streptococci. It may occur in sporadic or in epidemic form, the latter depending on the epidemiology of the predisposing viral infection.

The bronchi and trachea are involved more often and more severely than in pneumococcal pneumonia. There is lymphangitis and more involvement of interstitial tissues. The exudate is haemorrhagic and streptococci are numerous. The pleura is usually inflamed.

Symptoms.—The symptoms are not characteristic. The disease often begins as an aggravation of the mild primary disease. There are fever, cough, pain in the chest, chills or chilly sensations and prostration, in widely varying degrees of severity. The sputum is often thin, mucopurulent and bloody. Bacteriaemia is uncommon. The leukocytes may be normal or increased in number. Massive pleural effusion with serosanguineous fluid or

empyema are common. The patient may be mildly sick or extremely so with ashy pallor, cyanosis and evidence of circulatory collapse. The pulmonary signs are chiefly those of atypical pneumonia with patchy areas of congestion and areas of undeveloped consolidation. Flatness is present over an effusion.

The mortality rate in untreated patients at mid-20th century varied from 10% to 60%; not enough patients had been treated to judge the beneficial effects of penicillin or sulfadiazine.

The diagnosis is made chiefly by the epidemiologic characteristics of the disease and by the predominance of a specific type of haemolytic streptococcus of group A in the sputum, blood or exudate. Retrospective diagnosis may be made by the demonstration of specific precipitins, antistreptolysin and antifibrinolysin in the blood. Roentgenography is useful in determining the nature and extent of the pulmonary lesions.

Treatment.—Penicillin is indicated and must be given in large dosage. Sulfadiazine is said to be of some value. The symptomatic treatment is the same as for other pneumonias. Pleural effusions should be repeatedly aspirated and if empyema is present, penicillin must be injected into the cavity.

Staphylococcal Pneumonia.—The staphylococcus, like the haemolytic streptococcus, may invade the lung particularly during minor viral infections of the respiratory tract. A large outbreak occurred in the influenza pandemic of 1918–19. Staphylococcal pneumonia may occur in epidemic form during epidemics of viral diseases of the respiratory tract or as sporadic cases.

The causative staphylococci are usually those which are normally present in the patient, but they may be acquired from outside sources. They invade pulmonary tissue injured by other infectious agents, chiefly viruses, and give rise to patchy areas of inflammation. In the course of several days, multiple small abscesses form and tend to coalesce.

The symptoms usually are imposed upon a previous cold and usually begin gradually. They vary greatly in intensity from mild to fulminating and are characterized by a high irregular fever, chills or chilliness, sweating, cough and uncharacteristic staphylococci-laden sputum. The leukocyte count is variable and bacteriaemia seldom occurs. In severe cases there are cyanosis and prostration. As abscesses form and discharge, the sputum becomes purulent, increases in amount and the signs change from those of patchy pneumonia to those of cavitation. The mortality rate is variable; in some series of cases, most patients recovered and in others 70% died.

Diagnosis is based on the epidemiologic aspects of the disease, the presence of great numbers of staphylococci in the sputum, their presence in the blood stream or in exudates, and the signs and roentgenographic evidence of the development of multiple cavities.

Treatment.—Penicillin is the agent of choice, but it must be given in large amounts parenterally.

Friedlander's Bacillus Pneumonia occurs chiefly in debilitated or senile persons. The onset is often like that of pneumococcal pneumonia, and the disease is often characterized by a severe course, with chills, but with less pronounced evidence of true consolidation of the lung and an irregular fever. The sputum is bloody, mucinous or mucopurulent and contains a predominance of capsulated gram-negative coccobacilli. A chronic form with cavitation resembling tuberculosis may develop.

Because the disease occurs chiefly in debilitated or senile persons its mortality rate is high, and is said to be 50% to 70%.

The treatment is not as effective as for other forms of pneumonia. Good results were reported from the use of sulfadiazine. Only a few patients up to 1951 had been treated with streptomycin, and the results were said to be good.

Rarer forms of pneumonia are caused by *H. influenzae, B. anthracis, P. pestis, Coccidioides immitis, Coxiella burneti* (Q fever) and others. (*See* TUBERCULOSIS for tuberculous pneumonia.)

The Viral Pneumonias.—While much attention was given to the bacterial forms of pneumonia because of their seriousness, little was paid to pneumonias of viral origin because they seldom caused death and the technique of handling viruses remained difficult. Viral diseases such as measles were known to be characterized by pneumonia as early as 1861, but the nature of the pulmonary lesion was obscured by the activity of secondarily invading bacteria. However, the experimental production of bacteria-free pneumonia with the viruses of vaccinia, influenza and others, and the absence of bacteria in the lungs of patients who died during the influenza pandemic of 1918 left no doubt that viruses cause pneumonia. Pneumonia is a common occurrence in smallpox and influenza and has been described in chickenpox, vaccinia and lymphocytic choriomeningitis. Between 1920 and 1938 European and U.S. roentgenologists demonstrated unsuspected pneumonias by roentgenography in ambulatory and bedfast patients with undifferentiated mild respiratory tract diseases. These pneumonias were different from the bacterial forms.

Wide interest in the subject followed the establishment of viral pneumonias as a separate entity by H. A. Reimann in 1938. Apparently there are a number of viral pneumonias caused by different agents, some occurring in epidemic form and others as sporadic cases. The epidemic forms of pneumonia apparently represent the severest cases of otherwise mild infections of the respiratory tract called colds, grip or pharyngitis. The sporadic cases resemble the pneumonias of psittacosis or ornithosis, but since the agents causing the latter can be seen microscopically and are influenced by antibiotics, their classification as viruses is questioned.

Confusion in nomenclature of this group of diseases is not surprising since up to 1951 the cause or causes of them had not been discovered. The term "atypical pneumonia" became widely used, but is undesirable since in Cole's view, any pneumonia not clinically the same as typical pneumococcal pneumonia is atypical, and furthermore pneumonia is absent in the majority of mild diseases of which most viral pneumonias represent the severest stage. The broad term "viral pneumonia" is preferable since all evidence, except the final proof of demonstrating a virus, indicates that viruses are the cause. The name "viroid" was proposed to include both pneumonic and nonpneumonic forms of the respiratory tract disease in question.

In the search for the cause of viral pneumonias, about 25 related or unrelated viruses had been encountered up to 1951, most of which proved to be natural residents of animals used in the experiments, so that the cause or causes still were unknown. However, all other facts pointed to a viral cause, especially the epidemiologic aspects of the disease, the absence of special bacteria in the sputum, the absence of any bacteria in the lungs at necropsy, and experiments in which volunteers inhaled filtered bacteria-free exudates from patients with the disease and developed respiratory tract disease several days later with or without pneumonia, identical with the natural form.

The pneumonic forms begin with symptoms of gradually increasing severity over several days. There is headache, dry paroxysmal cough, slight sore throat, sweating and fever which is irregular, but seldom high, a pulse rate often relatively slow, slight indefinite or absent physical signs of pneumonia which are strikingly less than the roentgenographic evidence of pulmonary invasion, a normal or slightly elevated leukocyte count and rate of sedimentation of erythrocytes, followed by recovery by lysis and few complications. Encephalitis occurs in a small number of patients. Pleural effusion is uncommon. The mortality rate is 0.2%. The few deaths which occur are caused by circulatory collapse, severe infections and by the presence of other disease or complications.

The incidence of viral pneumonias varies from year to year but great increases in number of cases come with epidemic periodicity. Epidemics occur at any season of the year, but most commonly in the winter months. During the years 1941 to 1944 viral pneumonias outnumbered all other forms of pneumonia in military groups and among civilians.

Diagnosis is made on the epidemiologic aspects, the clinical behaviour, the leukocyte count and the absence of the usual bacterial causes of pneumonia in the sputum. Retrospective diagnosis may be aided by the ability of the serum to agglutinate erythrocytes at low temperature (the cold-agglutinin test) after the tenth day

of disease in 50% of cases. Diagnosis of the pneumonia of influenza of Q fever, of psittacosis and of ornithosis, is made by isolation of the respective causative agents or the serologic demonstration of their activity by appropriate tests. The pneumonia of psittacosis, ornithosis, Q fever, coccidioidomycosis, tularaemia, tuberculosis and other known forms may closely resemble the viral pneumonias of unknown cause and must be differentiated since specific therapy for some of them is available. Penicillin and aureomycin are effective for psittacosis and ornithosis, and streptomycin for pneumonia caused by the influenza bacillus and for tularaemia and tuberculosis.

Pathologically, viral pneumonias are characterized by involvement of the structure of the lung and the larger air tubes, and an exudate composed chiefly of monocytic cells. The mucous membrane of all or of parts of the upper respiratory passage may be inflamed and invaded with mononuclear cells. No bacteria are present in the tissue unless secondary invasion occurs.

Treatment.—Penicillin, sulfonamide compounds and streptomycin have no effect on viral diseases. They are used if complications occur caused by pathogenic bacteria susceptible to their effects. Aureomycin, chloramphenicol and terramycin apparently shorten the course in many instances; in others, no effect is evident. Convalescent serum and roentgentherapy are of no value. Oxygen is helpful for cyanosis and dyspnea.

THE OTHER GROUPS OF PNEUMONIAS

Pneumonias of Systemic Diseases.—Pneumonia may occur as an integral part of many systemic diseases. It may dominate the clinical picture, or be a minor factor or not occur at all in tuberculosis, tularaemia, plague, undulant fever, glanders, syphilis, rheumatic fever, ascariasis, periarteritis nodosa, sarcoidosis and many others. The pneumonia is usually not characteristic clinically and is often obscured by symptoms of disease elsewhere. Pathologically it may assume features characteristic of the respective disease. The treatment is that of the disease itself.

Pneumonia of Mixed Infections.—The pneumonias brought about by injury to the lung or interference of their self-cleansing process by obstruction of the airways, foreign bodies, tumours, failing circulation, submersion in or aspiration of fluids, trauma after surgical operation, shock and many other causes, are usually caused by a mixture of various kinds of bacteria which reside habitually in the air passages and are enabled to become invasive by the presence of injured tissue. Pneumococci, influenza bacilli, haemolytic streptococci and staphylococci are most frequently implicated. The treatment is primarily directed at correcting or removing the primary cause, the use of antibiotic agents according to the sensitivity of the invading bacteria to the respective agents, and appropriate supportive measures.

Pneumonia Caused by Noninfective Agents.—The aspiration of oil over long periods or in large amounts often causes a form of chronic reaction commonly called lipoid pneumonia. Long exposure to roentgen rays may also give rise to a pulmonary reaction called irradiation pneumonitis which leads to fibrosis. The inhalation of certain irritating chemicals and certain gases used in warfare or for industrial uses, or fumes from certain molten metals may cause forms of pneumonia. Allergic pneumonitis or Loeffler's syndrome apparently represents the hyperergic inflammatory reaction of sensitized lung tissue to repeated exposure to the specific antigen. The treatment of each condition mentioned under this heading is the removal of the offending agent.

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PNEUMONOCONIOSIS is the term applied to an industrial or occupational disease of the lungs which has for its distinguishing feature the formation of fibrous tissue in the lungs—pulmonary fibrosis.

The disease has been recognized since earliest times. Pliny and Hippocrates described it, and so did Agricola in 1556. It was gold mining in South Africa that focused attention on dust diseases of the lungs about the turn of the 20th century. In 1916 the Miners' Phthisis Prevention committee of the Union of South Africa issued a comprehensive report and the South African authorities thereafter were in the forefront of investigation and research. Extensive investigations of working conditions and laboratory research were carried on in the Union of South Africa, England, Australia, Canada, the U.S., Germany, Italy and other countries.

Pneumonoconiosis is a generic term and includes such specific diseases as silicosis, asbestosis and pneumonoconiosis produced by diatomaceous earth, and also anthracosis, produced either by coal dust alone or in combination with silica. The dusts that produce pneumonoconiosis are inorganic. Excluded from consideration are organic dusts, living organisms (bacteria, fungi) and so-called toxic dusts. These, such as lead, mercury or arsenic, are systemic poisons and do not produce the characteristic fibrous changes which are typical of the pneumonoconioses.

Silicosis is the most important form of pneumonoconiosis because of its severity and its frequent association with tuberculosis; also because the number of persons exposed to the silica hazard is much greater than for the other dust diseases. Formerly the terms miners' phthisis, grinders' rot, potters' rot and similar local designations were in use to describe the condition.

Silicosis arises only under certain conditions: (1) The dust must contain pure silica (SiO_2). With the exception of asbestos, a silicate, silica dust is the principal dust that can cause disability and death. (2) The dust particles must be sufficiently small, not more than five microns in greatest diameter, in order to penetrate through the finer air passages and reach the actual breathing spaces where the absorption of oxygen from the air takes place. (3) There must be sufficient concentration of dust in the air. In the United States a concentration of 5,000,000 particles per cubic foot is the generally accepted maximum allowable concentration. This standard is accepted by the United States bureau of mines and the United States public health service. Studies indicate that if this concentration is not exceeded, a disabling pneumonoconiosis is not likely to be produced in the average working lifetime. (4) The exposure of the individual must be over a sufficiently long period. Widespread measures for dust control have been adopted in mines and factories, and the development of silicosis is most frequently a matter of years (10 to 20). (5) The element of individual susceptibility seems to play a part, but to what extent it is not possible to define accurately.

The cardinal symptom of silicosis is a gradually increasing shortness of breath (dyspnoea). This may appear after ten or more years of exposure, depending upon the various factors mentioned above. If the exposure is continued, disability may result and the silicotic may become a victim to a complicating tubercle infection. The diagnosis depends upon the roentgenogram of the lungs which is characteristic, plus a history of exposure to siliceous dust.

The prevention of silicosis depends upon engineering control and medical supervision. Engineering control in mine, mill or factory implies the trapping of the dust at its source, as far as practicable, before it can be disseminated into the air; also adequate ventilation which serves to dilute the dust, exhaust equipment applied to different types of machinery, and the use of water to lay the dust and similar measures. Once the dust becomes distributed in the atmosphere of working places, the protection of the individual becomes difficult and unsatisfactory. Respirators are of little avail, except the positive pressure type, and these are not applicable to many occupations. The average workman cannot wear a respirator and do hard work all through a working shift, day after day, especially if the work place is hot and humid.

Asbestosis and the pneumonoconioses of coal miners are among other important forms of pneumonoconiosis. The method of occurrence is identical—breathing dust-laden air. The pathology differs more or less from silicosis but the procedures for diagnosis and prevention are similar.

See A. J. Lanza (ed.), *Silicosis and Asbestosis* (1938). (A. J. LA.)

PNEUMOTHORAX. The chest is divided into two airtight compartments by the mediastinum. A thin membrane called the pleura (*see* COELOM AND SEROUS MEMBRANES) covers each lung, and is reflected at the root of the lung to form the lining of the

inner surface of the chest wall. Normally the visceral pleura (covering the lung) is in contact with the parietal pleura (covering the inner surface of the thorax), and the potential space between them is spoken of as the pleural space. A pneumothorax exists if the two layers of pleura are separated by air and the lung collapses away from the chest wall. Air may be introduced into the pleural space as the result of trauma, by spontaneous rupture of the visceral pleura or by means of a needle inserted through the chest wall.

Traumatic Pneumothorax.—Since the lung is an elastic organ and tends to be pulled toward the lung root, the pressure in the pleural space is less than atmospheric, averaging minus five centimetres of water. This means that air under atmospheric pressure will be sucked into the pleural space if the visceral pleura is torn (*e.g.*, by a fractured rib) or if an open wound in the chest wall penetrates the parietal pleura. If a "sucking wound" of the chest wall exists, more air may be pulled into the pleural cavity via the wound than is pulled into the lung via the larynx, with the result that the collapsed lung and mediastinum are pushed toward the healthy side on inspiration and away from it on expiration. This paradoxical motion of the lung and mediastinum causes progressive asphyxia unless the wound is closed.

Spontaneous Pneumothorax.—The sudden collapse of the lung without previous trauma is termed spontaneous pneumothorax, and is usually associated with severe chest pain and difficulty in breathing. Most cases occur in apparently healthy persons. Because spontaneous pneumothorax may occur as a complication of pulmonary tuberculosis, it was assumed for years that almost all cases were due to tuberculosis. This is not true. In 1932 H. Kiaergaard suggested that emphysematous blebs in the pleural surface of the lung were the common cause of spontaneous pneumothorax, and this concept was later confirmed. Superficial blebs on the pleural surface are weakened areas of pleura, and may blow out as a result of suddenly raising the intrapleural pressure by lifting, coughing or laughing.

Artificial Pneumothorax.—In 1882 Carlo Forlanini first reported the successful use of artificial pneumothorax in the treatment of pulmonary tuberculosis, and placed the method on a firm scientific basis. The primary aim of artificial pneumothorax is the closure and healing of ulcerations (cavities) in the lung. This is accomplished by relaxation of the collapsed lung and presumably by the occlusion of small bronchi draining cavities.

Air is introduced into the pleural space by means of a needle attached by a rubber tube to a bottle. Water is siphoned into the bottle slowly, thus displacing air which is forced into the pleural cavity. Small amounts of air are introduced daily until the lung is suitably collapsed, and the pneumothorax is maintained by periodic refills at varying intervals (usually one to three weeks) depending upon the rate of reabsorption of air. Artificial pneumothorax is usually maintained for two to five years unless cavity closure does not occur or complications necessitate earlier re-expansion. Complications of pneumothorax therapy are frequent and include accumulation of fluid in the pleural space, formation of adhesions between the two layers of pleura, infection of the pleural space (empyema) and reduction of the patient's respiratory reserve after the lung has been re-expanded. Because of these limitations other procedures such as thoracoplasty and pulmonary resection are often more suitable for treatment of cavernous tuberculosis. Artificial pneumothorax is sometimes used for diagnostic purposes to distinguish on X-rays between disease in the lung and pleura, and is used by some thoracic surgeons preliminary to pulmonary resection. It has no value in the treatment of other pulmonary diseases.

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(R. H. E.)

PNOM PENH, capital of Cambodia (*q.v.*), Indochina. Pop. (1936) 103,000 (Cambodians, Annamese, Chinese, Malays). The city is on the Mekong river, 173 mi. from its mouth, at the junction with the Tonle Sap.

Steamers connect Pnom Penh with Saigon and with many towns on the Mekong and the Tonle Sap. Excellent highways lead to Saigon, Angkor Wat, Bangkok and northern Indochina. It is the terminus of railway from Singapore and Bangkok. Rice, fish, cotton, rubber and forest products are the chief items of a trade affecting all of Cambodia and Laos, and parts of Thailand in the Mekong valley. The citadel, in the centre of the city, contains the king's palace and residences of senior French officials.

PO (anc. *Padus*, Gr. Πάδος), a river of northern Italy, and the dominating factor in its geography. It is the longest river in Italy (310 mi. direct, 420 mi. including its many windings), and the area of its basin, which includes portions of Switzerland, is estimated at 26,798 sq.mi. For its course and principal tributaries, *see* ITALY. The lower valley of the Po was at an early period occupied by people of the Palaeolithic and Neolithic stages of civilization, who built houses on piles along the swampy borders of the streams. The river regulation works originated in pre-Roman times. The reclaiming and protecting of the riparian lands went on rapidly under the Romans, and in several places the rectangular divisions of the ground are still remarkably distinct. (*See* ESTE.) During the barbarian invasions much of the protective system decayed but the later middle ages saw the works resumed, so that the present arrangement existed in the main by the close of the 15th century. The Ligurian name of the Po was Bodincus or Bodencus; *i.e.*, the bottomless. The name Padus was taken from the Celts or the Veneti. Thus Bodincomagus is found as a town name (Industria) on the upper course, and Padua as a name of one of the mouths of the river. The name Ἠ ῥιδανός (Eridanus) of Greek poetry was identified with it at a comparatively late period.

See A. Beltramelei, *Da Comacchio ad Argenta* (Bergamo, 1905); A. Cappellini, *Il Polesine* (Rovigo, 1925).

POBÊDONOSTSEV, CONSTANTINE PETROVICH (1827–1907), Russian jurist and state official. Born in Moscow in 1827, he studied at the School of Law in St. Petersburg, and entered the public service as an official in one of the Moscow departments of the senate. In the early years of the reign of Alexander II (1855–1881), Pobêdonostsev maintained that occidental institutions were radically bad in themselves and totally inapplicable to Russia. Parliamentary methods of administration, modern judicial organization and procedure, trial by jury, freedom of the press, secular education—these were among the principal objects of his aversion. He therefore persecuted the dissenters, Stundists, Doukhobors and others, and insisted on severe measures of repression in education and in the press. He exercised considerable influence by inspiring and encouraging the Russification policy of Alexander III (1881–1894). Pobêdonostsev died on March 23, 1907.

POCAHONTAS (1595–1617), daughter of the Indian chief, Powhatan, is the heroine of one of the best-known traditions connected with the beginnings of American history. The story is that Capt. John Smith, as head of a band of soldiers in search of food and exploring the Chickahominy river, was waylaid by Indians and taken prisoner by their chief, Powhatan. Smith had been forced to kneel down while his head was laid on a stone preparatory to having his brains crushed out with heavy clubs, when Pocahontas, a young daughter of the chief, sprang forward, seized his head in her arms, and saved his life. She is supposed to have come again to his aid a year later by revealing a plot made against Smith by her father. All this is said to have happened in connection with the expedition under Capt. Bartholomew Gosnold and others, who landed in Chesapeake bay in 1607, explored the James river, and formed a settlement. Owing to the fact, however, that no mention of this experience is made in the minute personal narrative covering this period, written by Capt. Smith at the time of the supposed occurrence and published immediately thereafter, nor in the recollections of his comrades who usually gave him full credit for any of his exploits, doubts have arisen as to the authenticity of the tale. The first story concerning Pocahontas appears in the *Generall Historie*, first published in 1624, after she had been made much of in England as the attractive daughter of an emperor and the first convert of her tribe to Christianity, and it is to be feared that the temptation to bring her on the stage as heroine in a new character in connection with Smith, ever the hero of his own chronicles, was more than he or the publishers of the *Generall Historie* could withstand. Many prominent Virginia families trace their ancestry to the son of Pocahontas and her husband, John Rolfe.

POCATELLO, a city of southeastern Idaho, U.S., on the Portneuf river, at an altitude of 4,460 ft., 170 mi. S. by W. of

Yellowstone National park; the county seat of Bannock county. It is on federal highways 30N and 91 and the Union Pacific railway system, and has a municipal airport.

The population was 26,131 in 1950; 18,133 in 1940 by federal census. Beyond the Snake river (15 mi. distant) to the north and west stretches the Snake river lava plain of 20,000 sq.mi. American Falls (1950 pop. 1,874), 23 mi. W. of Pocatello, is the centre of a great hydroelectric power and irrigation project. Pocatello has extensive railroad shops and a variety of manufacturing (including cheese factories, feed mills, wheat elevators, phosphate fertilizer plants and huge electric furnaces producing elemental phosphorus). A U.S. navy ordnance plant which services the guns of the Pacific fleet is also located there. It is the home of Idaho State college, a state-operated liberal arts college. Seven miles north is the Fort Hall Indian reservation, and within its limits is the site of old Fort Hall, built in 1834 at the intersection of the Missouri-Oregon and the Utah-Canada trails. At Massacre Rocks, 38 mi. S.W. of Pocatello, an emigrant train was annihilated by Indians in Aug. 1862. The city is built on 2,000 ac. sold by Indians to the U.S. It began as a tent colony in 1882, when the railroad was completed to this point, and was incorporated in 1892. Its growth was attributable at first to the railroad shops, and later to irrigation projects.

POCHARD, a diving duck, *Nyroca ferina,* the female of which is sometimes called the dunbird. In the male in full plumage the head is coppery-red, the breast black, and the back and flanks a dull white, closely barred with fine undulating black lines. The tail coverts and quill feathers are black and the lower surface dull white. The female is duller. The pochard breeds throughout the northern hemisphere, migrating to the coast in winter and retiring southward. The American subspecies is larger. A second American species is the much bigger canvasback duck (*q.v.*). Both species are excellent table birds when they frequent fresh water, the canvasback being pre-eminent.

Allied to the pochards are the scaup duck (*N. marila*), the tufted duck and the eiders.

POCKET GOPHER, the name of a group of (chiefly North) American ratlike rodents, characterized by large cheek pouches, the openings of which are external to the mouth, while their inner surface is lined with fur. The second and third front claws are greatly enlarged, and the fingers are furnished along their sides with bristles. The eyes are small, and the external ears rudimentary. Pocket gophers, which typify a family, the Geomyidae, spend practically all their time underground, their powerful claws being adapted for digging, while the bristles on the toes prevent the earth from passing between them. The upper incisor teeth are employed to loosen the ground, like a fork; and the little rodents are able to move both backward and forward in their runs. The cheek pouches are employed in carrying food, which consists of roots. The common pocket gopher, *Geomys bursarius,* of the Mississippi valley measures about 8 in. in length, plus a tail of between 3 and 4 in.; its colour being rufous brown and grayish beneath. Another well-known representative is the northwestern plains pocket gopher *Thomomys talpoides,* which is considerably smaller than the former. (*See* RODENTIA.)

POCKET MOUSE, the name of a number of small mouse-like, chiefly North American rodents belonging to the family Heteromyidae and including several genera, all with fur-lined external cheek pouches, like the pocket gophers. The typical pocket mice (*Perognathus*) are small, with rather long tails and hind feet. They live in deserts and on the Great Plains, feeding on seeds. Kangaroo mice (*Microdipodops*) are closely related to them but have a very broad head. *Heteromys* and *Liomys,* the spiny pocket rats, have bristles mixed in their pelage. They are dark gray or blackish in colour. Most species of these two genera are Central American, extending to northern South America.

(J. E. HL.)

POCOCKE, EDWARD (1604–1691), English orientalist and biblical scholar, the son of a Berkshire clergyman, was educated at Corpus Christi college, Oxford. He discovered in a Bodleian ms. the missing Syriac versions of the four New Testament epistles (2 Peter, 2 and 3 John, Jude) which were not in the old Syriac canon, and were not contained in European editions of the Peshito. His edition of these was published at Leyden in 1630. In 1649 he published the *Specimen historiae arabum,* a short account of the origin and manners of the Arabs, taken from Barhebraeus (Abulfaragius), with notes from a vast number of ms. sources. This was followed in 1655 by the *Porta Mosis,* extracts from the Arabic commentary of Maimonides on the Mishna, with translation and learned notes; and in 1656 by the annals of *Eutychius* in Arabic and Latin. His *magnum opus*—a complete edition of the Arabic history of Barhebraeus (*Greg. Abulfaragii historia compendiosa dynastiarum*), was dedicated to the king in 1663. After this his most important works were a *Lexicon heptaglotton* (1669) and English commentaries on Micah (1677), Malachi (1677), Hosea (1685) and Joel (1691).

PODĚBRAD, GEORGE OF (1420–1471), king of Bohemia, was the son of Victoria of Kunstat and Poděbrad, a Bohemian nobleman, who was one of the leaders of the "Orphans" or modern Taborites during the Hussite wars. George became prominent early as leader of the National, or Calixtine party in Bohemia, becoming its chief at the death of Ptacek of Pirkstein. In 1448, during the minority of Ladislas Posthumus, having raised a force of 9,000 men in northeast Bohemia, where the National cause was strongest and where his own ancestral castle was situated, he marched on Prague and took it, afterward defeating the Romanist or Austrian party led by Ulrich von Rosenberg. In 1451 the emperor Frederick III, Ladislas' guardian, entrusted Poděbrad with the administration of Bohemia. In the same year a diet assembled at Prague also conferred on Poděbrad the regency. The struggle of the Bohemians against Rome continued uninterruptedly, and Poděbrad's position became very difficult when Ladislas, who was crowned in 1453, expressed his sympathies for the Roman Church, though recognizing the compacts and ancient privileges of Bohemia. In 1457 King Ladislas died suddenly. Public opinion from an early period accused Poděbrad of having poisoned him; but the suggestion is undoubtedly a calumny. On Feb. 27, 1458, the estates of Bohemia unanimously chose Poděbrad as king, even the adherents of the Austrian party voting for him. A year later, Pius II became pope, and his hostility proved a serious obstacle to Poděbrad's rule.

Though refusing to let the compacts be abolished, as Pius demanded, Poděbrad placated him by punishing the most advanced enemies of the papacy, including the newly-founded community of the Bohemian brethren; but his endeavours to establish peace with Rome proved ineffectual, although the death of Pius II prevented him from carrying out his planned crusade against Bohemia. Despite the prosperity enjoyed by Bohemia under Poděbrad's rule, the malcontent nobles of the Romanist party, meeting on Nov. 28, 1465, at Zelena Hora, formed a confederacy against him which was supported by the Roman see. On Dec. 23, 1466, Paul II, the successor of Pius II, excommunicated Poděbrad and pronounced his deposition as king of Bohemia, forbidding all Romanists to continue in his allegiance. The emperor Frederick III, and King Matthias of Hungary, Poděbrad's former ally, joined the insurgents. Matthias conquered a large part of Moravia and was crowned king of Bohemia at Brünn on May 3, 1469. On March 22, 1471, Poděbrad's death ended the war. He was the only native king of Bohemia, and the only one not a Catholic.

PODGORICA, the commercial capital of Montenegro, Yugoslavia. Pop. (1931) 10,651. The town lies in a fertile plain on the Moracha, there spanned by a fine old Turkish bridge, while a tributary separates the Turkish town lying within the ruined ramparts, and inhabited by Albanians, from the Montenegrin quarter built in 1878.

PODIUM: SHOWING MOULDED BASE, PLANE SURFACE OR DADO, AND CORNICE

PODIATRIST: *see* CHIROPODIST.

PODIUM, in architecture, a continuous pedestal, a low wall supporting columns, or the lowest portion of the wall of a building when given a separate archi-

tectural treatment. Sometimes the basement (*q.v.*) story of a classic building may be treated as a podium. The podium is usually designed with a moulded base and plinth (*q.v.*) at the bottom, a central plane surface known as a die or dado, and a projecting cornice or cap. The majority of Etruscan and Roman temples were raised on podiums and the entrance steps ascended between wing walls which were the continuations of the podium at the sides.

PODMOKLY (Ger. Bodenbach), a town on the Elbe in northwest Bohemia, Czechoslovakia. Situated on the main Prague-Dresden-Berlin railway, it is an important junction with a transit trade, in part supplied by its industries, which include textiles, porcelain, chemicals and foodstuffs. Pop. (1947) 17,558.

PODOCARPACEAE: *see* GYMNOSPERMS.

PODOLSK, a town of the Russian S.F.S.R., 55° 27′ N., 37° 28′ E., 26 mi. S. of Moscow, on the railway and on the Pakhra river, crossed by a suspension and a railway bridge. Pop. (1939) 72,422. It manufactures cement, lime, silicates and silk goods and has a railway repair shop. Until 1781 it was a dependency of the Danilov monastery of Moscow. Near it is an unkept park on the banks of the Pakhra, on the former estate of Count Tolstoi.

PODOPHYLLIN, a drug obtained from the rhizome of the American mandrake or May apple. As met with in commerce, the rhizome occurs in cylindrical pieces 2 or 3 in. long and about ¼ in. in diameter, of a chocolate or purplish-brown colour, smooth, and slightly enlarged where the juncture of the leafy stem is indicated by a circular scar on the upper and a few broken rootlets on the under side. The odour is heavy and disagreeable, and the taste acrid and bitter.

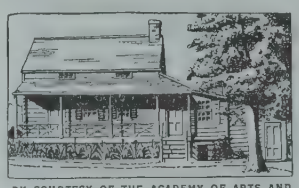
Podophyllin is a resinous powder obtained by precipitating an alcoholic tincture of the rhizome by means of water acidulated with hydrochloric acid. The powder is soluble in alcohol and strong solutions of alkalis. There are at least two resins in the powder (which is known officially as *Podophylli resina*), one being soluble and the other insoluble in ether. Each contains an active substance, which can be obtained in crystalline form, and is known as podophyllotoxin. It is soluble in alcohol, ether, chloroform and boiling water. The properties of podophyllin resin vary with the reaction of the tissue with which it is in contact; where this is acid the drug is inert, the picropodophyllin being precipitated.

Podophyllin was known to the American Indians, who realized its cathartic and escharotic properties. It is no longer included in the *Pharmacopoeia of the United States of America.* The *British Pharmacopoeia* recognizes preparations from an Indian species, *P. emodi.* Podophyllin is used chiefly for its cathartic properties in patent medicines, often combined with aloes or calomel. It should be used cautiously since its intense action may lead to inflammation of the bowel and death. It finds some use applied locally to certain types of warts. (*See* MAY APPLE.)

PODOSTEMONACEAE, a remarkable family of dicotyledonous plants, living only on rocks in rushing streams. The seeds are shed on the rocks during the dry season, germinating when the rocks become submerged in the rainy season. The vegetative parts consist mainly of a flattened green thallus, usually derived from adventitious roots. There are 40 genera and about 175 species, nearly all tropical, a single representative, *Podostemon Ceratophyllum* (river weed), occurring in North America, found in shallow streams from Maine to Minnesota and southward to Georgia and Alabama. For a treatment of the genera, *see* A. Engler, "Podostemonaceae." Engler and Prantl, *Natürlichen Pflanzenfamilien,* ed. 2, 18a:3–68, fig. 1–61 (1930).

POE, EDGAR ALLAN (1809–1849), American poet and critic, cultivated the literature of mystery, and is himself, to a great extent, a mystery. His work owes much to the drift of romanticism (of which he is a late heir) toward the occult and the satanic. It owes much also to his own feverish dreams, to which he applied a strange power of logic and a rare faculty of shaping plausible fabrics out of impalpable materials. With an air of objectivity and spontaneity, his productions are closely dependent on his own idiosyncrasy and an elaborate technique.

Born in Boston, Mass., Jan. 19, 1809, he was not yet three years old when his mother, a young English actress, the widow of a U.S. player, died at Richmond, Va., in 1811. The well-to-do childless Mrs. Allan, who adopted him, gave him motherly care and affection—reluctantly seconded by her husband. Edgar received a good education, first in England, then in a private school at Richmond, then went, in 1826, to the University of Virginia, Charlottesville. Differences arose between him and his foster father. Prevented from returning to college after the end of the first year, the youth ran away to Boston, where he enlisted in the army. For three years he was a soldier (1827–31)—the last three months in the capacity of a cadet at West Point.



BY COURTESY OF THE ACADEMY OF ARTS AND SCIENCES

POE'S COTTAGE AT FORDHAM, NEW YORK CITY (RESTORED)

His inclination led him toward writing. In spite of untoward circumstances and uncongenial surroundings, he wrote poetry, which he managed to have published in Boston (*Tamerlane,* 1827), in Baltimore, Md., (*Al Aaraaf,* 1829) and in New York city (*Poems,* 1831). Poe settled as a man of letters at Baltimore in 1832, and struggled with poverty, at times with actual want, upheld by his pride and his set resolution to achieve work that would count in the U.S. and in the world. He had neither family nor friends. Disappointments in love and social slights threw a sombre cloud over his disposition. He was afflicted with a strange susceptibility to the effects of liquor, combined with an attraction toward it which he did not always resist successfully.

It was this defect (or hereditary flaw) that, in a large measure, made it impossible for him to remain literary editor, in Richmond, Va., Philadelphia, Pa., or New York city, of magazines which he had raised to prosperity; that later discouraged J. R. Lowell from taking him as contributor to the *Pioneer;* that disqualified him for a clerkship in a government office at Washington, D.C. He made worthy efforts to abstain from stimulants after he had married Virginia Clemm (1836), but relapsed when his child wife fell dangerously ill, in 1841, with scant hope of recovery. After the death of Virginia, in 1847, his morbid condition grew worse and seems to have assumed the form of a lesion of the brain with temporary crises of delirious fever. "I became insane," he wrote, "with intervals of horrible sanity." His last years were marked by fits of platonic erotomania, the objects of which were successively or at the same time women of letters, such as Mrs. Frances Sargent Osgood, Mrs. Shew (Maria Louise), Mrs. Whitman (Helen), Mrs. Lewis (Stella), and new or old friends, like Annie and Mrs. Elmira Shelton.

Poe died after letting himself be entrapped into drinking too much liquor at Baltimore, in 1849.

For 40 years he had fought, against terrible odds, to keep his genius clear and accomplish the work of a creative artist. While continuing to write verse, he began composing prose tales in 1832, and started a career as literary critic in 1835 which he was to carry on steadily in various magazines till the end. His keen and sound judgment as appraiser of contemporary literature, his idealism and musical gift as a poet, his weirdness and dramatic power as a storyteller, though hardly appreciated in his lifetime, have secured him today a prominent place among universally known men of letters. The complex and elusive nature of his productions can best be understood when one tries to seize the relations of his personality to the working of his mind.

The outstanding fact in Poe's character is a strange duality. We find this trait in his temper, in his mind, in his art. The wide divergence of contemporary judgments on the man seems to point to the coexistence in him of two persons. With those he loved and who saw him in repose, he was gentle, affectionate, obliging and devoted. Others, who were the butt of his sharp criticism or who happened to meet him in moments of excitement, found him irritable, arrogant, self-centred, sombre, rebellious, and went so far as to accuse him of lack of principle and conscience. Was it, in the latter case, a double of the man rising from harrowing nightmares, or from the haggard inner vision of dark crimes, or

from appalling graveyard hallucinations, that ominously loomed through the gentler Poe's unstable being?

If we consider the mind of Poe, the duality is still more striking. On one side he was an idealist and a visionary. His yearning for the ideal was both of the heart and of the imagination. His sensitiveness to the beauty, purity and lovingness of woman, associated with the contemplation of her amid the sweetest objects of nature or in the glory of ethereal radiance, inspired him with his most touching lyrics ("To Helen," "The Sleeper," "Eulalie," "To One in Paradise"), and with the full-toned prose hymns to beauty and love in "Ligeia" and "Eleonora." His imagination carried him away from the earth and the material world into the angels' dwelling-place ("Israfel"), into fairyland or dreamland, or into the empyrean, where souls dwell in immortality, where Monos and Una, Eiros and Charmion, Oinos and Agathos hold discourses on the secrets of life and death, and whither the prophet of "Eureka" takes his flight to meditate on ultimate causes.

This Pythian mood was especially characteristic of the later years of his life. More generally, either in his verse ("Valley of Unrest," "Lenore," "The Raven," "For Annie," "Ulalume") or in his prose-tales, his familiar mode of evasion from the universe of common experience was through converse with death-in-life or life-in-death, and through haunting thoughts, impulses, or fears that seem to belong to an eerie world of horrible dreams, lurking in his abnormal subliminal consciousness. From these materials he drew the startling effects of his "tales of death" ("House of Usher," "Red Death," "Valdemar," "Premature Burial," "Oval Portrait," "Shadow"), of his "tales of wickedness and crime" ("Berenice," "Black Cat," "William Wilson," "Imp of the Perverse," "Cask of Amontillado," "Tell-Tale Heart"), of his "tales of survival after dissolution" ("Ligeia," "Morella," "Metzengerstein"), and of his "tales of fatality" ("Assignation," "Man of the Crowd"). Even when he does not hurl his characters into the clutch of fearful, mysterious or supernal forces or on to the untrodden paths of the beyond, he uses the anguish of imminent death as the means of causing the nerves to quiver and the flesh to creep ("Pit and the Pendulum"), and his very grotesque inventions deal with corpses and decay in an uncanny play with the aftermath of death.

On the other side, Poe is conspicuous for a close observation of minute details, which characterizes the realist or the painter of *trompe-l'oeil* landscapes or familiar scenes. He resorts to this gift of precise, Defoe-like apprehension in the long narratives and in many of the descriptions that introduce the tales or constitute their setting. Closely connected with this accurate scanning of actual or imagined things, is his power of ratiocination. He prided himself on his faultless logic and he carefully handled this real accomplishment so as to impress the public with his possessing still more of it than he had. Hence the would-be feats of thought-reading, problem-unravelling and cryptography which he attributed to his Legrand and his Dupin. This suggested to him the "analytical tales," which introduced into literature the detective story, and his "tales of pseudo-science."

The same duality is evinced in his art. He was capable of writing angelic or weird poetry with a supreme sense of rhythm and word-appeal, or prose of sumptuous beauty and suggestiveness, with the apparent abandon of compelling inspiration; and he would write down a problem of morbid psychology or the outlines of an unrelenting plot in a hard and dry style, with the clear-cut directness of algebraic reasoning. He was capable of throwing massively into a poem or a prose-tale the most impressive unity of effect, as if urged by a flashing vision or an irresistible creative impulse; and he would dissect in cold blood that seemingly unanalysable whole and show by precept and rule that it was the result of the most deliberate and artificial technique. In Poe's masterpieces, the double contents of his temper, of his mind and of his art are fused into a oneness of tone, structure and movement, the more effective, perhaps, as it is compounded of various elements that give depth and intensity to the total sheen or dismal glow.

Poe's genius was first recognized abroad. None did more to persuade the world, and, in the long run, America, of Poe's greatness than Baudelaire and Mallarmé. The one was a romanticist and the other a symbolist; they hailed Poe as the wizard of letters who had had intimation of immortal truths and the divine faculty of calling up an other-worldly thrill. Even if the present and the future generations are less likely to tremble in awe at Poe's would-be revelations of Elysian or Tartarian lore, they will concur with his "discoverers" in admiring his fecund and startling invention, his exact dosage of artifice and spontaneity, and his supreme artistry.

Poe's works have been edited by J. A. Harrison (1903, containing biography and letters), and by E. C. Stedman and G. E. Woodberry (1914, with a memoir, biography and criticism).

See J. H. Ingram, *Edgar Allan Poe* (1880); G. E. Woodberry, *Life of E. A. Poe* (1909); C. Baudelaire, *Edgar Poe* (1856); J. W. Robertson, *Edgar A. Poe* (1922); S. Cody, *Poe* (1924); C. Mauclair, *Le genie d'Edgar Poe* (1925); H. Allen, *Israfel* (1926); M. E. Phillips, *Edgar Allan Poe* (1926); J. W. Krutch, *Edgar Allan Poe* (1926). (C. C.)

POELZIG, HANS (1869–1936), German architect, was born in Berlin on April 30, 1869. He studied architecture at the Berlin Technische Hochschule and was subsequently director of the Breslau academy of arts (1903–16). He was city architect of Dresden from 1916 to 1920, and also an honorary professor at the Technische Hochschule there. In 1920 he started an advanced atelier for applied arts at the Berlin academy of arts. From 1924 to 1935 he was also professor of the architectural faculty of the Berlin Technische Hochschule. With the architect Peter Behrens (1868–1938), Poelzig was a pioneer of the German industrial-art movement: he was president of the Deutscher Werkbund, an association of progressive architects, designers and industrialists founded in 1907. Poelzig, like Behrens, was much concerned with freeing buildings from all superficial mannerisms: thus his sulphur factory (1912) at Lauban (Luban), Pol., was a group of purely functional block-shapes, and the façade of the Berlin radio building (Funkhaus) of the late 1920s was virtually a great expanse of smooth wall pierced by well-balanced ranges of simple windows. However, he was also responsible for the remarkably decorated Grosses Schauspielhaus, Berlin, which he converted for Max Reinhardt from the old Schumann circus building. Poelzig died on June 14, 1936.

See Th. Heusz, *Hans Poelzig* (1948).

POERIO, ALESSANDRO (1802–1848), Italian poet and patriot, was descended from an old Calabrian family, his father, Baron Giuseppe Poerio, being a distinguished Neapolitan lawyer. In 1815 he and his brother Carlo accompanied their father, who had been identified with Murat's cause, into exile, and settled at Florence. In 1818 they were allowed to return to Naples. Alessandro fought as a volunteer, under Guglielmo Pepe (*q.v.*), against the Austrians in 1821, but when the latter reoccupied Naples and the king abolished the constitution, the family was again exiled and settled at Gratz. Alessandro studied in Germany, and at Weimar he became the friend of Goethe. In 1835 the Poerios returned to Naples. In 1848 Alessandro accompanied Pepe as a volunteer to fight the Austrians in northern Italy, and on the recall of the Neapolitan contingent he followed Pepe to Venice. He was severely wounded in the fighting round Mestre, and died on Nov. 3, 1848. His poetry "reveals the idealism of a tender and delicate mind"; but he could also sound the clarion note of patriotism, as in his stirring poem *Il Risorgimento*.

His brother Carlo (1803–67), after returning to Naples, practised as an advocate, and from 1837 to 1848 was frequently arrested and imprisoned. Under the short lived constitution of 1848 he was minister of education. He resigned office in April and took his seat in parliament, where he led the constitutional opposition. After the Austrian victory Poerio was arrested (July 19, 1849) tried, and condemned to 19 years in irons. Chained in pairs, he and other political prisoners were confined in one small room in the bagno of Nisida, near the lazaretto. The exposure (1851) of the horrors of the Neapolitan dungeons by Gladstone, who emphasized especially the case of Poerio, awakened the indignation of Europe, but he was not released till 1858. He and other exiles were then placed on board a ship bound for the United States, but the son of Settembrini, another of the

exiles, who was on board in disguise, compelled the crew to land them at Cork, whence Poerio made his way to London. In the following year he returned to Italy, and in 1860 he was elected deputy to the parliament of Turin, of which he was chosen vice-president in 1861. He died at Florence on April 28, 1867.

See Baldachini, *Della Vita e de' tempi di Carlo Poerio* (1867); W. E. Gladstone, *Two Letters to the Earl of Aberdeen* (1851); *Carlo Poerio and the Neapolitan Police* (1858); Vannucci, *I Martiri della libertà italiana*, vol. iii. (Milan, 1880); Imbriani, *Alessandro Poerio a Venezia* (Naples, 1884); Del Giudice, *I Fratelli Poerio* (Turin, 1899); Countess Martinengo Cesaresco, *Italian Characters* (1901).

POET LAUREATE. The laurel (Lat. *laurea*) was sacred to Apollo, and as such was used to form a crown or wreath of honour for poets and heroes. The word "laureate" or "laureated" thus came in English to signify eminent, or associated with glory, literary or military. "Laureate letters" in old times meant the despatches announcing a victory; and the epithet was given, even officially (*e.g.*, to John Skelton) by universities, to distinguished poets. The term "poet laureate" was ultimately restricted to the office of the poet attached to the royal household, first held by Ben Jonson, for whom the position was, in its essentials, created by James I. in 1617. (Jonson's appointment does not seem to have been formally made as poet-laureate, but his position was equivalent to that). The office was really a development of the practice of earlier times, when minstrels and versifiers were part of the retinue of the king; it is recorded that Richard Coeur de Lion had a *versificator regis* (Gulielmus Peregrinus), and Henry III. had a versificator (Master Henry); in the 15th century John Kay, also a "versifier," described himself as Edward IV.'s "humble poet laureate." Moreover, the Crown had shown its patronage in various ways; Chaucer had been given a pension and a perquisite of wine by Edward III., and Spenser a pension by Queen Elizabeth. Sir William Davenant succeeded Jonson in 1638, and the title of poet laureate was conferred by letters patent on Dryden in 1670, two years after Davenant's death, coupled with a pension of £300 and a butt of Canary wine. This was the beginning of the official laureateship. The successors of Dryden were T. Shadwell (who originated annual birthday and new year odes), Nahum Tate, Nicholas Rowe, Laurence Eusden, Colley Cibber, William Whitehead, Thomas Warton, H. J. Pye, Southey, Wordsworth, Tennyson, Alfred Austin, Robert Bridges (appointed 1913) and John Masefield (appointed 1930).

The poet laureate, being a court official, was considered responsible for producing formal and appropriate verses on birthdays and state occasions. Wordsworth stipulated before accepting the honour, that no formal effusions from him should be considered a necessity; but Tennyson was generally happy in his numerous poems of this class. The emoluments of the post have varied. To Pye an allowance of £27 was made instead of the Canary wine. Tennyson drew £72 a year, and £27 in lieu of the "butt of sack."

See Walter Hamilton, *Poets Laureate of England* (1879), and E. K. Broadus, *The Laureateship* (1921).

POETRY. In modern criticism the word poetry (*i.e.* the art of the poet, Gr. *ποιητής*, maker, from *ποιεῖν*, to make) is used sometimes to denote any expression (artistic or other) of imaginative feeling, sometimes to designate a precise literary art, which ranks as one of the fine arts. As an expression of imaginative feeling, as the movement of an energy, as one of those great primal human forces which go to the development of the race poetry in the wide sense has played as important a part as science. In some literatures (such as that of England) poetic energy, and in others (such as that of Rome) poetic art is the dominant quality. It is the same with individual writers. In classical literature Pindar may perhaps be taken as a type of the poets of energy; Virgil of the poets of art. With all his wealth of poetic art Pindar's mastery over symmetrical methods never taught him to "sow with the hand," as Corinna declared, while his poetic energy always impelled him to "sow with the whole sack."

In some writers, and these the very greatest—in Homer, Aeschylus, Sophocles, Dante, Shakespeare, Milton, and perhaps Goethe—poetic energy and poetic art are seen in something like equipoise. It is of poetry as an art, however, that we have mainly to speak here; and all that we have to say upon poetry as an energy is that the critic who, like Aristotle, takes this wide view of poetry —the critic, who, like him, recognizes the importance of poetry in its relations to man's other expression of spiritual force, claims a place in point of true critical sagacity above that of a critic, who, like Plato, fails to recognize that importance.

With regard to poetry as an art, most of the great poems of the world are dealt with elsewhere in this work, either in connection with the names of the writers or with the various literatures to which they belong; consequently, these remarks must be confined to general principles. Under VERSE the detailed questions of prosody are considered: here we are concerned with the essential principles which underlie the meaning of poetry as such.

All that can be attempted is to inquire:

(1) What is poetry?

(2) What varieties of poetic art are the outcome of the two great kinds of poetic impulse, dramatic imagination, and lyric or egoistic imagination?

Definition of Poetry.—Definitions are for the most part alike unsatisfactory and treacherous; but definitions of poetry are proverbially so. Yet some definition must be here attempted; and, using the phrase "absolute poetry" as the musical critics use the phrase "absolute music," we may, perhaps, without too great presumption submit the following:

Absolute poetry is the concrete and artistic expression of the human mind in emotional and rhythmical language.

This, at least, will be granted, that no literary expression can, properly speaking, be called poetry that is not in a certain deep sense emotional, whatever may be its subject-matter, concrete in its method and its diction, rhythmical in movement, and artistic in form.

That the expression of all real poetry must be concrete in method and diction is obvious, and yet this dictum would exclude from the definition much of what is called didactic poetry. With abstractions the poet has nothing to do, save to take them and turn them into concretions; for, as artist, he is simply the man who by instinct embodies in concrete forms that "universal idea" which Gravina speaks of—that which is essential and elemental in nature and in man; as poetic artist he is simply the man who by instinct chooses for his concrete forms metrical language.

As an example of the absence of concrete form in verse take the following lines from George Eliot's *Spanish Gipsy:*

> "Speech is but broken light upon the depth
> Of the unspoken; even your loved words
> Float in the larger meaning of your voice
> As something dimmer."

Without discussing the question of blank verse cadence and the weakness of a line where the main accent falls upon a positive hiatus, "of the unspoken," we would point out that this powerful passage shows the spirit of poetry without its concrete form. The abstract method is substituted for the concrete. Such an abstract phrase as "the unspoken" belongs entirely to prose.

That poetry must be metrical or even rhythmical in movement, however, is what some have denied. Here we touch at once the very root of the subject. Aristotle seems to have assumed that the indispensable basis of poetry is invention; and perhaps the first critic who tacitly revolted against the dictum that substance, and not form, is the indispensable basis of poetry was Dionysius of Halicarnassus, whose treatise upon the arrangement of words is really a very fine piece of literary criticism.

By the poets themselves metre was for long considered to be the one indispensable requisite of a poem, though, as regards criticism, even in the time of the appearance of the *Waverley Novels*, the *Quarterly Review* would sometimes speak of them as "poems"; and perhaps even later the same might be said of romances so concrete in method and diction, and so full of poetic energy, as *Wuthering Heights* and *Jane Eyre*, where we get absolutely all that Aristotle requires for a poem. However, at all events this at least may be said, that the division between poetical critics is not now between Aristotelians and others; it is of a different kind altogether. While one group of critics may still perhaps say with Dryden that "a poet is a maker, as the

name signifies" and that "he who cannot make (that is, invent) has his name for nothing," another group contends that it is not the invention but the artistic treatment, the form, which determines whether an imaginative writer is a poet or a writer of prose—contends, in short, that emotion is the basis of all true poetic expression, whatever be the subject-matter, that thoughts must be expressed in an emotional manner before they can be brought into poetry, and that this emotive expression demands even yet something else, viz., style and form.

Although many critics are now agreed that "L'art est une forme," that without metre and without form there can be no poetry, there are few who would contend that poetry can exist by virtue of any one of these alone, or even by virtue of all these combined. Quite independent of verbal melody, though mostly accompanying it, and quite independent of "composition" there is an atmosphere floating around the poet through which he sees everything, an atmosphere which stamps his utterances as poetry. This atmosphere is what we call *poetic imagination.*

In order to produce poetry the soul must for the time being have reached that state of exaltation, that state of freedom from self-consciousness, depicted in the lines:—

> "I started once, or seemed to start, in pain
> Resolved on noble things, and strove to speak
> As when a great thought strikes along the brain
> And flushes all the cheek."

Whatsoever may be the poet's "knowledge of his art" into this mood he must always pass before he can write a truly poetic line. For, notwithstanding all that may be said upon poetry as a fine art, it is in the deepest sense of the word an "inspiration." No man can write a line of genuine poetry without having been "born again" (or as the true rendering of the text says, "born from above"); and then the mastery over those highest reaches of form which are beyond the ken of the mere versifier comes to him as a result of the change.

It might almost be said, indeed, that Sincerity and Conscience, the two angels that bring to the poet the wonders of the poetic dream, bring him also the deepest, truest delight of form. It might almost be said that by aid of sincerity and conscience the poet is enabled to see more clearly than other men the eternal limits of his own art—to see with Sophocles that nothing, not even poetry itself, is of any worth to man, invested as he is by the whole army of evil, unless it is in the deepest and highest sense good, unless it comes linking us all together by closer bonds of sympathy and pity, strengthening us to fight the foes with whom Fate and even Nature, the mother who bore us, sometimes seem in league—to see with Milton that the high quality of man's soul which in English is expressed by the word virtue is greater than even the great poem he prized, greater than all the rhythms of all the tongues that have been spoken since Babel—and to see with Shakespeare and with Shelley that the high passion which in English is called love is lovelier than all art, lovelier than all the marble Mercuries that "await the chisel of the sculptor" in all the marble hills.

Varieties of Poetic Art.—We have now reached the inquiry: What varieties of poetic art are the outcome of the two kinds of poetic impulse, dramatic imagination and lyric or egoistic imagination? Allowing for all the potency of external influences, we shall not be wrong in saying that of poetic imagination there are two distinct kinds—(1) the kind of poetic imagination seen at its highest in Aeschylus, Sophocles, Shakespeare, and Homer, and (2) the kind of poetic imagination seen at its highest in Pindar, Dante, and Milton, or else in Sappho, Heine, and Shelley. The former, being in its highest dramatic exercise unconditioned by the personal or lyrical impulse of the poet, might perhaps be called *absolute* dramatic vision; the latter, being more or less conditioned by the personal or lyrical impulse of the poet, might be called *relative* dramatic vision. It seems impossible to classify poets, or to classify the different varieties of poetry, without drawing some such distinction as this, whatever words of definition we may choose to adopt.

For the achievement of all pure lyric poetry such as the ode, the song, the elegy, the idyll, the sonnet, the stornello, it is evident that the imaginative force we have called relative vision will suffice. And if we consider the matter thoroughly, in many other forms of poetic art—forms which at first sight might seem to require absolute vision—we shall find nothing but relative vision at work.

Even in Dante, and even in Milton and Virgil, it might be difficult to trace the working of any other than relative vision. And as to the entire body of Asiatic poets, it might perhaps be found (even in view of the Indian drama) that relative vision suffices to do all their work. Indeed the temper which produces true drama is, it might almost be said, a growth of the Western mind. For, unless it be Semitic, as seen in the dramatic narratives of the Bible, or Chinese, as seen in that remarkable prose story *The Two Fair Cousins* translated by Rémusat, absolute vision seems to have but small place in the literatures of Asia. The wonderfulness of the world and the romantic possibilities of fate or circumstance, or chance—not the wonderfulness of the character to whom these possibilities befall—are ever present to the mind of the Asiatic poet. It was left for the poets of Europe to show that, given the interesting character, given the Achilles, the Odysseus, the Helen, the Priam, any adventure happening to such a character becomes interesting.

What then is this absolute vision, this true dramatic imagination which can hardly be found in Asia—which even in Europe cannot be found except in rare cases? Between relative and absolute vision the difference seems to be this, that the former only enables the poet, even in its very highest exercise, to make his own individuality, or else humanity as represented by his own individuality, live in the imagined situation; the latter enables him in its highest exercise to make special individual characters other than the poet's own life in the imagined situation.

"That which exists in nature," says Hegel, "is a something purely individual and particular. Art, on the contrary, is essentially destined to manifest the general." And no doubt this is true as regards the plastic arts, and true also as regards literary art, save in the very highest reaches of pure drama and pure lyric, when it seems to become art no longer—when it seems to become the very voice of Nature herself. The cry of Priam when he puts to his lips the hand that slew his son is not merely the cry of a bereaved and aged parent; it is the cry of the individual king of Troy, and expresses above everything else that most naïve, pathetic, and winsome character. Put the words into the mouth of the irascible and passionate Lear and they would be entirely out of keeping.

Lyric, Epic, and Dramatic Singers.—It may be said then that, while the poet of relative vision, even in its very highest exercise, can only, when depicting the external world, deal with the general, the poet of absolute vision can compete with Nature herself and deal with both general and particular. If this is really so, we may perhaps find a basis for a classification of poetry and of poets. That all poets must be singers has already been maintained. But singers seem to be divisible into three classes: first the pure lyrists, each of whom can with his one voice sing only one tune; secondly the epic poets, save Homer, the bulk of the narrative poets, and the quasi-dramatists, each of whom can with his one voice sing several tunes; and thirdly the true dramatists, who, having like the nightingale of Gongra many tongues, can sing all tunes.

It is to the first-named of these classes that most poets belong. With regard to the second class there are not of course many poets left for it; the first absorbs so many. But, when we come to consider that among those who, with each his one voice, can sing many tunes are Pindar, Firdausi, Jami, Virgil, Dante, Milton, Spenser, Goethe, Byron, Coleridge, Shelley, Keats, Schiller, Victor Hugo, the second class is so various that no generalization save such a broad one as ours could embrace its members. And now we come to class three, and must pause. The third class is necessarily very small. In it can only be placed such names as Shakespeare, Aeschylus, Sophocles, Homer, and (hardly) Chaucer.

These three kinds of poets represent three totally different kinds of poetic activity.

With regard to the first, the pure lyrists, the impulse is mere

egoism. Many of them have less of even relative vision at its highest than the mass of mankind. They are often too much engaged with the emotions within to have any deep sympathy with the life around them. Of every poet of this class it may be said that his mind to him "a kingdom is" and that the smaller the poet the bigger to him is that kingdom. To make use of a homely image—like the chaffinch whose eyes have been pricked by the bird-fancier, the pure lyrist is sometimes a warbler because he is blind. Still, he feels that the Muse loves him exceedingly. She takes away his eyesight, but she gives him sweet song. And his song is very sweet, very sad, and very beautiful; but it is all about the world within his own soul—its sorrows, joys, fears, and aspirations.

With regard to the second class the impulse here is no doubt a kind of egoism too; yet the poets of this class are all of a different temper from the pure lyrists. They have a wide imagination; but it is still relative, still egoistic. They have splendid eyes, but eyes that never get beyond seeing general, universal humanity (typified by themselves) in the imagined situation. Not even to these is it given to break through that law of centrality by which every "me" feels itself to be the central "me"—the only "me" of the universe, round which all other spurious "me's" revolve. This "me" of theirs they can transmute into many shapes, but they cannot create other "me's"—nay, for egoism, some of them scarcely would, perhaps, if they could.

The third class, the true dramatists, whose impulse is the simple yearning to create akin to that which made "the great Vishnu yearn to create a world," are, "of imagination all compact"—so much so that when at work "the divinity" which Iamblichus speaks of "seizes for the time the soul and guides it as he will."

The distinction between the pure lyrists and the other two classes of poets is obvious enough. But the distinction between the quasi-dramatists and the pure dramatists requires a word of explanation before we proceed to touch upon the various kinds of poetry that spring from the exercise of relative and absolute vision. Sometimes, to be sure, the vision of the true dramatists—the greatest dramatists—will suddenly become narrowed and obscured, as in that part of the *Oedipus Tyrannus* where Sophocles makes Oedipus ignorant of what every one in Thebes must have known, the murder of Laius. And again, finely as Sophocles has conceived the character of Electra, he makes her, in her dispute with Chrysothemis, give expression to sentiments that, in another play of his own, come far more appropriately from the lofty character of Antigone in a parallel dispute with Ismene. And, on the other hand, examples of relative vision in its furthest reaches can be found in abundance everywhere, especially in Virgil, Dante, Calderon, and Milton.

In Coleridge's "Ancient Mariner" we find an immense amount of relative vision of so high a kind that at first it seems absolute vision. When the ancient mariner, in his narrative to the wedding guest, reaches the slaying of the albatross, he stops, he can proceed no farther, and the wedding guest exclaims:—

> "God save thee, Ancient Mariner,
> From the fiends that plague thee thus!
> Why look'st thou so?" "With my cross-bow
> I shot the albatross."

But there are instances of relative vision—especially in the great master of absolute vision, Shakespeare—which are higher still—so high indeed that not to relegate them to absolute vision seems at first sight pedantic. Such an example is the famous speech of Lady Macbeth in the second act, where she says:—

> "Had he not resembled
> My father as he slept, I had done't."

Marvellously subtle as is this speech it will be found, if analysed, that it expresses the general human soul rather than any one special human soul. Indeed, Leigh Hunt records the case of a bargeman who, charged with robbing a sleeping traveller in his barge, used in his confession almost identical words—"Had he not looked like my father as he slept, I should have killed as well as robbed him." Again, the thousand-and-one cases (to be found in every literature) where a character, overwhelmed by some sudden surprise or terror, asks whether the action going on is that of a dream or of real life, must all, on severe analysis, be classed under relative rather than under absolute vision—even such a fine speech, for instance, as that where Pericles, on discovering Marina, exclaims:—

> "This is the rarest dream that e'er dull sleep
> Did mock sad fools withal"—

even here, we say, the humanity rendered is general and not particular, the vision at work is relative and not absolute. The poet, as representing the whole human race, throwing himself into the imagined situation gives us what general humanity would have thought, felt, said, or done in that situation, not what one particular individual and he alone would have thought, felt, said, or done.

Now what we have called absolute vision operates in a very different way. So vividly is the poet's mere creative instinct at work that the *ego* sinks into passivity—becomes insensitive to all impressions other than those dictated by the vision—by the "divinity" which has "seized the soul." Shakespeare is full of examples. Take the scene in the first act of *Hamlet*, where Hamlet hears for the first time, from Horatio, that his father's ghost haunts the castle. Having by short sharp questions elicited the salient facts attending the apparition, Hamlet says, "I would I had been there." To this Horatio makes the very commonplace reply, "It would have much amazed you." Note the marvellously dramatic reply of Hamlet—"Very like, very like! Stayed it long?" Suppose that this dialogue had been attempted by any other poet than a true dramatist, or by a true dramatist in any other mood than his very highest, Hamlet, on hearing Horatio's commonplace remarks upon phenomena which to Hamlet were more subversive of the very order of the universe than if a dozen stars had fallen from their courses, would have burst out with: "Amazed me!" and then would have followed an eloquent declamation about the "amazing" nature of the phenomena and their effect upon him. But so entirely has the poet become Hamlet, so completely has "the divinity seized his soul," that all language seems equally weak for expressing the turbulence within the soul of the character, and Hamlet exclaims in a sort of meditative irony, "Very like, very like!" It is exactly this one man Hamlet, and no other man, who in this situation would have so expressed himself.

While all other forms of poetic art can be vitalized by relative vision, there are two forms (and these the greatest) in which absolute vision is demanded, viz., the drama, and in a lesser degree the Greek epic, especially the *Iliad*. This will be seen more plainly perhaps if we now vary our definitions and call relative vision *egoistic imagination;* absolute vision *dramatic imagination.*

The nature of this absolute vision or true dramatic imagination is easily seen if we compare the dramatic work of writers without absolute vision, such as Calderon, Goethe, Ben Jonson, Fletcher, and others, with the dramatic work of Aeschylus and of Shakespeare. While of the former group it may be said that each poet skilfully works his imagination, of Aeschylus and Shakespeare it must be said that each in his highest dramatic mood does not work, but is worked by his imagination. Note, for instance, how the character of Clytaemnestra grows and glows under the hand of Aeschylus. The poet of the *Odyssey* had distinctly said that Aegisthus, her paramour, had struck the blow, but the dramatist having imagined the greatest tragic female in all poetry, finds it impossible to let a man like Aegisthus assist such a woman in a homicide so daring and so momentous. And when in that terrible speech of hers she justifies her crime (ostensibly to the outer world, but really to her own conscience), the way in which, by sheer magnetism of irresistible personality, she draws our sympathy to herself and her crime is unrivalled out of Shakespeare and not surpassed even there.

Epic and Drama Compared.—Much has been said as to the scope of these. If in epic the poet has the power to take the imagination of his audience away from the dramatic centre and show what is going on at the other end of the great web of the world, he can do the same thing in drama by the chorus, and also

by the introduction into the dramatic circle of messengers and others from the outside world. But as regards epic poetry, is it right that we should hear, as we sometimes do hear, the voice of the poet himself as chorus bidding us contrast the present picture with other pictures afar off, in order to enforce its teaching and illustrate its pathos? This is a favourite method with modern poets and a still more favourite one with prose narrators. Does it not give an air of self-consciousness to poetry? Does it not disturb the intensity of the poetic vision? Yet it has the sanction of Homer; and who shall dare to challenge the methods of the great father of epic? An instance occurs in *Iliad* v. 158, where, in the midst of all the stress of fight, the poet leaves the dramatic action to tell us what became of the inheritance of Phaenops, after his two sons had been slain by Diomedes. Another instance occurs in iii. 243–244, where the poet, after Helen's pathetic mention of her brothers, comments on the cause of their absence, "criticizes life" in the approved modern way, generalizes upon the impotence of human intelligence—the impotence even of human love—to pierce the darkness in which the web of human fate is woven. Thus she spoke (the poet tells us); but the life-giving earth already possessed them, there in Lacedaemon, in their dear native land:—

ὣς φάτο· τοὺς δ' ἤδη κάτεχεν φυσίζοος αἶα
ἐν Λακεδαίμονι αὖθι, φίλῃ ἐν πατρίδι γαίῃ.

This, of course, is "beautiful exceedingly," but, inasmuch as the imagination at work is egoistic or lyrical, not dramatic; inasmuch as the vision is relative, not absolute, it does not represent that epic strength which we call specially "Homeric."

The deepest of all the distinctions between dramatic and epic methods has relation, however, to the nature of the dialogue. Aristotle failed to point it out, and this is remarkable until we remember that his work is but a fragment of a great system of criticism. In epic poetry, and in all poetry that narrates, whether the poet be Homer, Chaucer, Thomas the Rhymer, Gottfried von Strassburg, or Turoldus, the action, of course, is moved partly by aid of narrative and partly by aid of dialogue, but in drama the dialogue has a quality of suggestiveness and subtle inference which we do not expect to find in any other poetic form save perhaps that of the purely dramatic ballad. In ancient drama this quality of suggestiveness and subtle inference is seen not only in the dialogue but in the choral odes. The third ode of the *Agamemnon* is an extreme case in point, where by a kind of *double entendre* the relations of Clytaemnestra and Aegisthus are darkly alluded to under the cover of allusions to Paris and Helen. Of this dramatic subtlety Sophocles is perhaps the greatest master; and certain critics have been led to speak as though irony were the heart-thought of Sophoclean drama. But the suggestiveness of Sophocles is pathetic (as Professor Lewis Campbell well pointed out), not ironical. This is one reason why drama more than epic seems to satisfy the mere intellect of the reader, though this may be counterbalanced by the hardness of mechanical structure which sometimes disturbs the reader's imagination in tragedy.

The Lyric Imagination.—But we must now give undivided attention to pure egoistic or lyric imagination. This, as has been said, is sufficient to vitalize all forms of poetic art save drama and the Greek epic. It would be impossible to discuss adequately here the Hebrew poets, who have produced a lyric so different in kind from all other lyrics as to stand in a class by itself. As it is equal in importance to the Great Drama of Shakespeare, Aeschylus, and Sophocles, we may perhaps be allowed to call it the "Great Lyric." The Great Lyric must be religious—it must, it would seem, be an outpouring of the soul, not towards man, but towards God, like that of the God-intoxicated prophets and psalmists of Scripture. Even the lyric fire of Pindar owes much to the fact that he had a childlike belief in the myths to which so many of his contemporaries had begun to give a languid assent. But there is nothing in Pindar, or indeed elsewhere in Greek poetry, like the rapturous song, combining unconscious power with unconscious grace, which we have called the Great Lyric. It might perhaps be said indeed that the Great Lyric is purely Hebrew. But, although we could hardly expect to find it among those whose language, complex of syntax and alive with self-conscious inflexions, bespeaks the scientific knowingness of the Western mind, to call the temper of the Great Lyric broadly "Asiatic" would be rash. It seems to belong as a birthright to those descendants of Shem, who, yearning always to look straight into the face of God and live, could (when the Great Lyric was sung) see not much else.

Though two of the artistic elements of the Great Lyric, unconsciousness and power, are no doubt plentiful enough in India, the element of grace is lacking for the most part. The Vedic hymns are both nebulous and unemotional, as compared with Semitic hymns. And as to the Persians, they, it would seem, have the grace always, the power often, but the unconsciousness almost never. This is inevitable if we consider for a moment the chief characteristic of the Persian imagination—an imagination whose wings are not so much "bright with beauty" as heavy with it—heavy as the wings of a golden pheasant—steeped in beauty like the "tiger-moth's deep damasked wings." Now beauty of this kind does not go to the making of the Great Lyric.

Then there comes that poetry which, being ethnologically Semitic, might be supposed to exhibit something at least of the Hebrew temper—the Arabian. But, whatever may be said of the oldest Arabic poetry, with its deep sense of fate and pain, it would seem that nothing can be more unlike than the Hebrew temper and the Arabian temper as seen in later poets. It is not with Hebrew but with Persian poetry that Arabian poetry can be usefully compared. If the wings of the Persian imagination are heavy with beauty, those of the later Arabian imagination are bright with beauty—brilliant as an Eastern butterfly, quick and agile as a dragon-fly or a humming-bird. To the eye of the Persian poet the hues of the earth are (as Firdausi says of the garden of Afrasiab) "like the tapestry of the kings of Ormuz, the air is perfumed with musk, and the waters of the brooks are the essence of roses." And to the later Arabian no less than to the Persian the earth is beautiful; but it is the clear and sparkling beauty of the earth, as she "wakes up to life, greeting the Sabaean morning"; we feel the light more than the colour. But it is neither the Persian's instinct for beauty nor the Arabian's quenchless wit and exhaustless animal spirits that go to the making of the Great Lyric; far from it. In a word, the Great Lyric, as we have said, cannot be assigned to the Asiatic temper generally any more than it can be assigned to the European temper.

The Ode.—In the poetry of Europe, if we cannot say of Pindar, devout as he is, that he produced the Great Lyric, what can we say of any other European poet? The truth is that, like the Great Drama, so straight and so warm does it seem to come from the heart of man in its highest moods that we scarcely feel it to be literature at all. Passing, however, from this supreme expression of lyrical imagination, we come to the artistic code. Whatever may have been said to the contrary, enthusiasm is, in the nature of things, the very basis of the ode; for the ode is a mono-drama, the actor in which is the poet himself; and, as Marmontel has well pointed out, if the actor in the mono-drama is not affected by the sentiments he expresses, the ode must be cold and lifeless. But, although the ode is a natural poetic method of the poet considered as a prophet—although it is the voice of poetry as a fine frenzy—it must not be supposed that there is anything lawless in its structure. "Pindar," says the Italian critic, Gravina, "launches his verses upon the bosom of the sea; he spreads out all his sails; he confronts the tempest and the rocks; the waves arise and are ready to engulf him; already he has disappeared from the spectator's view; when suddenly he springs up in the midst of the waters and reaches happily the shore." Now it is this Pindaric discursiveness, this Pindaric unrestraint as to the matter, which has led poets to attempt to imitate him by adopting an unrestraint as to form. Although no two odes of Pindar exhibit the same metrical structure (the Aeolian and Lydian rhythms being mingled with the Doric in different proportions), yet each ode is in itself obedient, severely obedient, to structural law. This we feel; but what the law is

exactly no metricist has perhaps ever yet been able to explain.

It was a strange misconception that led people for centuries to use the word "Pindaric" and irregular as synonymous terms; whereas the very essence of the odes of Pindar (of the few, alas! which survive to us) is their regularity. There is no more difficult form of poetry than this, and for this reason: when in any poetical composition the metres are varied, there must be a reason for such freedom, and that reason is properly subjective—the varying form must embody and express the varying emotions of the singer. But when these metrical variations are governed by no subjective law at all, but by arbitrary rules, supposed to be evolved from the practice of Pindar, then that very variety which should aid the poet in expressing his emotion crystallizes it and makes the ode the most frigid of all compositions. Great as Pindar undoubtedly is, it is deeply to be regretted that no other poet survives to represent the triumphal ode of Greece—the digressions of his subject matter are so wide, and his volubility is so great.

The great difficulty of the English ode is that of preventing the apparent spontaneity of the impulse from being marred by the apparent artifice of the form; for, assuredly, no writer subsequent to Coleridge and to Keats would dream of writing an ode on the cold Horatian principles adopted by Warton, and even by Collins, in his beautiful "Ode to Evening."

Fervour being absolutely essential, we think, to a great English ode, fluidity of metrical movement can never be dispensed with. The more billowy the metrical waves the better suited are they to render the emotions expressed by the ode, as the reader will see by referring to Coleridge's "Ode to France" (the finest ode in the English language according to Shelley), and giving special attention to the first stanza—to the way in which the first metrical wave, after it has gently fallen at the end of the first quatrain, leaps up again on the double rhymes (which are expressly introduced for this effect), and goes bounding on, billow after billow, to the end of the stanza. Not that this fine ode is quite free from the great vice of the English ode, rhetoric. If we except Spenser, and in one instance Collins, it can hardly be said that any English writer before Shelley and Keats produced odes independent of rhetoric and supported by pure poetry alone. But fervid as are Shelley's "Ode to the West Wind" and Keats's odes "To a Nightingale" and "On a Grecian Urn" they are entirely free from rhetorical flavour. Notwithstanding that in the "Ode on a Grecian Urn" the first stanza does not match in rhyme arrangement with the others, while the second stanza of the "Ode to a Nightingale" varies from the rest by running on four rhyme-sounds instead of five, vexing the ear at first by disappointed expectation, these two odes are, after Coleridge's "France," the finest regular odes perhaps in the English language.

The main other varieties of lyrical poetry, such as the idyll, the satire, the ballad, the sonnet, etc., are treated in separate articles.

(T. W.-D.; X.)

MODERN DEVELOPMENTS IN BRITISH POETRY

This note purports only to deal with the principal developments of British verse in the 20th century. The difficulty, however, is to decide when that century began. We cannot, unhappily, for this purpose permit the composers of almanacs to settle the question. Something more subtle than arithmetic is at work. What we have actually to do is to isolate the moment at which Victorianism was definitely spent and something new was born. From that point of view an attempt will be made to show that the new period was precipitated not earlier than 1910 with the Georgians. Till then we are still in the spacious days of great Victoria.

The '90s were, of course, essentially Victorian, in the sense that every blind reaction is an integral part of that from which it reacts. The Rhymers' club was not that new way of saying "yes" which alone is the mark of a new movement. It was merely spirited contradiction, or even what we should now call a rather blatant exhibition of an inferiority-complex. When Arthur Symons, for example, wrote his defence of the prostitute, with cock-robin self-consciousness, he was not so much shocking the suburbs as Lord Tennyson. When Ernest Dowson fainted prettily with Pierrot, or invited Cynara to share his exquisite self-depreciation, he was not in fact languid or corrupt. He was protesting against the heartiness of Dickens and the incorruptibility of King Arthur. In that way a queer self-condemned poetry of artifice arose, which had its roots neither in life nor in the refusal of life, but in the rejection of the poet laureate. That, however amusing or lively, is not a broad enough basis for a new period of literature.

Poetry of the '90s.—Two objections may fairly be raised to this interpretation of the '90s. On the one hand the names of Robert Bridges, Thomas Hardy and Rudyard Kipling will be advanced as proving that at that time there was a volume of virile and important verse being written which was influenced neither by liking nor distaste for Victorianism. On the other hand, it will be pointed out that W. B. Yeats and A. E. Housman—two of the most considerable poets of our time—had both fully established themselves in the '90s. Having regard to the profound influence of *A Shropshire Lad* an objector might go so far as to claim that the 20th century began not in 1906 but ten years earlier in 1896.

Yet these objections, though serious, are not valid. In every period there are distinguished writers who do not influence, and are not influenced by their contemporaries in their sphere of creation. That is essentially true, though for different reasons, of Bridges, Hardy and Kipling. Robert Bridges in such a poem, for example, as "I have loved flowers" permanently enriched the English treasury. But it has that curiously withdrawn quality, that affinity to the grave unswerving mould of the classic, which distinguishes all his work. Both in his simplicity here, and his metrical experiments and complexities elsewhere, Bridges is neither Victorian nor post-Victorian. He contributes, but he neither borrows nor influences. So, too, with Hardy. That reluctant expression, that constant effect of breaking a chisel on obdurate stone, may be admired: it can never be imitated, and it is doubtful whether any one would seek to imitate it. Standards that apply to no other poet, and to no other poetry, have been applied to Hardy, and by those standards he has by some been adjudged triumphantly successful. But he has no disciples as he had no master. To some his poetry may stand out like Stonehenge in a great plain, and in these it will inspire awe and perhaps worship. But it will remain as rugged, as isolated, and to many as unmanageable as those great monoliths. Kipling again, though incomparably the most popular poet of his time, is not, and could not be, a poet's poet. In so far as he was a brilliant and sometimes vicious pamphleteer, he was bound to suffer the fate of all politicians. As the author of *Barrack Room Ballads* he created not so much a new school of verse as a new army, just as in his poems of empire he joined hands with Cecil Rhodes and Joseph Chamberlain, and turned his back on Parnassus. When he consented to be a poet, as in such a perfect lyric as the Valour and Innocence poem in *Rewards and Fairies*, he did not affect his fellow poets because they had been frightened away by the outcries of the imperial buccina. The small body of his real verse will be winnowed out by Time from the great quantity of chaff, but its effect will not be felt till the separation is complete.

W. B. Yeats did start, or was an important part of, a new and fertile period. But it was an Irish and not an English period. It is indeed one of the curiosities of literature (and races) that the Celtic revival so little influenced poetry in the sister-island. Yeats, "A. E." and James Stephens affected the English hardly at all. It is, however, true that for Ireland the 20th century began in the '90s and what a century! Yeats and the Abbey Theatre, rather than all the politicians who spoke and died for Erin, were the fathers of the Revolution. Poets in Ireland always, more than elsewhere, have been recognized as

"the movers and shakers Of the world for ever."

Yeats wrote the first draft of the Constitution of the Free State in "The Lake-isle of Innisfree."

The answer to the objectors, therefore, remains. The typical poets of the '90s did not look forward eagerly, but backward contemptuously. They were not creating; they were for the most part sneering. The more considerable names either like Yeats belonged to Irish literature, or like the other three belonged to themselves only, or with Kipling to himself and certain echoes

overseas. But there is still A. E. Housman. In his case it is certain that he did profoundly influence his fellow writers, but it is more open to question whether it was not rather with the last enchantment of the old than with the first of the new age. Perhaps Housman is no more than Robert Louis Stevenson signalling in vain from his Pacific island to the future. Because, though this has not been generally accepted, if at all, it is Stevenson in verse that was the most potent influence in the early part of the 20th century, and that influence was exerted in part at least through Housman, a disciple so unconscious of his master that he would certainly have repudiated him. Yet the two are in essence the same—poets of comment and not of participation. They have each a small neat explanation of the events they so competently, and sometimes so endearingly, describe. The older man was the more human, the younger the better poet. But Housman carried on the Stevenson note of deliberate interpretation with feeling introduced from without. Housman attracted, and deserved to attract, general attention, but when his *Last Poems* was published in 1922 it became clear that he belonged to the world of Stevenson and not to ours. His lads found the brook of the 20th century too broad for leaping. They do not lie on the further side, but they stand there a little wistful and dim against a background of end-of-the-century self-consciousness. They belong to the horizon whose margin fades behind us "for ever and for ever as we move."

Predecessors of the New Age.—Of the writers who carry over from the '90s to the first decade of the 20th century (for purposes of the almanac) none can be saluted even as the St. John the Baptist of the New World. Three at least deserve mention as writers of importance, though each must be denied the title of the forerunner—John Davidson, "Michael Field" and Stephen Phillips. Of these Davidson in his baffled fury, his fundamental inability to clinch with his hated antagonist because he never recognized him, is nearest to being the prophet. He did not hate Victoria, or the Victorians. He did not hate the gently anaemic Rhymers. But what inspired his fits of temper, that sometimes rose almost into a genuine poetry of hate? Life, of course, but it is doubtful whether he ever knew exactly what in life it was that bit him. Had it ever declared itself then Davidson might have set the trumpet of the herald to his mouth. As it was, the instrument was something of a broken reed. "Michael Field" was the name chosen by those two remarkable women Katherine Bradley and Edith Cooper, aunt and niece, who composed their poems together. For all their lovely cadence the verses never could have been more than a museum piece in a living world of letters. Though there is in bulk a surprising quantity of their work, and though much of it will endure, yet even while it was written it had the air of a gracious antique. It was a little as though those delicate fingers had discovered a lost art, and were, like Count Caloveglia in Norman Douglas' *South Wind*, moulding a faun with the enigmatic ecstasy of some disciple of Praxiteles. Their best poems had an old and final ring.

Stephen Phillips is a very different case, and much more difficult to assess. In his poetic youth the fixed stars of poetry were crowded by the critics to give place to this new and larger luminary. Within less than a quarter of a century he passed "unwept, unhonoured and unsung." So much so that when a posthumous play of his was published the writer who had undertaken the preface used it to indicate his author's remarkable shortcomings. The truth about Stephen Phillips' rise and fall has not been told yet, and certainly the present estimate of his work is unfair to the writer who rediscovered the blank verse line. The rhetoric of *Herod* will disappear. It was inspired rather by Beerbohm Tree than the tetrarch. But "Marpessa" will quietly and in due course climb to its modest place among the quieter candles of the night. For the purpose of this essay, however, Stephen Phillips is important because of the disappointment he provoked. It was believed that the great tradition of English verse that Swinburne had for all his exotic beauty failed to renew, had returned. The blank verse line is the most English and at its best the most decisive of metres. In Stephen Phillips it was hoped that it had resumed its old immortal mastery in a new prevailing way. Stephen Phillips had some of the manner but none of the substance to restore the accent of the heroes. He had a genuine singing impulse, and hands fit for a flute with two stops. He was asked to play the organ in the Albert hall. He should have been strong enough to refuse, but the blame attaches not a little to all the noisy pack of fawning critics who bayed him on to his doom. Whoever's the fault, at least he left no mark on his successors.

They were pressing on. At the very moment when the world was beginning to doubt its new idol, and in their doubt of him renewing their despair in poetry in general, the New Age was beginning in Oxford with a swarthy malcontent called James Flecker, at Cambridge with a group which Rupert Brooke led by unquestioned right, and outside Cambridge, but still in the polite world, with a certain Walter Ramal (Walter de la Mare) and a much less certain John Masefield, and outside the world altogether with W. H. Davies, who was not so much a man on the tramp as a bird on the wing. But before all these gathering rivulets converged into the broad flood of Georgianism that forced its way ever widening into the threshold of World War I and, beyond it, strained and parcelled into the swamps of death, there were still the names of Herbert Trench, Sturge Moore, Henry Newbolt and Laurence Binyon, each with his individual claim and contribution. While roaring and laughing by their side, like two huge children in H. G. Wells's *Food of the Gods*, Hilaire Belloc and G. K. Chesterton shouted to each other across the world, and "when all church bells were silent, their caps and bells were heard."

It is perhaps not necessary to attempt to range the first three in this list. Herbert Trench was a far from negligible poet, but he wrote in the grand manner at a time when events were conducting themselves in a manner at once small and obscene. His verse was too much a stranger to the times in which he lived ever to be at home there. He speaks, therefore, always a little like a foreigner. Sturge Moore, also a poet of distinction, perhaps influenced his generation of writers more by his personality than his work, interesting and diverse as it is. He has to his credit not merely a brilliant anthology of "Michael Field," but a solid body of mature and constructive criticism. Henry Newbolt, who is at times unfairly bracketed with Alfred Noyes as a poet of "patriotism," has suffered by succeeding with his worst work. "Drake's Drum" had (and continues to have) almost a music-hall success. The result is that Newbolt has quite unfairly been classified as a minor Kipling—another partisan of the white man's beneficent destiny to take up his dividends. But that is wholly unjust to a poet with a clear perception of realities, and an almost humble readiness to adapt his manner to his subject. He came a little too early to belong to the new movement. If there had been no new movement his name would have stood very high. Nor need we reclassify Hilaire Belloc and G. K. Chesterton. They refused to be treated as grown-up poets. They were Trinculo, Falstaff or Father Christmas in *The Christmas Carol*, and they deceived the world into believing them to be mere wassaillers. They almost deceived themselves, but not quite. Both, when they hated, wrote poetic satire unequalled since Pope, and Chesterton, at least, when he loved had a star hidden up his sleeve. In vain he assured his audience to the contrary. Why, his very words are on fire!

But Belloc and Chesterton stood outside the main stream of development, watching it as though two players in a football match should stand among the spectators applauding heartily. In the circumstances it is difficult to accuse them of desertion: it is better to take them for what they are—and to be thankful. We may turn from them to the players, who are thinking and who thought of nothing but the game.

Georgian Poetry.—The name "Georgian poetry" was coined in the first anthology of contemporary poets published in 1911 under the editorship of Edward Marsh, to whom, and to Harold Monro the publisher of this and the subsequent volumes, modern British poetry owes much. But the name is misleading, and has constantly misled critics. It has been assumed that it represented a single school of writers with the same aim and the same method, much as were exhibited in the case of painting by the Pre-Raphaelites. This is in fact a quite false view. The contributors

to the Georgian volume—and to Georgian poetry—represented at least five divergent streams, their only link being a common passion for verse, and a common response to something in the age which was evoking it. Those who believe that the name is more than convenient shorthand may be asked to explain what community of aim and method are represented by de la Mare, Masefield, Hodgson, Drinkwater, Rupert Brooke, Flecker, Harold Monro, D. H. Lawrence and W. H. Davies, to name only nine of the leading figures in the revival. Can the dark Arabian musician mute his strings while Saul Kane is smashing a beer-bottle with a hammer? Would the Song of Honour be audible among the mild country sounds of the Cotswolds? How would the young men "into cleanness leaping" endure the doubtfully delicious neighbourhood of "Yasmin," and what would happen in Harold Monro's week-end cottage if two of D. H. Lawrence's lovers set about breaking up the eloquent crockery in the course of their noisily stark embraces? And would W. H. Davies's nightingales sing through it all like choir boys when the organ's loud? The wealth and the strength of the period consists in its amazing diversity. It was the great achievement of Edward Marsh and Harold Monro to find a common meeting place for all these vigorous tendencies, but they had the wisdom to make no attempt to assimilate them.

It is difficult, if not impossible, to explain why one period rather than another should be rich in poetry. It is, for example, maintained that great verse generally coincides with some great national excitement, either of victory or defeat. Men sing, this view would maintain, best when they are most disturbed, and poetry, like trade, follows the battle-flag. This theory could easily be destroyed by instances both from England and France, and there is another theory which better explains the periods of fertility that supervene, as did the Georgian, on a long period of barrenness. It may perhaps be stated that poetry goes in long cycles for two reasons. First because it is the most intensive form of art: it is a divine shorthand, and can summarize in a page what may require a volume in prose. Poetry therefore is liable quickly to absorb its material. In the second place, though mankind never wants much poetry, it always demands a little. Poetry is in a sense the ultimate luxury of the human mind: it is a luxury that no men want all the time, few men want much of the time, but that all men must have some time. So great a need and so vast a desire do in the long run precipitate their object, and thus after silence song is born.

The Georgian period may have owed something to the stormy days in which it was generated. Imperialism had seen itself in the mirror of the Boer War and found that it looked uncommonly like a skeleton. Industrialism which for a century had been an affair of capital was with urgent creaks and groans becoming a problem of labour. Victorian comfort was changing into the lurid extravagance of Edwardianism. The oil-engine was challenging the printing-press for the control of the soul of man.

Here were conditions which called for examination, explanation, defence and condemnation, and if the prose-writers—Wells, Bennett, Galsworthy and Shaw—were at work, how and why should the poets be still? They weren't. But poetry is a subtler thing than prose. It is less like a photograph than a picture, less like a picture than a face seen by a lightning flash and remembered in a dream. Therefore it is not surprising that this grossly confused age should express itself supremely in a poet of sheer and airy music like Walter de la Mare, or in so consciously exquisite a craftsman as Flecker. These two with Masefield, Davies and Brooke stand out as the leading names of the period.

It is not our business to range as much as to record. The world was in fact brought to the realization of the re-birth of poetry not by Brooke, nor by the first Georgian anthology, nor by the publication of Flecker's *Bridge of Fire*, nor even by the establishment of the Poetry Bookshop in 1912. It was not to the marvel of *The Listeners* that the gates swung open, but to the huge hammer-blows of *The Everlasting Mercy* published in the *English Review*. The effect of that poem was almost comparable to the excitement induced by the appearance of *Don Juan*. Poetry with Masefield had once again ceased to be a matter for poets and coteries: it had become the possession of the people.

By that one blow Masefield flung the door of public interest wide, and the rest of the waiting poets flooded through it with a shout. The period is so rich that in the first place there must be a catalogue of names like the Homeric catalogue of the ships—Lascelles Abercrombie, Gordon Bottomley, Rupert Brooke, W. H. Davies, John Drinkwater, F. S. Flint, John Freeman, Ralph Hodgson, W. W. Gibson, Gerald Gould, D. H. Lawrence, Walter de la Mare, Harold Monro, John Masefield, Thomas Goult, Charlotte Mew, Edward Shanks, Fredegond Shove, J. C. Squire, Anna Wickham, and of the Irish, W. B. Yeats, "A.E.," James Stephens, Padraic Colum, Francis Ledwidge, Seumas O'Sullivan and Dr. Douglas Hyde. And when it is recalled that all belong to the pre-War period, it is reasonable to suggest that Victorianism was dead, that a new and fertile period had begun. It is difficult to classify material so various, or in respect of work so recent to identify the prevailing influence, particularly as these influences are still working themselves out. Certain of these poets, it was clear from the outset, whatever their individual merits, would not be likely to found a school. Lascelles Abercrombie and Gordon Bottomley, for example, both engaged in revising the blank verse line and, if possible, in re-establishing the poetic drama, were necessarily monks of verse. With such preoccupations they would be bound to stand outside the main stream. Both added notably to the intensification of poetic language, and Bottomley in *Gruach* wrote a play in verse which in time will be recognized as a permanent part of British dramatic effort. But they were not likely to impinge on the work of their fellows. D. H. Lawrence, if a poet at all, was one so savagely individual, so arrogantly physical, that he must have abashed even his admirers. He reached the extreme of remorseless resignation to the senses. He might be endured: he could not be copied. Charlotte Mew, Fredegond Shove and Anna Wickham of the women all had their own self-centred emotions. In each case their output was limited to the attar of their spiritual nature. No other poets of their period reached such continuous intensity of expression, but its very merit made it fatiguing. They are all three poets whose poems should be lived with like a great picture rather than caught suddenly like the colour of a flower. Finally, of those not likely to fit into a scheme or to herald a new world those two distinguished poets Gerald Gould and Ralph Hodgson should be mentioned. Both were poets of discontent with their age. Gerald Gould carried into action what Ralph Hodgson immortally expressed in such a poem as "The Gipsy Girl." But each had his own secret. Gould was on a pilgrimage: he was not sure whither, nor could he guide others. But he must seek. Ralph Hodgson of all his age saw loveliness most directly and strongly. He recorded it, and was struck dumb by the very completeness of his utterance.

These were then all poets who belonged to no school. But of the rest it might have been expected that de la Mare, Flecker or Masefield might each have set a fashion, though in fact it was Brooke who with Drinkwater and Harold Monro created that general attitude to which Freeman, Squire, Shanks and later Martin Armstrong, F. W. Harvey and Edmund Blunden attached themselves—the attitude to which the generic term "Georgian" has tended to be specifically applied. Of these in time Squire assumed the leadership, and he will be entitled to special memory if not as the founder at least as the saviour of a school of poetry.

De la Mare founded no school, though his rhythms have effected a profound revolution in the structure of English verse. No poet writing for the next 50 years will or can be unaffected by those fairy declensions, those elfin ascents. De la Mare need not fear mortality. His accent is now a part of English verse. He will continue to have imitators of his manner, but he is too incorrigibly delicate in substance to prevail upon the mind of other poets. Flecker perhaps failed of influence because of his long illness and untimely death. A poet cannot found a correspondence school, and Flecker, except for the earliest years of his output—the Oxford and Cambridge years—was first an exile in the East, and then a dying man in a Swiss sanatorium. It is, even so, surprising that "The Old Ships" should drag no lesser ships in their shining wake, or that no later pilgrims should have set out on "The

Golden Journey to Samarkand."

Effects of the War.—It is a question whether Masefield might not have created a school, if his violence had not been outpointed by the War. Strength and beauty, ranging hand in hand, were an intoxicating sight for all men, but most of all for poets. And it might have been supposed at least that Masefield would restore the narrative poem to its proper place in English poetry. He has not, and it is more than likely that the War, which encouraged pastoral poetry, the verse of retreat from uproar, may have equally turned men's minds from poetry, like Masefield's, of conflict and tumult.

However that may be, it is true that when war had with its usual foul impartiality murdered good and evil alike, it was to Brooke and the poets of release that the world for a moment turned. Brooke burst into fame with his War sonnets consecrated by his death in that Greek island. He became for the moment the expression of the youth of the world, gladly offering itself to wholesale assassination. But behind that momentary magnificence were the more enduring meadows of Grantchester. In these the wracked world might find peace. In these—or by the trees, whose whisper Freeman overheard, in the long wholesome stretches of Drinkwater's Cotswolds, by the harsher northern uplands of Wilfrid Gibson, in Harold Monro's most endearing consolation of the country cottage, or with the birds and the moon of Squire. This was a corporate offer to the world, and it was eagerly accepted.

For the moment. Because it was the habit of the War to make and break its idols almost simultaneously. Hardly had the new recruits flocked to the banner, hardly had Edward Shanks and Martin Armstrong added their conspiracy of release, when the poets of hatred burst upon the world like an angry shell. Robert Graves, Robert Nichols, Wilfred Owen, Siegfried Sassoon one after another blasted the romantic assumption that war was the consecration of youth by fire. In the teeth of a world staggering under its weight of stupid ugliness, these poets flung the single word "Murderers." The other poetry grew for the moment strangely dim and pale. Men were listening to this new and abominable accusation—and even the fields, the birds and the moon could not distract them from it.

The name of Edward Thomas should be mentioned in this connection. Thomas was a much older man than the other poets here mentioned, and had written much before the War. But the War in some way released his response, and his reputation—growing and deserved—is wholly post-War. Because of the circumstances in which he wrote Thomas was entirely a poet for posterity. He could do nothing to arrest the doom of silence which the exhaustion of the War was suddenly to impose. Relentlessly this poison-gas of despair advanced till a period that had seemed to be most fertile since the Elizabethan, ended choking in the fog of the spirit that denies. By the end of the decade which had seen its origin Georgian poetry was spent, and the war poetry with it. Because it seemed that the poets, who had exposed its horrors and cursed its originators, were content to forget, or at least to live back into peace. Wilfred Owen was quiet for ever, Robert Nichols turned to prose and play writing, Siegfried Sassoon at long intervals reminded the world of his genius. Only Robert Graves remained to write new forms of verse in the desperate hope of escaping from the memories he had permanently established in traditional shapes.

After the War.—And thereupon the silence smashed in 1910 began slowly to settle again. The Georgian period is over, and the war-period is over. There have been two later revolts, one known as "the Imagist" headed by F. S. Flint, with Transatlantic sanction, another led by Edith, Osbert and Sacheverell Sitwell. The first revolt like the poetry against which it protested has apparently ended. Flint, Richard Aldington and the Americans "H. D." and Ezra Pound, have contributed some ravishing melodies in free verse. They seem now to be replaced by verse not so much of freedom but in dissolution. They cannot compete, and they are wisely content to let the beauty they have made speak for itself. The Sitwell family on the other hand, and in a world of denial, affirm that with a slight shifting of the vision, a little readjustment of values, living beauty can still be restored. At a time when verse was in active danger of dying of suffocation, they breathed new life into it. Their work at least is not dead.

For the rest of the most recent work there should be mentioned Edmund Blunden and Humbert Wolfe. Blunden, though associated with the Georgian school, has lived at first hand with his fields and his farms. To read him is not like paying a visit to the country but like living there. Humbert Wolfe attempted both satire and verse that is accused of a facile romanticism. His *Requiem* was in some quarters regarded as making an advance on his earlier work; but with him, as with the Sitwells, for the moment we must be content with saying that he continued the attack.

Two things have still to be said. Among the greatest of the names in contemporary poetry are the Irish poets, who have only been mentioned, but not discussed. That was for the reason given above, that Yeats created the new Irish poetry and had far less effect on purely English verse than Housman. But the body of English literature is one and indivisible, and though it is possible in the light of the strong impulse given by Yeats to see Irish verse of the century separately, it must at least be mentioned here. All of it, as it was bound to be, is informed by a passionate consciousness of Ireland. But if the matchless rhythms of Yeats turned back to legend for consolation and hope, if "A. E." plunged into a mysticism as profound as Blake's, though, unlike Blake's, regulated by a sweet humanity, James Stephens was already looking forward. He has found truth through laughter, the laughter of a thrush. He has probably more than the other two influenced the latest developments of Irish verse. Padraic Colum and Seumas O'Sullivan are not of the same order as these, though both are poets of distinction. Colum has the quiet dignity of the inspired peasant, while O'Sullivan writes in the immediate shadow of Yeats. There remain Francis Ledwidge, who died young after an early lyric promise of almost torturing loveliness, and Bertram Higgins and Austin Clarke who are going steadily forward in the paths laid down by Yeats and his peers.

(H. Wo.; X.)

United States; Modern Developments.—Modern American poetry, characteristic of the 20th century, attempted a complete fusion of romanticism and realism; Carl Sandburg defined it as a "synthesis of hyacinths and biscuits." It was experimental and, to a large extent, anti-traditional. It sought to find fresh subject matter and unexploited material as opposed to "literary" conventions; it placed its emphasis on the local scene instead of on foreign or mythical regions; it cultivated a native idiom rather than the customary poetic diction. As early as the middle of the 19th century Walt Whitman had invited the Muse to migrate from Greece and Ionia, to "cross out those immensely overpaid accounts, that matter of Troy and Achilles' wrath, and Aeneas', Odysseus', wanderings," and turn from retrospections, recording proofs of the past, to the American continent—

> For know a better, fresher, busier sphere, a wide, untried domain awaits, demands you.

Whitman and Emily Dickinson prepared the way for the changes which followed. The pioneer vitalism of the former proclaimed a new force and unity through affirmation of the democratic spirit; the puritan mysticism of the latter achieved another kind of vigour which encouraged the use of daring metaphors and audacious turns of phrase. It took time to establish the new forces. The first edition of Whitman's *Leaves of Grass* was published in 1855 and Whitman prefaced a "deathbed edition" in 1891; Emily Dickinson's first posthumous volume was published in 1890, but no attempt at a biography of Emily Dickinson was written until 1924 and volumes of further unpublished poems kept appearing as late as 1935.

What has been called "the new era in American poetry" manifested itself suddenly in 1913. Edwin Markham's "The Man With the Hoe" had already struck the social conscience, but there was little to rouse the aesthetic consciousness. A number of small magazines devoted themselves exclusively to poetry; controversy was in the air; every month another new name was a signal for dispute which augmented the poetic "renaissance." *General William Booth Enters Into Heaven* (1913) by Vachel Lindsay (1879–

1931) and *The Congo* (1914) brought excitement and a curiously syncopated music into verse; Lindsay's *Collected Poems* (1923) gave America its wide-swinging jazz in terms of literature. A missionary and evangelist at heart, Lindsay combined revivalism and ragtime; he preached the Gospel of Beauty through a saxophone.

Robert Frost's *A Boy's Will* appeared in England in 1913, but it was *North of Boston* (1914) which fully revealed Frost's union of playfulness with profundity and his gift for suggestive understatement. A restrained but distinctive tone of voice rose from all his subsequent work, six volumes of which were assembled in *Collected Poems* (1939), and showed him to be a farmer by circumstance, a philosopher by instinct, and a teacher by experience. Though his backgrounds were those of New England, his half-whimsical, half-sombre lyrics and monologues gave regionalism a universal amplitude and traditionalism a new direction.

The year 1914 marked the rise of free verse and the Imagist movement, a movement which recalled the program of the French Symbolists and which was divided between poetry and propaganda. Amy Lowell (1874–1925) was its militant champion; her own craftsmanship, at its best in *Selected Poems* (1928), preoccupied itself with enamelled images, vivid surfaces and the swiftly changing contours of the external world.

John Gould Fletcher, another Imagist, intensified motion with emotion; his *XXIV Elegies* (1935) are a far cry from the unrelated "colour symphonies" of *Goblins and Pagodas* (1916). "H. D.," who, with Ezra Pound, was one of the first Imagists, revealed a cumulative tensity beneath the stripped technique of her *Collected Poems* (1925). Edgar Lee Masters' *Spoon River Anthology* (1916) explored the limbo between prose and verse in a set of sociological epitaphs; its disillusioned gossip and documentation of the "small town" gave rise to a school of satire and self-criticism, of which Sinclair Lewis's *Main Street* (1920) was a prose counterpart.

The ranging impulses and far-flung creative energies extended throughout the country and into the mid-twenties. Edwin Arlington Robinson had been writing for years (his concise *Children of the Night* appeared as early as 1897), but *The Man Against the Sky* (1916) was the first of his characteristically astringent works to draw an audience which reached great numbers with *Tristram* (1927); his voluminous *Collected Poems* (1937) appeared two years after his death. Carl Sandburg first blended folk-stuff and fantasy, slang and mysticism in *Chicago Poems* (1916); his *The People, Yes* (1936) added national significance to the peculiar fusion. Edna St. Vincent Millay's remarkable *Renascence* (1917) was succeeded by ten volumes which displayed her virtuosity and which, at the best, engagingly combined the voice of a precocious, eager child and the mind of an experienced, disillusioned woman. Her later work evoked varying degrees of enthusiasm; several critics deprecated the "destructive role of unofficial feminine laureate" which Miss Millay seemed called upon to assume in such collections as *Conversation at Midnight* (1937) and *Huntsman, What Quarry?* (1939). Sara Teasdale (1884–1933) became something of a vogue with *Rivers to the Sea* (1915), but the graver music of her *Dark of the Moon* (1926) was almost unnoticed. Elinor Wylie (1885–1928) strengthened the notes sounded by the contemporary singers; her lyrics and sonnets grew from the adroitness of *Nets to Catch the Wind* (1921) to the exaltation of the posthumously published *Angels and Earthly Creatures* (1929).

The strain of lyrical poetry was swelled by Léonie Adams, Louise Bogan, Genevieve Taggard, Jean Starr Untermeyer, and Dorothy Parker, whose wry flippancies were collected in *Not So Deep as a Well* (1936). A still more subtle music was registered in Conrad Aiken's *Selected Poems* (1929); in (or in spite of) the typographical oddities of E. E. Cummings; and in the modern ballads of William Rose Benét and Stephen Vincent Benét, whose *John Brown's Body* (1928) was panoramic in scope and epic in effect. Efforts to sound the "realistic" implications of the American scene were made by Kenneth Fearing, Muriel Rukeyser, and the pioneering William Carlos Williams, whose *Complete Collected Poems 1906–1938* were applauded alike by radicals and conservatives. Robinson Jeffers unleashed a violent, and often uncontrolled, power in a series of volumes from *Roan Stallion* (1926) to *Such Counsels You Gave to Me* (1938). Archibald MacLeish shaped words into surprisingly suspended cadences in *Poems 1924–1933*, fitted them into a new type of poetic drama in *Panic* (1935), put them to work on the radio and on the soundtrack in *Land of the Free* and *Air Raid* (1938).

A definite and seemingly determined attempt to join traditional metaphysical poetry with indigenous accents was expressed by a group calling itself "The Fugitives"; its leading exponents were John Crowe Ransom, Allen Tate, Donald Davidson and Robert Penn Warren. Their verse was alternately teasing and tortuous; the very richness of their allusive material made it difficult. Equally fascinating to the student and equally forbidding to the average reader were the abstract elegances of Wallace Stevens, the verbal legerdemain of Hart Crane, the crowded imagery of Horace Gregory, and the erudite intricacies of two celebrated expatriates: Ezra Pound and T. S. Eliot. Eliot's work was the most considerable; it ranged from the baffled frustration of *Prufrock and Other Poems* (1917) through the drought and disintegration of *The Waste Land* (1922) to the desperate faith of Eliot's later religious plays and essays. Finally there were the prodigies, notably Nathalia Crane, whose *The Janitor's Boy* (1924) was published when its author was not quite eleven; George Dillon, who won prizes in his teens and whose *Boy in the Wind* (1927) was published in his twenty-first year; and Merrill Moore, a psychiatrist, who wrote many of his poems in shorthand, and whose third volume, starkly entitled *M* (1938), contained 1,000 autobiographical sonnets.

(L. Un.)

POEY Y ALOY, FELIPE (1799–1891), Cuban naturalist, was born in Havana on May 26, 1799. He received his degree in law at the University of Madrid (1820) but abandoned practice to devote himself to natural history. He returned to Cuba and formed a collection which he carried back to Paris. Here he remained until 1833, publishing many articles and his *Centurie de Lepidopteres de L'ile de Cuba* (1832). He became professor of zoology and comparative anatomy in the University of Havana in 1842 and in 1863 was appointed to the chair of botany, mineralogy and geology. From 1873 until his death at Havana on Jan. 28, 1891, he was professor of philosophy and belles lettres. His magnum opus is the *Catálogo rozonado de los peces cubanos*, an atlas of ten volumes with over 1,000 of his own drawings, and describing about 800 tropical fish, about half of which he first made known to science.

POGGIO (1380–1459). Gian Francesco Poggio Bracciolini, Italian scholar of the Renaissance, was born in 1380 at Terranuova, a village in the territory of Florence. He studied Latin under John of Ravenna, and Greek under Manuel Chrysoloras. His distinguished abilities and his dexterity as a copyist of mss. brought him into early notice with the chief scholars of Florence. Coluccio Salutati and Niccolo de' Niccoli befriended him, and in the year 1402 or 1403 he was received into the service of the Roman curia. His functions were those of a secretary; and, though he profited by benefices conferred on him in lieu of salary, he remained a layman to the end of his life. It is noticeable that, while he held his office in the curia through that momentous period of 50 years which witnessed the Councils of Constance and of Basle, and the final restoration of the papacy under Nicholas V, his sympathies were never attracted to ecclesiastical affairs. Nothing marks the secular attitude of the Italians at an epoch which decided the future course of both Renaissance and Reformation more strongly than the mundane proclivities of this apostolic secretary, heart and soul devoted to the resuscitation of classical studies amid conflicts of popes and antipopes, cardinals and councils, in all of which he bore an official part. Thus, when his duties called him to Constance in 1414, he employed his leisure in exploring the libraries of Swiss and Swabian convents. The treasures he brought to light at Reichenau, Weingarten, and above all St. Gall, restored many lost masterpieces of Latin literature, and supplied students with the texts of authors whose works had hitherto been accessible only in mutilated copies. In one of his epistles he describes how he recovered Quintilian, part of Valerius Flaccus, and the commentaries of Asconius Pedianus at St. Gall.

Manuscripts of Lucretius, Columella, Silius Italicus, Manilius and Vitruvius were unearthed, copied by his hand, and communicated to the learned. Wherever Poggio went he carried on the same industry of research. At Langres he discovered Cicero's *Oration*

for Caecina, at Monte Cassino a ms. of Frontinus. He also could boast of having recovered Ammianus Marcellinus, Nonius Marcellus, Probus, Flavius Caper and Eutyches. If a codex could not be obtained by fair means, he was ready to use fraud, as when he bribed a monk to abstract a Livy and an Ammianus from the convent library of Hersfield.

Poggio embraced the whole sphere of contemporary studies, and distinguished himself as an orator, a writer of rhetorical treatises, a panegyrist of the dead, a violent impugner of the living, a translator from the Greek, an epistolographer and grave historian and a facetious compiler of *fabliaux* in Latin. Of his moral essays it may suffice to notice the dissertations *On Nobility, On Vicissitudes of Fortune, On the Misery of Human Life, On the Infelicity of Princes* and *On Marriage in Old Age.* These compositions belonged to a species which, since Petrarch set the fashion, were very popular among Italian scholars. They have lost their value, except for the few matters of fact which are embedded in a mass of commonplace meditation, and for occasional brilliant illustrations.

Poggio's *History of Florence,* written in avowed imitation of Livy's manner, requires separate mention, since it exemplifies by its defects the weakness of that merely stylistic treatment which deprived so much of Bruni's, Carlo Aretino's and Bembo's work of historical weight. A somewhat different criticism must be passed on the *Facetiae,* a collection of humorous and indecent tales expressed in such Latinity as Poggio could command. This book is chiefly remarkable for its unsparing satires on the monastic orders and the secular clergy.

Among his contemporaries Poggio passed for one of the most formidable polemical or gladiatorial rhetoricians; and a considerable section of his extant works are invectives. One of these, the *Dialogue against Hypocrites,* was aimed in a spirit of vindictive hatred at the vices of ecclesiastics; another, written at the request of Nicholas V., covered the anti-pope Felix with scurrilous abuse. But his most famous compositions in this kind are the personal invectives which he discharged against Filelfo and Valla. All the resources of a copious and unclean Latin vocabulary were employed to degrade the objects of his satire; and every crime of which humanity is capable was ascribed to them without discrimination. In Filelfo and Valla Poggio found his match; and Italy was amused for years with the spectacle of their indecent combats. About the year 1452 Poggio finally retired to Florence, where he was admitted to the burghership, and on the death of Carlo Aretino in 1453 was appointed chancellor and historiographer to the republic. He had already built himself a villa in Valdarno, which he adorned with a collection of antique sculpture, coins and inscriptions. In 1435 he had married a girl of 18 named Vaggia, of the famous Buondelmonte blood. His declining days were spent in the discharge of his honourable Florentine office and in the composition of his history. He died in 1459, and was buried in the church of Santa Croce. A statue by Donatello and a picture by Antonio del Pollajuolo remained to commemorate a citizen who chiefly for his services to humanistic literature deserved the notice of posterity.

Poggio's works were printed at Basle in 1538, "ex aedibus Henrici Petri." Dr. Shepherd's *Life of Poggio Bracciolini* (1802) is a good authority on his biography. For his position in the history of the revival, *see* Voigt, *Wiederbelebung des classischen Alterthums* (3rd ed., 1893) and Symonds, *Renaissance in Italy* (1875–86). (J. A. S.; X.)

POGLIZZA (Serbo-Croatian, Poljica), a tract of mountainous land in Dalmatia, Austria; formerly the seat of an independent republic. The territories of Poglizza lay chiefly within the south-easterly curve made by the river Cetina before it enters the Adriatic at Almissa (Omiš). They also comprised the fastnesses of the Mossor range (4,500 ft.) and the fertile strip of coast from Almissa to Stobrez, 10 mi. W.N.W. The population of Poglizza numbered 6,566 in 1806. In the following year, however, the republic incurred the enmity of Napoleon by rendering aid to the Russians and Montenegrins in Dalmatia; and it was invaded by French troops, who plundered its villages, massacred its inhabitants, and finally deprived it of independence.

See the *Annuario Dalmatico* for 1885 (published at Zara); and A. Fortis, *Travels into Dalmatia* (1778).

POINCARÉ, JULES HENRI (1854–1912), French mathematician, was born at Nancy, on April 29, 1854. He studied at the École Polytechnique, devoting himself to scientific mining, and took his degree in 1879. He was lecturer at Caen and then was transferred to the University of Paris in 1881, lecturing first on physical mechanics, then on mathematical physics, and ultimately on astronomical mechanics.

Poincaré's work falls into three main divisions: his work in pure mathematics, in astronomy and in physics. Most important is his work in pure analytical mathematics; he took the main points of an existing theory, simplified it and then developed it beyond all recognition. In this way he opened up new fields for the mathematician and gave new material to the mathematical physicist. In pure analytical mathematics a good deal of his work is on the theory of functions. He developed automorphic functions and his work on the "Fuchsian" functions he applied to the non-Euclidean geometry of Lobatchevski; he also wrote a number of papers on Abelian functions. Poincaré's work on differential equations is also important; here he extended the work of Cauchy; he dealt with linear differential equations on the lines of Riemann and Fuchs and he wrote a number of papers on the differential equations which occur in physics. In astronomy he dealt chiefly with the theory of orbits; he began with an idea due to Hill and investigated the general problem of three bodies. In addition to his purely mathematical and scientific work he also wrote on philosophy. He died in Paris on July 17, 1912.

His works include *Cours de physique mathématique,* 10 vol. (1889, etc.); *Leçons de la mécanique céleste* (1905, etc.); *Théorie de Maxwell et les oscillations hertziennes* (1907); *La théorie du potentiel newtonien* (1899); *Science d'hypothèse* (1903); *La valeur de la science* (1904); *Science et méthode* (1908).

POINCARÉ, RAYMOND (1860–1934), French statesman, was born at Bar-le-duc on Aug. 20, 1860, the son of Nicolas Poincaré, a distinguished civil servant and meteorologist. Educated at the university of Paris, Raymond was called to the Paris bar, and was for some time law editor of the *Voltaire.* He had served for over a year in the department of agriculture when in 1887 he was elected deputy for the Meuse. He made a great reputation in the chamber as an economist, and sat on the budget commissions of 1890–91 and 1892. He was minister of education, fine arts and religion in the first cabinet (April–Nov. 1893) of Charles Dupuy, and minister of finance in the second and third (May 1894–Jan. 1895). In the succeeding Ribot cabinet Poincaré became minister of public instruction. Although he was excluded from the Radical cabinet which followed, the revised scheme of death duties proposed by the new ministry was based upon his proposals of the previous year. He became vice-president of the Chamber in the autumn of 1895, and in spite of the bitter hostility of the Radicals retained his position in 1896–97.

In March 1906 Poincaré became minister of finance in the Sarrien Government, but he gave up his portfolio to Caillaux in October of the same year, when Sarrien was succeeded by Clemenceau as prime minister. During the next five years, though he still continued to exercise a powerful influence in the senate, Poincaré devoted himself mainly to his legal career. In 1909 he was elected a member of the French Academy. In Jan. 1912, Caillaux, who had been prime minister since the beginning of the previous year, resigned, whereupon Poincaré formed a government in which he himself held the portfolio of foreign affairs.

Poincaré's cabinet constituted an *entente nationale,* and his first aim was to pursue a more definite foreign policy. In home affairs the problem which presented the greatest difficulties was that of electoral reform. Poincaré induced the chamber to pass a proportional representation bill. But above all diplomatic affairs claimed his constant attention; for during the negotiations with Germany which took place in consequence of the dispatch of a gun-boat by that country to Agadir, certain incidents had occurred during the Caillaux administration which had produced a feeling of disquietude in regard to foreign policy. Poincaré therefore sought to re-establish a continuity of policy; and though he maintained courteous relations with Germany his main

endeavour was to prove that France would remain faithful to both friends and allies. The ratification by the senate of the Franco-German Treaty of Nov. 4, 1911, was followed by France's definite establishment in Morocco.

Almost immediately after the establishment of the Poincaré Government, an incident had occurred which temporarily obscured the friendly relations between France and Italy. The Italians, who at that moment were at war with the Turks, seized two French mail-steamers, the "Carthage" and the "Manouba," which were on their way to Tunis, on Jan. 16 and 18, 1912. But Poincaré, by his calmness and resolution, succeeded in re-establishing amicable relations between the two countries. By the end of October Italian sovereignty in Libya was recognised, and by a mutual declaration of the two Governments, full liberty of action was granted to France in Morocco and to Italy in Libya. When in the autumn of 1912 the Balkan War broke out, Poincaré made every effort possible to prevent the conflagration from spreading. Nevertheless the succession of European crises, combined with the ever-increasing menace from Germany and Austria-Hungary, rendered it necessary to take precautions; and Poincaré induced parliament to vote a programme of naval construction; through the strengthening of Franco-British relations it became possible to concentrate the whole of the French fleet in the Mediterranean.

On Jan. 17, 1913, Poincaré was elected president of the republic in place of Fallières. In power, he endeavoured to cement the friendships and strengthen the alliances of France. (*See* FRANCE, HISTORY.) At a later stage, his enemies at home and abroad criticised him severely for this policy; yet it is hardly reasonable because a man is sufficiently far-seeing to apprehend a storm and make preparations for it, to accuse him of wishing to hasten it. He claimed that he did his utmost to avert war, holding that the way to prevent the conflict was for those powers against whom the menace was directed to present a powerful and united front, thus making it imprudent to attempt any act of aggression.

In July 1914 Poincaré went to Russia on a visit which had been planned for some time past. He was on his way home, having arranged to visit the three Scandinavian capitals, when the news of the Austrian ultimatum to Serbia reached him. After a short stay in Stockholm he returned hastily to Paris; and in a letter to King George V. he pleaded for a clear declaration that the *entente cordiale*, if necessary, would prove its strength on the battlefield, pointing out that such a statement would have a restraining effect on the policy of Vienna and Berlin. Throughout the World War he continued to perform his duty with the same energy and discretion as before; though sometimes he visited the front, he never placed any obstacle whatever in the way either of the Government or of the army. In Nov. 1917 he gave proof of his vision and disregard of self by placing in power Clemenceau, who, though undoubtedly the man of the moment, was one with whom he had little sympathy. During the critical months of 1918, Poincaré revealed an inflexible resolution and a supreme confidence in the ultimate victory.

During the peace negotiations divergence of views again became apparent between Poincaré and Clemenceau. On more than one occasion the president found it necessary to write to the prime minister pointing out the errors which, from his point of view, were being committed. His counsels, however, were not followed, and at the beginning of 1920, after having completed seven years as president, he left the Elysée and was shortly after re-elected senator for the department of the Meuse. In Jan. 1922, the Briand cabinet having resigned, Poincaré once more became prime minister and minister for foreign affairs. He made it his chief aim to insist on the fulfilment by Germany of her obligations in regard to reparations. During the first year of his new government he failed to arrive at any agreement on this subject with the British cabinet, whose views differed so widely from his own. The Inter-Allied Conference in London in Aug. and Dec. 1922 produced no result. A further conference took place in Paris on Jan. 2 and 5, 1923. But Poincaré rejected the proposals drawn up by Bonar Law.

At this moment, the Reparations Commission, with Britain dissenting, having declared that Germany had failed to fulfil her obligations in regard to the delivery of coal and coke, Poincaré, in agreement with Belgium, undertook the occupation of the Ruhr (*q.v.*). At first this measure involved merely a method of control, but gradually, owing to the passive resistance of the Germans, it became necessary to exploit the railways and to some extent also the mines by means of Franco-British supervision. But by autumn the passive resistance had ceased, and Poincaré awaited the German proposals which never came. He then accepted the American suggestion that a group of experts should be given the task of finding the solution of the reparation problem; this resulted in the adoption of the Dawes Plan. But Poincaré had made up his mind not to withdraw from the Ruhr until he was satisfied that this plan was being carried out.

During the first three months of 1924 Poincaré had to face a financial crisis due to the state of the exchange. Not without difficulty he induced parliament to vote new taxes and succeeded in saving the situation. But from now onwards he had to withstand strenuous opposition from the parties of the Left consisting of the Radicals and Socialists. The policy of these groups met with a marked success at the general elections of May 11, 1924, and resulted in a majority for the Left which now formed a coalition under the name of the Cartel des Gauches. Immediately the results were announced, Poincaré stated that he would retire on the day when the new Chamber was to assemble, which took place on June 1, 1924.

Thenceforward he took his place in the senate, intervening only rarely in political debates. But he was to come into power once more. When, in the middle of the summer of 1926, the financial crisis, which successive cabinets since 1924 had been unable to check, became more and more serious, public opinion saw in him the only man capable of meeting the situation. After the fall of the Briand-Caillaux cabinet, which only lasted a few weeks, and of the Herriot cabinet, which only existed a few hours, Poincaré, in the last days of July, formed a ministry which included both moderate Republicans and Radical-Socialists, and had as its object the stabilization of French finances by means of a policy of national union. Public opinion was immediately reassured. At the beginning of August the ministry caused the national assembly, meeting at Versailles, to pass, as articles embodied in the constitution, and therefore not at the mercy of political changes, regulations for the establishment of an automatic sinking-fund, to which would be attributed funds which could not be touched (death duties, revenues from the tobacco monopoly, etc.).

In three months he succeeded in raising the value of the franc from 264 francs to the pound sterling, to 124. This rate was achieved in Dec. 1926, and thenceforward the value of the franc did not fluctuate. For a year and a half Poincaré, who had restored a strict financial equilibrium, maintained this stabilization of the currency *de facto*. The general election of April 1928 having returned a majority which approved of his policy, a law was voted in June by the new assembly, and by the senate, establishing the stabilization *de iure*. It was one of the most successful operations of this nature in history. Withdrawal of the Radical-Socialist support from his government, engineered by Caillaux, caused his resignation on Nov. 7, 1928, but he formed a new ministry on Nov. 12. He resigned because of illness, on July 27, 1929. Poincaré undertook the publication of an important work in 10 volumes, entitled *Au service de la France; neuf années de souvenirs*, the plan of which is to describe the sequence of events from 1911 to 1920 and the rôle which he himself played in them. Four of these volumes appeared in 1926, 1927 and 1928 under the titles of *Le lendemain d'Agadir, Les Balkans en feu, L'Europe sous les armes*, and *L'Union sacrée*. He died Oct. 15, 1934.

See H. Girard, *Raymond Poincaré* (1913); E. Charton, *L'Angleterre et M. Poincaré* (1923); S. Huddleston, *Poincaré* (1924); Sir George Arthur, ed., *Memoirs of Raymond Poincaré* (1929). (P. B.)

POINSETTIA, a popular greenhouse winter-flowering shrub of the family Euphorbiaceae. The *Euphorbia pulcherrima* of gardens, a native of Mexico and Central America, with its scarlet bracts, stands high among decorative plants. The white-bracted sort, var. *alba*, is not so effective, but the double-flowered, var. *plenissima*, in which the inflorescence is branched, is as brilliant

as the type, and keeps long in flower.

They are propagated by cuttings in spring. When taken off with a heel, cuttings strike freely in brisk heat. They require good turfy loam, with an addition of one-sixth of leaf mould and a little sand, and should be kept in a heat of from 65° to 70° at night, with a rise of 10° by day. About August they may be inured to a heat of 50° at night, and should be placed out of doors for a month under a south wall in the full sun. This treatment matures and prepares them for flowering. In autumn they must be removed to a house where the temperature is 50° at night, and by the end of September some of them may be put in the greenhouse, where they will come into flower, the remainder being placed under heat later for succession.

POINT, in finance, the unit used to estimate or quote the changes in market price of securities, commodities or exchange. In the security market a point is 1% or $1 per share of stock or $10 per bond. Variations in securities are quoted as low as one-eighth of a point, 12½ cents on stock and $1.25 on bonds. In commodities such as cotton, coffee and sugar the point is one one-hundredth cent per pound, and no fractional points are quoted. Thus in cotton a decline or advance of one-fourth cent a pound would be 25 points or $1.25 per bale. A point in exchange is one one-hundredth cent. Thus an advance in sterling from 4.8625 to 4.8635 would be a ten-point rise. In the English market stock is quoted at so much per £100 and the loss of a point would not necessarily mean the loss of 1%. If, for example, £100 worth of stock were quoted at "£87, dropped one point," this would be equivalent to £86. On the other hand, £100 stock quoted at "£237, gained one point" would indicate that the closing price was £238.

POINT SETS. A point set is a collection of points selected from a given space. The study of the properties of point sets constitutes that branch of mathematics known as point sets, or the theory of sets of points. Generally speaking, the properties of a point set may be classified under two heads, (1) topological and (2) metric. For a description of the former *see* TOPOLOGY. A brief introduction to the metric properties of point sets is given below.

The Problem of Measure.—In order to approach the subject by as simple an example as possible, let us confine ourselves to the case where the given space is an ordinary straight line, L. If P and Q are distinct points of L, then the point set consisting of P and Q together with all points between them is called an interval and is denoted by $[P,Q]$. Let us imagine that we have a common foot rule which can be applied to L in order to measure lengths. Then given an interval $[P,Q]$ we can measure its length and say that it is a certain number of feet. Of a single point we would say, in accordance with the ordinary geometry notion, that its length is zero. If we are given two intervals which have no point in common, it is not natural to speak of the length of the set of points which they represent, the word "length" being usually applied only to connected pieces. In this case we shall use the word "measure," and say that the measure of this point set is the sum of the lengths of the two intervals.

However, when we speak of a point set on L, this does not necessarily imply that we are thinking of an interval, a single point or a set of intervals; we sometimes mean to indicate a set of points which contains no connected portion; *i.e.*, which contains no interval. One might be tempted to say that since a point has length zero, the "measure" of such a set would be the sum of the lengths of its individual points; *i.e.*, the sum of a set of zeros, and hence zero. Such a hasty decision would not lead to very fruitful results, however, for the following reason. If we determine upon a "measure" for two point sets, A and B, which have no points in common, the sum of their measures should naturally be the measure of the point set which is made up by them taken together. Thus, above, we have stated that the measure of a set consisting of two intervals with no common point is the sum of the lengths of those intervals. Now any interval $[P,Q]$ can easily be shown to be the sum of two sets A and B each of which fails to contain any interval, and if we arbitrarily call the measure of both A and B zero, the sum of their measures would be zero, which is not the length of $[P,Q]$, no matter how small the length of $[P,Q]$. In other words, we want a measure of a set of points which will correspond to the ordinary idea of length.

We have now introduced what is known, in the theory of sets of points, as the problem of measure. There have been several methods devised for finding a measure of an arbitrary set of points. We shall describe, briefly, the theory of Lebesgue measure, which is the foundation of the Lebesgue theory of integration.

Lebesgue Measure.—A set, A, is said to be covered by a collection, G, of intervals, when every point of A is in some interval of G. If the set of intervals G is denumerable, then we shall say that it is a covering of A. (A set is called denumerable if its elements can be "tagged" with positive integers in such a way that no two elements of the set are "tagged" with the same integer.) If the sum of the lengths of the intervals of G exists, let us call this the sum-length of the covering. Now of all possible coverings of A consider the corresponding sum-lengths, and let N be the largest number which is not greater than any of these sum-lengths. Then N is called the exterior measure of A and is denoted by m_eA. Suppose, now, that $[P,Q]$ is some interval, whose length we shall denote by d, such that all points of A are within $[P,Q]$. Let B be the set of all points of $[P,Q]$ that do not belong to A, and let m_eB denote the exterior measure of B, found just as m_eA was found. If it happens that $m_eA+m_eB=d$, then m_eA is accepted as the measure of A, and is what is known as the Lebesgue measure of A. Of course we know at the same time that m_eB is the Lebesgue measure of B, and in accordance with our ideas of length we have required that the sum of the two measures give the length of $[P,Q]$. To be sure, the Lebesgue measure of a set of points may not exist, but it does exist for all ordinary point sets. Indeed it is not at all easy to give an example of a set of points which has no Lebesgue measure, and all those examples which have been given make use of certain methods which are held to be unacceptable by many mathematicians.

For the measure of a set of points in a plane, areas are employed. Thus, the measure of the set of all points in a square is the area of the square. And to get the measure of a general plane point set M, a covering of M is made by means of squares. In three dimensions cubes are employed, and we deal with sum-volumes.

The introduction of the notion of measure has led to an enriching of the content of general analysis that could hardly have been realized otherwise. The effect has been felt not only in mathematics itself, but in the closely allied fields of mechanics and dynamics.

BIBLIOGRAPHY.—*Encyklopädie der mathematischen Wissenschaften,* Band II3 Heft 7 (1924); in ss. 18–200 will be found a summary of various kinds of measure; on p. 858 are given references to applications of the notion of measure to problems in physics, astronomy, etc. E. W. Hobson, *The Theory of Functions of a Real Variable and the Theory of Fourier's Series,* vol. i, p. 158 *et seq.* (2nd ed., 1921), or Chaps. I and II (3rd ed., 1927); Edward Kasner and James Newman, *Mathematics and the Imagination,* pp. 201–207 (1940). (R. L. WI.)

POISON. Toxicology is the science which embodies the knowledge of the sources, characters and properties of poisons, the symptoms which they produce, the nature of their fatal effects and the remedial measures which should be employed to combat their actions or effects.

Poison is a substance which, when taken into the mouth or stomach, or when absorbed into the blood, is capable of affecting health seriously or of destroying life by its action on the tissues with which it comes into contact immediately or after absorption.

The Legal Aspect.—The law does not require that a poison should be defined further than as a substance which, when administered, is injurious to health or life. The law on the subject, as applicable to England, is contained in the Offences Against the Person act, 1861, sections 11, 22, 23 and 24. With regard to poisons and abortion, sections 58 and 59 are relevant.

Section 11 states that whosoever shall administer, or cause to be administered to, or to be taken by, any person, any poison, or other destructive thing with intent to commit murder shall be guilty of felony. Section 22 covers the administration of substances calculated to enable the commission of a crime. It provides that any person shall be guilty of felony who unlawfully,

with intent thereby to enable himself or any other person to commit an indictable offense (or to assist any other person in committing such an offense) (*a*) applies or administers (or attempts to apply or administer) to any person any chloroform, laudanum or other stupefying or overpowering drug, matter or thing; or (*b*) causes (or attempts to cause) such drug, matter or thing to be administered to, or taken by, any person. Sections 23 likewise makes it a felony for any person unlawfully and maliciously to administer to, or cause to be administered to, or taken by, any other person, any poison or other destructive or noxious thing, so as thereby to endanger the life of such person, or so as thereby to inflict upon such person any grievous bodily harm. Section 24 enacts that if the substance was administered with intent only to injure, aggrieve, or annoy, the person who administered or caused it to be administered shall be guilty of a misdemeanour. Relating to abortion, section 58 states that every woman being with child, who with intent to procure her own miscarriage, shall unlawfully administer to herself any poison, or other noxious thing, and whosoever, with intent to procure the miscarriage of any woman, whether she be, or be not with child, shall unlawfully administer to her, or cause to be taken by her, any poison or other noxious thing, shall be guilty of felony. Finally, section 59 states that whosoever shall unlawfully supply or procure any poison or other noxious thing, knowing that it is intended to be unlawfully used, with intent to procure the miscarriage of any woman, whether she be with child or not, shall be guilty of a misdemeanour.

To constitute a "noxious thing," it has been held that there must not only have been intentional administration of a noxious substance, but it must have been administered in sufficient quantity to be noxious. Within the meaning of the Offences Against the Person act, a noxious thing means a thing that will produce the effect mentioned in the statute, namely to produce miscarriage. If a substance actually produced miscarriage, that fact is sufficient to establish that it is a noxious thing. A vegetable decoction of a harmless character which as such would not produce a miscarriage is not a noxious thing. The Offences Against the Person act is applicable to England. By Scots law, to cause death by poisoning is a capital crime at common law. At common law, an attempt to poison is also a crime. Under statute, an attempt to poison is punishable by death, whether the administration of the poison was with intent to murder, to disable or to do some grievous bodily harm.

It would appear that the term "grievous bodily harm" is intended to be applied when the injury causes some measure of pain or inconvenience to the affected person, and so affects the health of that person.

The Sale of Poison.—The following are the statutes governing the sale of poisons in Great Britain: Pharmacy and Poisons act, 1933; Poisons rules, 1935; Poisons (Colouring) rules, 1936; and statutory rules and orders made in connection with the Pharmacy and Poisons act, 1933; Dangerous Drugs act, 1951, and statutory regulations and orders made in connection with them; Therapeutic Substances act, 1925; and Therapeutic Substances regulations, 1931–44.

The objects of these acts, put broadly, are to control the sale of poisons to the public and to reduce the danger to human life from indiscriminate sale by unqualified persons. The Dangerous Drugs acts regulate the use of drugs of addiction such as opium, morphine and cocaine. With certain exceptions, only duly qualified and registered pharmacists and registered medical practitioners are permitted to sell poisons.

In the United States, the Caustic Poison act, 1927, safeguards the distribution and sale of certain dangerous caustic or corrosive acids, alkalies or other substances in interstate and foreign commerce. This act names 12 materials which are classified as dangerous, caustic or corrosive substances: hydrochloric acid, sulphuric acid, nitric acid, carbolic acid, oxalic acid, salt of oxalic acid, acetic acid, hypochlorous acid, sodium hydroxide, potassium hydroxide, ammonium hydroxide and silver nitrate. The Food, Drug, and Cosmetic act, 1938, successor of the Food and Drugs act, 1906, prohibits the movement in interstate commerce of adulterated and misbranded food, drugs, devices and cosmetics. Both the Caustic Poison act and the Food, Drug, and Cosmetic act are enforced by the food and drug administration. The U.S. public health service administers the Virus, Serum and Toxin act, 1902, which provides for the maintenance of potency and purity of biological products. The Harrison Narcotic act, 1914, and the Marihuana act, 1937, are administered by the bureau of narcotics of the U.S. treasury department. These acts regulate the importation, sale or giving away of preparations of opium or coca leaves and of marijuana, respectively.

Poisoning.—Poisoning may be accidental, suicidal or homicidal. By far the commonest type is poisoning from accidental causes. In spite of the precautions taken by the state in the sale of poisons, far too little care is taken by the public in the safeguarding of poisons in their possession. As a result, these are frequently taken by mistake instead of other substances of a harmless nature, or often an overdose is taken from pure carelessness. Thus, oxalic acid crystals when purchased in a paper packet may be transferred to an unlabelled bottle or jar and then taken by mistake for Epsom salts which they closely resemble. Similarly, tablets of corrosive sublimate have been taken by mistake instead of such harmless tablets as Blaud's pills. It is the duty of every individual possessing a substance of poisonous nature to take the utmost care that this is correctly labelled and kept safely guarded under lock and key.

Two poisons very commonly responsible for poisoning are lysol and carbon monoxide. Both are usually present in the average home.

Carbon monoxide is responsible annually for many deaths as the result of accident or suicide. It is a constituent of illuminant gas; for example, town gas, when prepared in the vertical retort, may contain as much as 22% of carbon monoxide. Defective gas heaters, especially in bathrooms, and fractured gas pipes and mains may provide a source of poisoning. Exhaust gases from internal-combustion engines also cause poisoning. It has been estimated that such gases contain from 1% to 7% depending on the richness of the mixture.

Self-administration of barbiturates is a dangerous practice, since the patient having already become confused by an initial dose of a barbituric compound may continue, on the same occasion, to take further and possibly fatal quantities of the drug without realizing the danger. This is the possible explanation of some of the acute and even fatal cases of barbiturate poisoning which might otherwise appear inexplicable.

ACTION OF POISONS

Poisons may have a local action or a general systemic action after absorption into the circulatory system, or they may act in both ways. Almost all poisons have a general systemic action. Some poisons such as corrosives destroy the mucous membrane or tissues with which they come in contact and cause serious or dangerous injury thereby. Irritant poisons set up a local inflammatory reaction in the mucous membrane of the alimentary tract.

Apart from these local effects, the common result of absorption of a poison is the harmful effect produced on the important organs of the body; for example, the liver, kidneys, heart and nervous system are almost certain to be adversely affected. A poison after absorption attacks all the organs of the body in varying degrees, and it is a mistake to regard poisons as being exclusively selective in their action though some poisons appear to direct the brunt of their attack on a particular system.

Among the conditions affecting the action of a poison may be mentioned the following:

Amount Taken.—From the point of view of dosage, potent drugs can be divided, in an arbitrary manner, into two groups: those in which the lethal dose lies far in excess of the active dose, and those in which it lies close to the active dose. There is a definite distinction between the terms "toxic dose" and "fatal dose," since the former merely causes symptoms of poisoning while the latter induces poisoning to such a degree that death results. The term "fatal dose" when applied to a poison means

the smallest dose which is known to have caused death in an adult. Usually the quantity of a poison taken bears a relation to the effects produced. Exceptions to this rule are substances in the case of which, owing to the quantity taken, vomiting occurs so that most of the poison is expelled; oxalic acid and tartar emetic are examples. Frequently larger doses may be taken without death resulting, but much depends on other factors than quantity, and also on whether adequate treatment has been adopted.

Habit.—A tolerance to some poisons occurs after their repeated use, and in some cases doses far greater than a normal fatal dose may be tolerated without serious symptoms developing. Examples of such drugs are arsenic, morphine, opium, cocaine and alcohol. In the case of some of these poisons their repeated use leads to addiction, with all its pernicious symptoms and effects.

Idiosyncrasy.—Some persons are exceedingly intolerant of certain drugs which in moderate doses may thus cause in them dangerous or even fatal symptoms. Examples are morphine, cocaine, quinine, iodine, bromine, salicylates and acetylsalicylic acid (aspirin), which in some persons have a severe cardiac depressant action.

Age.—Usually children are much more susceptible to the effects of a poison than adults. The dosage of drugs in the case of children has been fixed by a pharmacological rule, but exceptions to this are morphine, opium and its preparations which are much more toxic than the rule would indicate; on the other hand, children tolerate belladonna preparations better than adults. Aged persons withstand poisons badly.

State of Health.—A relatively small dose, from which a stronger person would probably recover, may kill a weakly person. In disease, drugs are usually much more toxic, and this is especially so where the excretory organs are affected. For example, in nephritis, medicinal doses of such drugs as morphine, salvarsan, hyoscine, etc., often cause dangerous symptoms; likewise in cirrhosis of the liver there is a greatly increased susceptibility to such drugs. In conditions of gastritis or enteritis, drugs like arsenic are especially toxic. On the other hand, in some conditions associated with delirium or pain, large doses of sedative drugs produce little effect provided that the excretory organs are healthy.

Condition and Mode of Administration.—If a poison is taken in solution, by the mouth, it acts much more powerfully than if taken in an insoluble form. For example, an insoluble preparation of arsenic may produce little poisonous effect even in large doses; similarly strychnine given in hard pills has a much-delayed action.

The presence of food in the stomach has a marked influence on the effect of a poison. If the stomach is empty the effect will be rapid, particularly so when the poison is in a soluble form; on the other hand, if the stomach is full, considerable delay may occur in the action of the poison as is well shown in acute arsenical poisoning.

A poison acts most rapidly when inhaled in a gaseous or vaporous form or when injected intravenously; next in order of rapidity, when injected subcutaneously; and least rapidly when ingested. Poisons may be absorbed by the skin or mucous membrane of the vagina or rectum, with fatal result.

Chemical Combination.—Some substances when in certain combinations are very poisonous, but when in others are comparatively innocuous. While the component parts of a mixture may have a poisonous action when administered singly, the compound may be comparatively inert.

Cumulative Action.—Certain poisons tend to accumulate within the body as the result of slow excretion (for example, strychnine, lead, mercury, digitalis and carbon monoxide) and therefore the continued administration of relatively small doses may occasion symptoms of poisoning.

DIAGNOSIS AND TREATMENT OF POISONING

Evidence of Poisoning.—It must be remembered that the symptoms of poisoning may be closely simulated by the symptoms of natural disease, and the greatest care must be taken before a diagnosis of poisoning is arrived at. Thus, the symptoms of acute arsenical poisoning closely resemble those of cholera or of acute bacterial food poisoning. The only certain differentiation is the finding of arsenic in the vomit, faeces or urine, or of the bacteriological evidence of a cholera or food poisoning infection.

Various factors may provide evidence of poisoning: (1) The symptoms are usually sudden in their onset and they occur after the taking of food or drink, or after exposure to poisonous gases or vapours. (2) If several persons are similarly exposed all are affected more or less with similar symptoms. An exception may occur in the case of bacterial food poisoning, where certain persons may be relatively immune and some may be specially susceptible. (3) The analysis which should always be carried out in suspected cases may reveal the presence of the poison in the vomit, urine and faeces, and possibly also in some articles of food or medicine.

Post-mortem Evidence.—If death occurs, a post-mortem examination should be made only following instructions from the coroner. The post-mortem signs found should be consistent with those occurring from poisoning by the suspected poison. The analysis of the viscera should yield results consistent with that of poisoning by the suspected poison, taking into account the circumstances of administration and death.

Treatment.—The mode of treatment to be adopted varies according to the nature of the poison.

The poison should be removed from the stomach without delay, antidotes should be administered, the poison should be eliminated from the body by natural channels, symptomatic treatment should be undertaken and stimulation of the respiratory and circulatory systems should be resorted to immediately indications present themselves. Emetics are a poor substitute for the emptying and washing out of the stomach by means of the funnel and stomach tube, but they may be employed if the more effective treatment is impossible. Safe emetics are mustard and water, salt and water, ammonium carbonate or apomorphine. The emptying and washing out of the stomach by means of the stomach tube and funnel is, however, contraindicated when poisoning occurs from the corrosive mineral acids or alkalies. In such cases there is a danger of perforation. After the stomach has been emptied and washed out, suitable antidotes should be given, such as chalk and lime water to neutralize oxalic acid and the mineral acids, lime water for carbolic acid. Atropine may be given hypodermically in the case of morphine poisoning. Where morphia and cocaine are taken, the stomach should be washed out with diluted permanganate of potash solution.

Elimination by the bowel is facilitated by colon washes with warm normal saline solution and by free bowel evacuations. The symptoms of poisoning are subdued by the administration of appropriate remedies; thus, pain may be relieved by hypodermic injection of morphine, and the convulsions from strychnine by chloroform inhalation.

CHARACTERISTICS OF DIFFERENT POISONS

Classification.—Poisons may be classified in many different ways; *e.g.*, according to their chemical composition, to their action on the body, to their physical characters, etc.

The following is a convenient and simple classification.

Corrosive Poisons are those which destroy by direct action the tissues with which they come in contact. To this category belong the mineral acids, such as sulphuric, hydrochloric, nitric, etc.; the caustic alkalies, such as caustic soda, caustic potash, ammonia, carbolic acid; metallic poisons, such as corrosive sublimate, zinc chloride, silver nitrate. The last-mentioned will also be considered under irritant poisons. It should be remembered that corrosive poisons in diluted condition lose their corrosive effect and become irritants.

Irritant Poisons.—These poisons by their direct action on the mucous membrane set up inflammation. Examples are: oxalic acid and its soluble salts; arsenic compounds and antimony compounds; most of the metallic poisons in solution; phosphorus; bromine; iodine; boracic acid, etc.

Systemic Poisons which act on the nervous system or other important organs such as the heart, liver, lungs or kidneys without

having any special irritant or corrosive effect. This group includes the majority of poisonous substances such as the vegetable poisons or their alkaloids, hydrocyanic acid and its salts, chloral, chloroform, alcohol, ether, hypnotic drugs such as veronal, sulfonal, etc. Certain poisons affect the liver and produce toxic jaundice (for example, tetrachlorethane, trinitrotoluene, picric acid, etc.), while others, such as cantharides and turpentine, involve the kidneys.

Gaseous Poisons such as chlorine, carbon monoxide and coal gas, carbon dioxide, etc. (see *War Gases,* below).

Poisonous Foods such as mushrooms, shellfish and food contaminated with dangerous pathogenic bacteria.

CORROSIVE POISONS

Symptoms.—Corrosive poisons produce severe symptoms immediately they are taken—a burning pain in the mouth, throat and oesophagus and pain referred from the stomach and intestines. Vomiting occurs quickly and the vomit contains blood which may be altered in colour by the action of the poison; often also shreds of destroyed mucosa are present. Collapse occurs early; and perforation is common when, should the patient survive, signs of general peritonitis develop.

An examination of the patient will show signs of the corrosive action of the poison on the mouth and throat, and marked tenderness will be present on palpation over the stomach and intestine. Corrosive poisons if swallowed in poisonous quantity are usually fatal within 24 hours unless immediate treatment with a suitable antidote is adopted.

Should the patient survive the immediate effects of the poison, serious aftereffects result from damage to the alimentary tract, and in the case of volatile corrosives serious pulmonary complications often ensue. Post-mortem examination shows evidence of the destructive action of the poison on the mucous membrane of the mouth, throat, oesophagus and stomach, there being often extensive haemorrhage in the underlying tissues.

Among examples of corrosive poisons may be named:

The Corrosive Mineral Acids.—These include *sulphuric acid,* commonly known as oil of vitriol; this is used in various industries and in all chemical laboratories. It is a most powerful corrosive in the concentrated form, whether taken internally or applied externally as in cases of "vitriol throwing." One drachm has caused death in an adult, and half that quantity in a child.

Hydrochloric acid is known also as muriatic acid or spirits of salts. It is used largely for industrial and chemical purposes and is a common article of domestic use. It is readily obtainable and is very commonly used for suicidal purposes. It is a most dangerous corrosive and one drachm has caused death in an adult.

Nitric acid, known as aqua fortis and red spirit of nitre, is used for industrial and chemical purposes. It is a most dangerous corrosive and produces characteristic yellow staining of the tissues with which the strong acid comes in contact. The vapour of the acid, if inhaled into the lungs, often produces an acute fatal form of pneumonia which is a common cause of death in nitric acid poisoning.

Other mineral acids such as *hydrofluoric, phosphoric* and *sulphurous* acids in concentrated form produce similar effects.

Treatment.—The treatment of poisoning by corrosive mineral acids consists in giving as soon as possible harmless alkaline remedies such as magnesia powder, milk of magnesia, lime water or chalk. These should be administered freely, and plenty of egg albumen (white of egg) should also be given, since this tends to neutralize the acid by forming a protein combination, and also it has a soothing effect on the damaged mucosa.

The stomach should not be washed out for fear of perforation. Pain is relieved by the free use of morphine hypodermically, and after the swallowed acid has been neutralized food should be withheld by the mouth and normal saline given as freely as can be retained per rectum. In urgent cases of circulatory shock, caused by fluid loss and blood concentration, continuous intravenous infusion of normal saline, or saline with glucose, should be carried out.

The Caustic Alkalies.—Among these may be named the following: *caustic potash* or potassium hydrate or potash lye is a powerful corrosive, and *potassium carbonate,* known as salt of tartar, has a similar but less powerful effect. Both are used industrially. Forty grains of caustic potash have caused death.

Caustic soda or sodium hydrate or soda lye is a powerful corrosive and quite as dangerous as caustic potash. It is commonly used industrially.

Ammonia, liquid ammonia or spirits of hartshorn, is used largely for domestic and industrial purposes. It is also used in the form of smelling salts when mixed with carbonate of ammonia. It is a powerful corrosive poison and in addition the vapour has a very injurious effect on the lungs, giving rise to bronchopneumonia which may assume a septic type.

As regards treatment following ingestion, harmless acid drinks such as diluted vinegar, lemon juice, citric or tartaric acid should be given freely. Olive oil or egg albumen may be usefully employed. Pain should be relieved by the free use of morphine hypodermically and nourishment should not be given by the mouth, but rectal feeding adopted.

Corrosive Organic Acids.—*Carbolic acid,* or phenol, is commonly used as a disinfectant for domestic and surgical purposes. Allied preparations such as creosote or cresol have a similar poisonous effect. Lysol is a combination of cresol with soap and is similar in action to phenol.

Carbolic acid and the allied substances have a powerful corrosive action causing necrosis of the tissues with which they come in contact, the superficial part of which becomes of whitish appearance, the deeper parts becoming dark red as a result of haemorrhage into them. Carbolic acid is one of the poisons most frequently used by suicides, and owing to its common use for domestic purposes is also a frequent cause of accidental poisoning.

The symptoms caused by carbolic acid are those of corrosive poisoning, but owing to its local anaesthetic action vomiting may be absent and pain may be less marked. If death does not result from shock, the profound effect of the poison on the nervous system causes paralysis of the respiratory and cardiac centres, with rapid feeble pulse and stertorous breathing; coma develops in severe cases and is usually followed by death. Death has also resulted from absorption by the skin, and from rectal injections in solution. Usually death occurs within three to four hours following ingestion of a large dose.

The aim of treatment is to limit the absorption of the poison, to sustain the patient and to aid the elimination of the poison from the system. The stomach should be washed out by means of a soft stomach tube with diluted saccharated lime water or fresh lime water; by this means the phenol is converted into calcium phenate which is not poisonous. Alternatively, thorough gastric lavage, using a 10% solution of glycerine, or plain water, should be carried out without delay until the washings no longer emit an odour, and a quantity of medicinal paraffin should be left in the stomach. Egg albumen, since it precipitates phenol, will delay absorption. When necessary, rectal feeding should be adopted for several days.

IRRITANT POISONS

The more important irritant poisons will be considered under this heading (*vide* list above), but it must be remembered that many of the general poisons (*e.g.,* savin, cantharides, etc.) have an irritant action on the stomach and intestines in addition to their special action on important organs and nerve centres.

Oxalic acid occurs in colourless crystals resembling Epsom salts; it is very soluble in water. *Salts of sorrel* or *salts of lemon* is the quadrioxalate of potash; it is a white powder very soluble in water. Both of these substances are commonly used for domestic purposes; *e.g.,* for cleaning straw hats, removing ink stains, cleaning brasses, etc. They are frequently the cause of accidental and of suicidal poisoning.

When swallowed in solution the typical symptoms of irritant poisoning are set up, but in addition the poison when absorbed into the system has a profound depressant action on the heart and nervous system. Thus an acrid burning taste is experienced and pain occurs which is referred from the throat, oesophagus and

stomach and later possibly from the intestines. Vomiting is common, the vomit being very acid, and giving positive results to the tests for oxalic acid. It often contains blood. Unless immediate treatment is adopted collapse speedily occurs, the patient becoming cold, pale and faint with a rapid feeble pulse; at this stage death from syncope may occur. In some cases nervous symptoms such as tinglings and numbness, muscular spasms, convulsions, delirium and coma occur, but these symptoms are uncommon. Owing to the rapid absorption of the poison death is likely to occur rapidly (*e.g.*, within an hour), but it may be delayed.

For treatment, fresh lime water or, preferably, saccharated lime water which is 15 times as strong, should be given in large quantities and it should be mixed with calcium carbonate in the form of chalk or whiting. Since oxalic acid has only slight corrosive action the stomach should be washed out immediately if no antidote is at hand. It is best to give the antidote freely if immediately available and after a few minutes to wash out the stomach thoroughly with a soft stomach tube and funnel, and then finally introduce a pint of lime water made into a thin cream with an ounce of chalk, leaving this mixture in the stomach. Intravenous injections of calcium chloride or gluconate (calcium Sandoz) are recommended.

Arsenic is the most important of the irritant poisons and owing to the tasteless property of many of its compounds and preparations it is the commonest poison used for homicidal purposes.

The most notable and commonest compound is arsenious acid, arsenious oxide or white arsenic. It exists in the form of a white powder or in lumps of a white porcelainlike appearance. The powdered form resembles powdered sugar or flour and when mixed with food is almost tasteless. It is sparingly soluble in cold water, which will dissolve only 0.03 to 0.06 g. in 30 ml. About 4 g. in 30 ml., however, will be held in boiling water. When mixed with alkaline substances, white arsenic becomes freely soluble.

Commercial preparations containing white arsenic mixed with alkalies such as sodium hydrate or carbonate are weed killers, sheep-dip and wood preservatives which may contain from 20% to 40% of white arsenic. Copper arsenite (Scheele's green), lead arsenate and other arsenical preparations are used as insecticides for the spraying of fruit trees. Rat poisons may contain arsenic as the active ingredient. Wallpapers which formerly often contained green pigment (Scheele's green) or the yellow sulphides of arsenic are now coloured with arsenic-free pigments, arsenic being prohibited from use. White arsenic, if sold for other than medicinal purposes, must be mixed with a dye of distinctive colour which is water soluble.

Accidental contamination of food with arsenic has occurred in the past. Thus in 1900 a beer poisoning epidemic occurred as the result of the use of commercial glucose which contained arsenic in the preparation of beer. Prosecutions have been brought for the presence on apples of prohibitive amounts of arsenic alleged to have been caused by spraying of trees. (*See* ADULTERATION.)

When arsenic is taken by the mouth in poisonous quantities, symptoms of acute gastrointestinal irritation such as vomiting, diarrhoea and abdominal pain usually occur within a few hours. Death may ensue within a period varying from several hours to several days. A dose of 0.12 g. of arsenic has caused death, though larger quantities have been taken without fatal result. In acute arsenical poisoning the heart, kidneys and other organs are seriously affected so that the poison has a systemic action in addition to its irritant properties to the stomach and intestines.

Chronic arsenical poisoning occurs when small quantities of arsenic are absorbed over long periods. The gastrointestinal symptoms may be slight, but other symptoms, such as gradual loss of weight, alopecia, skin rashes and pigmentation and conjunctivitis, become manifest.

In suspected acute arsenical poisoning the diagnosis can be made certain by analysis of the vomit, urine and faeces. In chronic cases additional information may be obtained by analysis of the hair and nails.

Antimony is an irritant poison like arsenic. Tartar emetic or potassium antimony tartrate is one of the most commonly used compounds. It has on several occasions been used for homicidal purposes owing to the possibility of its being administered without detection by taste or smell.

Metallic poisons if taken by the mouth give rise to irritant poisoning. Examples are:

In large doses, the common salts of *lead* will cause gastrointestinal irritation. Acute poisoning by lead is rare. Chronic lead poisoning is caused by continued absorption of small quantities of lead and is a dangerous condition as it causes disease of the kidneys, blood vessels, heart and nervous system. Lead tetraethyl is a very poisonous organic compound of lead. It is used commercially as a constituent of ethyl gasoline, and is claimed to counteract "knocking" or "pinking" in motor engines. On inhalation in sufficient quantity it is extremely toxic. The sulphate of *copper* (blue vitriol) and other copper compounds are irritant poisons. The use of copper salts as a colouring matter of foodstuffs such as preserved green vegetables is reprehensible, and has often led to legal action. The Public Health (Preservatives, etc. in Food) regulations of England, 1925–40, prohibited all save scheduled colours and limited the preservatives to benzoic and sulphurous acids and sodium or potassium nitrate, and these only in specified amounts in certain foods.

Zinc salts are irritant poisons. The sulphate of zinc (white vitriol) occurs in crystals like Epsom salts for which it has been taken in mistake. Zinc chloride has a corrosive as well as an irritant action.

Barium salts, except for the quite insoluble sulphate, are irritant poisons and may also act on the cardiovascular or nervous system.

Chromates especially potassium bichromate are powerful irritant poisons.

The yellow variety of *phosphorus* is intensely poisonous and formerly was widely used in the manufacture of matches. Yellow phosphorus is used as a constituent of some vermin exterminators. The substance, in addition to being a gastrointestinal irritant, is a deadly poison to the liver and kidneys.

Acute *mercurial* poisoning usually arises from the taking of mercuric chloride (corrosive sublimate) or from the biniodide of mercury, both of which are extensively used as disinfectants for medical purposes. The immediate symptoms are those of acute gastrointestinal irritation (vomiting, abdominal pain and diarrhoea) but they are generally followed by suppression of urine and symptoms of acute ulcerative colitis which latter symptoms are commonly fatal. Chronic mercurial poisoning is characterized by inflammation of the mouth and gums.

SYSTEMIC POISONS

The systemic poisons include the following:

Prussic or Hydrocyanic Acid.—Hydrocyanic acid is one of the best known poisons and a very deadly one. In the pure state it is said to kill with lightninglike rapidity. It is met with in commerce only in a dilute state. In Great Britain two kinds of acid are commonly sold—the pharmacopoeial acid, containing 2% of anhydrous prussic acid, and Scheele's acid, containing 4% to 5%. About four millilitres of the 2% acid may cause death.

Hydrocyanic acid and the cyanides must be regarded as true protoplasmic poisons since they arrest the activity of all forms of living matter by inhibiting tissue oxidation and suspending vital functions. Such poisons not only inhibit the enzymic activities, but also act upon the central nervous system.

Given in fatal doses, the symptoms of prussic acid poisoning set in with great rapidity; and, in consequence of the readiness with which the poison is absorbed from the stomach and diffused through the circulation, the onset of symptoms is reckoned by seconds rather than by minutes. Occasionally the victim may be able to perform a few voluntary actions before loss of consciousness. There is first a very brief stage of difficult breathing and slow action of the heart, with a tendency for the organ to stop in the state of dilatation. With widely dilated pupils of the eye, the patient is then seized with violent irregular convulsive movements. The rhythm of the respiratory movements is disturbed, and the countenance assumes a bluish colour. The patient collapses with complete loss of muscular power; and the third or

asphyxial stage is reached, in which there are slow gasping respirations, loss of pulse and paralysis of motion. Death is frequently preceded by spasms. The lightninglike character of the illness and the speedy death of the patient, coupled with the peculiar odour of the acid in the breath and atmosphere around the body, seldom leave any doubt as to the nature of the case.

Other soluble cyanides, more especially cyanide of potassium, a salt largely used in photography and in the arts, are highly poisonous but are slightly less rapid in action than hydrocyanic acid.

When the poison has been swallowed, the stomach should be washed out immediately and free lavage established. A suitable medium for the purpose is water at body temperature containing a 5% to 10% solution of sodium thiosulphate, or a mixture of the sulphates (ferrous and ferric) of iron followed by a solution of potassium carbonate to form Prussian blue which is inert. Sodium thiosulphate (10 to 50 ml. of 20% solution) or methylene blue (50 ml. of 1% solution) may be administered intravenously, provided there is time for either of these preparations to act. Ammonia inhalations, artificial respiration and oxygen, with or without carbon dioxide (7%), should be used to stimulate respiration. In desperate cases, a slow venous injection of five millilitres of a 25% solution of coramine has been recommended. Stimulation of the cardiac and respiratory centres may be effected by injections of lobeline and cardiazol.

Strychnine and Strychnine-Yielding Plants.—The alkaloids strychnine and brucine, as well as the plants in which they are found, all act in the same manner, being highly poisonous and causing death after spasms of a severe character. Many vermin killers contain strychnine as their active ingredient.

Strychnine and all substances containing that alkaloid usually produce their effects within 10 or 15 min. The patient complains of stiffness about the neck, and his aspect exhibits terror. There is an impression of impending calamity or death. Very speedily the head is jerked back, the limbs extended, the back arched (opisthotonos) so that the body may rest on the head and heels only. In a few moments these symptoms pass off, and there is complete relaxation of the spasm. The spasmodic condition speedily returns, and is brought about by the slightest touch or movement of the patient. Accessions and remissions of the tetanic state ensue rapidly till the patient succumbs, usually within half an hour of the administration of the poison.

The best treatment is to put the patient under the influence of chloroform and wash out the stomach with a solution of potassium permanganate in water, four grams in two gallons. To follow, medicinal charcoal in water is recommended, and this should be freely given and removed from time to time. Sodium amytal or phenobarbital sodium should be given intravenously. Only a sufficient quantity to put the patient to sleep should be given, or, if convulsions are present, only enough to stop them.

Nicotine.—The alkaloid nicotine is obtained from the plant *Nicotiana tabacum* and has a pungent, acrid taste. Its content in tobacco leaves varies from 0.6% to 6%. Poisoning may be caused by absorption through the skin, by inhalation or by ingestion. Industrial poisoning caused by commercial preparations, such as fertilizers and fumigants, has occurred.

Cases of acute poisoning are comparatively rare, but subacute and chronic symptoms may result from the immoderate use of tobacco. When nicotine is absorbed in poisonous dose, the outstanding symptoms are those of successive central and peripheral stimulation, nausea, sickness, tachycardia, cardiac oppression and irregularity and severe prostration and cardiovascular collapse may become manifest. Treatment consists of gastric lavage when the poison has been ingested. Strong coffee or a hypodermic injection of coramine should be given.

Opium.—In consequence of the extent to which opium, its preparations and its active alkaloid morphia are used for the relief of pain, poisoning by opium is of frequent occurrence. It is largely used by suicides, and children, being very susceptible to its influence, frequently die from misadventure after administration of an overdose of the drug. The ordinary preparations of opium are the drug itself, which is the inspissated juice of the oriental poppy, and the tincture, commonly known as laudanum. Opium contains a variety of more or less active principles, the chief of which is the alkaloid morphia, which is present in good opium to the extent of about 10% in combination with meconic acid, which is physiologically inactive.

The treatment of opium poisoning is governed by the condition of each case in relation to the time of intake. It consists of free gastric lavage with warm water and then with two grams of potassium permanganate in two gallons of warm water. The use of medicinal charcoal is beneficial. In coma, the airway should be kept clear, the patient catheterized and artificial respiration and inhalations of oxygen, or of oxygen with 7% carbon dioxide, should be employed if thought necessary.

Heroin is an artificial derivative of morphine (diacetyl morphine hydrochloride) and is more toxic than morphine. It has been largely used medicinally. It is a dangerous drug of addiction.

Belladonna.—The belladonna, or deadly nightshade, *Atropa belladonna*, contains an alkaloid, atropine, which is largely used by oculists to procure dilatation of the pupils of the eye. The brown or black berries of the plant have been eaten by children, who are attracted by their appearance. Besides dilatation of the pupils, belladonna produces rapid pulse, hot, dry, flushed skin with an eruption not unlike that of scarlatina, soreness of the throat with difficulty in swallowing, and intense thirst and delirium.

The treatment consists of gastric lavage with a solution of 1 in 5,000 of potassium permanganate. Excitement should be controlled by sedatives or mild hypnotics. Lumbar puncture may prove beneficial in certain cases.

Stramonium, hyoscyamus (henbane), hyoscyamine, hyoscine and scopolamine all produce symptoms similar to atropine poisoning, the narcotic effects being more marked.

Aconite.—The ordinary aconite, wolfsbane or monkshood (*Aconitum napellus*), and an alkaloid extracted from it, aconitine, are perhaps the most deadly of known poisons. A dose of 0.004 g. of aconitine has proved fatal to man. The root of aconite has been eaten in mistake for that of horse-radish. All the preparations of aconite produce a peculiar burning, tingling and numbness of the parts to which they are applied. When given in large doses they produce violent vomiting, as a rule, more or less paralysis of motion and sensation and great depression of the heart, usually ending in death from syncope. Intelligence remains unaffected till almost the last.

The treatment consists of free gastric lavage with a solution composed of 12 g. of tannic acid in two gallons of warm water. Tannic acid (1.2 g. in 180 ml. of tepid water) should be given and followed by animal charcoal suspended in water. Cardiac and respiratory stimulants should be administered in accordance with clinical indications. Artificial respiration and oxygen inhalations may prove necessary.

Cocaine.—Cocaine is the active alkaloid of coca leaves—*Erythroxylum coca*—and is chemically methyl benzoylecgonine. The hydrochloric salt is the commonly used preparation. It is a powerful deliriant narcotic poison. If taken by the mouth, given hypodermically or otherwise absorbed, it may cause delirium and coma. Sometimes convulsions and sudden death occur. It acts on the heart and may cause fatal syncope. Cocaine is a dangerous drug of addiction (*see* DRUG ADDICTION).

Organic Compounds Used as Hypnotics.—These if taken in excessive doses act as poisons, and the symptom which attracts attention is the deep coma produced.

Examples are: chloral, veronal and its derivatives, medinal, proponal, luminal, sulfonal, trional and tetronal. Any hypnotic drug taken in excessive quantity will act as a coma-producing poison. (*See* BARBITURIC ACID; SULFONAL GROUP, THE.)

GASEOUS POISONS

Gaseous poisons include the following:

Carbon Monoxide.—Poisoning by carbon monoxide may occur from coal gas, water gas or from exposure to the suffocating fumes of fires, smoky grates and stoves; also from the fumes of gas heaters and internal-combustion engines.

The diagnosis may be made at once from the clinical symptoms of drowsiness, collapse and coma, and the cherry-red colour of the face, body and mucous membranes. Examination of the blood will make the diagnosis certain, since the presence of carboxyhaemoglobin may be readily detected by the spectroscope.

The treatment consists in giving oxygen with 7% carbon dioxide freely, and employing artificial respiration if necessary. The use of carbon dioxide is important since it stimulates breathing and breaks down the carbon monoxide-haemoglobin molecule. The body warmth must be maintained. This is important since carbon monoxide disturbs the heat-regulating centre with reduction in the processes of oxidation. Stimulants administered hypodermically will also prove beneficial.

Carbon Dioxide or Carbonic Acid.—This occurs in coal mines from chokedamp or afterdamp. Cellars of houses, wells, brewers' vats, lime kilns, etc., frequently contain large quantities of carbonic acid gas.

The treatment consists in fresh air, rest, oxygen, artificial respiration if necessary, and employment of warmth and stimulants.

Sulphuretted Hydrogen.—This occurs from contamination of the air with sewer gas, and from the gases evolved when iron slag becomes moistened with water. The gas is frequently produced in various chemical processes.

The treatment consists in giving the patient plenty of fresh air. Oxygen and stimulant treatment must be used.

WAR GASES

Despite the fact that a mixture of gases may be employed, it is customary to classify war gases into four groups: (1) gases producing irritation of the lungs (choking gases); (2) gases producing irritation of the nose (nasal irritants); (3) gases producing irritation of the eyes (lachrymators); and (4) gases producing irritation of the skin (vesicants).

Group 1 includes phosgene, diphosgene, chlorine and chloropicrin. All these gases when inhaled produce rapid bronchial and pulmonary irritation which may lead to death within a day or two from cardiac failure brought about by inflammatory oedema. A later fatal complication results from bronchopneumonia.

Group 2 includes smokes which are liberated from the highly toxic arsenical compounds diphenylamine chlorarsine, or DM, diphenyl chlorarsine, or DA, and diphenyl cyanarsine, or DC. These are capable of causing profound sensory disturbance which in warfare diminishes physical capacity and undermines morale.

Group 3 includes ethyl iodoacetate, or KSK, bromobenzyl cyanide, or BBC, and chloroacetophenone, or CAP. The vapours of these substances produce transient irritating effects on the eyes, which water copiously. If the liquids from which these vapours arise are brought into contact with the eyes severe and permanent damage may result.

Group 4 includes bis β-chlorethylsulphide, or mustard gas, and β-chlorvinyldichlorarsine, or lewisite. These liquids give off toxic vapours which affect the lung, eye and skin on account of their irritant action. In their liquid form such fluids cause severe burning with destruction of the tissue with which they are brought into contact. Their power of penetration of the skin is very considerable since they are capable of producing lipoid solubility. Mustard gas has a delayed action and on this account serious delay in treatment may occur. Lewisite acts much more rapidly. The arsenic content of lewisite when absorbed by the skin may produce tissue damage in the secretory and urinary systems. (*See* CHEMICAL WARFARE.)

FOOD POISONING

Food poisoning may be defined as poisoning induced by the ingestion of food containing toxic principles, metallic or otherwise, or pathogenic organisms. Thus poisoning may arise from vegetable poisons, including fungi; animal poisons, including shellfish; chemical poisons; and bacterial food poisons, including botulinum. It must not be forgotten, however, that sensitivity to certain food items may exist in a given individual and may give rise to manifestation of illness, such as signs and symptoms of gastrointestinal disorder, or to a skin lesion urticarial in character.

So-called mushroom poisoning is usually caused by the ingestion of toxic fungi instead of edible mushrooms. Such fungi frequently belong to the genus *Amanita,* especially the species *phalloides* and *muscaria.* Poisoning by the edible mussel, *Mytilus edulis,* is not uncommon, and the illness usually assumes a mild form, with urticarial manifestations, occasionally accompanied by asthma. Little need be said of chemical poisons which may contaminate food, since many of these have already been described.

True bacterial food poisoning, frequently, although not invariably, associated with canned food, was formerly termed ptomaine poisoning, but after the discovery that ptomaines, chemical substances related to amines, are harmless when administered by the mouth, this misleading term fell into disuse. Bacterial food poisoning is principally caused by various strains of the *Salmonella* group, and the commonest are perhaps *S. aertrycke* and *S. enteritidis* of A. Gärtner, the latter occurring in outbreaks. In 1945 at Stoke-on-Trent, Eng., about 30 cases of food poisoning occurred. There were six deaths, and the cause of all the deaths was *S. enteritidis. Clostridium botulinum,* a sporing anaerobe, whose normal habitat is garden soil, produces a fatal type of food poisoning. The exotoxin which this organism secretes is one of the most powerful yet discovered. The condition of poisoning which is produced is known as botulism or allantiasis. Its manifestations consist of paralysis of the muscles of the eyes and eyelids, the larynx and finally of the respiratory centre. The outbreaks in Europe are most frequently caused by meat or meat foods, while those in the U.S. have generally been traced to vegetable products. An outstanding British outbreak occurred in Scotland at Loch Maree in 1922, when all of eight persons who ate sandwiches filled with potted duck paste died. The incubation period is usually less than 48 hr. and may be as short as 4 hr.

(W. H. WI.; JO. GR.)

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(JO. GR.)

POISON FISH (*Synanceja verrucosa*), an ugly, rather shapeless, tropical, marine-bottom fish, of the family Scorpaenidae, reaching a length of about one foot, inconspicuous as it lies partly buried in the sand or in some hollow of a rock or coral bottom, which it commonly does.

Though veiled in skin, the spines of the dorsal fin of the poison fish have large poison glands at their bases and can inflict a severe wound. Like the related lion fish (*q.v.*) this species is found in the Indian ocean, East Indies and eastward into Polynesia (*see* SCORPION FISHES).

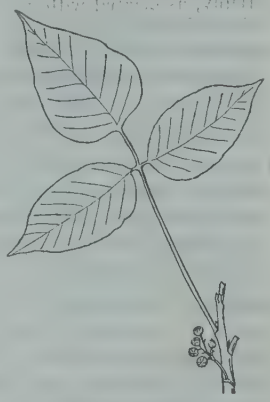
(J. T. N.)

POISON GAS: *see* CHEMICAL WARFARE.

POISON HEMLOCK: *see* WATER HEMLOCK.

POISON IVY, the name commonly applied to several, mostly white-fruited, trifoliate species of woody vines or shrubs of the genus *Toxicodendron* (family Anacardiaceae), native to North America. The forms with bushy habit and lobed leaflets are often called "poison oak," especially in the western United States. The common poison ivy (*Toxicodendron radicans*), the most widespread species, abundant in eastern North America and less common westward, is a variable species with a bushy or climbing habit, leaves with three leaflets which may be smooth and glossy or hairy, entire, toothed or lobed. Many of these not too constant variations have been designated as separate species or varieties.

The more common of these forms with their ranges are: *T. quercifolium*, with deeply lobed leaflets, Maryland to Texas; *T. radicans rydbergi*, with thicker leaves, Great Plains to Rocky mountains; and *T. diversilobum*, with leaflets mostly scalloped on the margin, Pacific coast. The poison sumac (*T. vernix*), native in swamps from Quebec to Minnesota and south to Texas and Florida, is a tall bush or small tree with pinnately compound leaves with 7 to 13 entire leaflets and drooping, axillary clusters of persisting white fruits. All species of *Toxicodendron* are poisonous to touch, producing in many persons a severe inflammation of the skin or dermatitis. Sumacs with red fruits are nonpoisonous. The toxic principle, urushiol, is produced in the resinous juice of the resin ducts of the leaves, flowers, fruits and bark of stems and roots but not in the pollen grains. Being almost nonvolatile, the urushiol may be carried from the plant on clothing, shoes, tools, soil, by animals, by smoke from burning plants, to persons who never go near the poison ivy plants. Poisoning may occur if clothing is worn a year after contact with poison ivy.



COURTESY, NEW YORK STATE COLLEGE OF AGRICULTURE AT CORNELL UNIVERSITY
FIG. 1.—A LEAF OF POISON IVY (TOXICODENDRON RADICANS)

The remedies and preventive treatments used against poisoning from contact with species of *Toxicodendron* are legion. With the exception of the following, none should be used without the advice of a physician. Either before exposure, or immediately after it is discovered that contact has been made with the plant, wash the exposed parts of the body thoroughly with water and an alkaline laundry soap. Lather the parts well and let the lather dry on. Repeat this treatment every three or four hours, leaving the dry lather on between applications. Avoid oily soaps or washing with alcohol to prevent spreading the toxic material.

(W. C. M.)

POISONOUS PLANTS. It is not practicable to divide the members of the vegetable kingdom into poisonous and nonpoisonous plants. Most of the 250,000 known species of plants are harmless; only a relatively few are poisonous under ordinary conditions; others are poisonous only under special conditions. Poisonous plants under natural conditions contain or produce physiologically active substances in quantities sufficient to cause death or a disease condition when eaten, or sometimes when touched, by man or animals.

COURTESY, NEW YORK STATE COLLEGE OF AGRICULTURE AT CORNELL UNIVERSITY
FIG. 2.—A LEAF OF POISON SUMAC (TOXICODENDRON VERNIX)

In general the toxic properties of poisonous plants result from the presence, in some or all parts of the plant, of one or more organic compounds such as alkaloids, glucosides, resinoids and organic acids. Alkaloids are responsible for the toxic properties in certain members of the families Liliaceae, Amaryllidaceae, Papaveraceae, Ranunculaceae, Leguminosae and Solanaceae. Among the glucosides that yield toxic substances upon hydrolysis are those produced in wild cherries (*Prunus* sp.), flax (*Linum* sp.), corn cockle (*Agrostemma githago*), foxglove (*Digitalis purpurea*) and various members of the mustard family, Cruciferae. Resinoids containing toxic substances occur in poisonous members of the heath family, Ericaceae, water hemlock (*Cicuta maculata*) and milkweeds (*Asclepias* sp.).

Not all parts of a poisonous plant are equally toxic. In some the toxic principle is mostly concentrated in the seed (*e.g.*, corn cockle (*Agrostemma githago*); in others the root is the most toxic part (*e.g.*, water hemlock, *Cicuta maculata*). Some plants are toxic only in certain stages of development. The cocklebur (*Xanthium orientale*) is very poisonous in the seedling stage and harmless in later stages of growth. Other plants are poisonous when eaten green but are harmless after they are thoroughly dried and the toxic principle is dissipated.

Some plants (*e.g.*, certain locoweeds, *Astragalus* sp.) vary greatly in their toxicity, depending upon the type of soil on which they grow.

Most cases of poisoning from eating toxic plants occur in animals; comparatively few occur in man. Some plants, such as water hemlock (*Cicuta maculata*), poison hemlock (*Conium maculatum*) and locoweeds (*Astragalus* sp.), produce characteristic symptoms in animals poisoned by eating them. Many poisonous plants, although belonging to widely unrelated plant families, may produce identical symptoms because their toxic principle is the same; *e.g.*, species of wild cherries (*Prunus* sp.), sorghum (*Holcus* sp.) and arrowgrass (*Triglochin maritima*) all produce the same symptoms because the toxic principle in them is prussic acid, which under certain conditions is released by the hydrolysis of glucosides produced in them. Another example of a disease caused by widely different plants is trembles, caused by white snakeroot (*Eupatorium rugosum*) in the eastern United States and by the rayless goldenrod (*Aplopappus heterophyllus*) from western Texas to Arizona and adjacent Mexico. In these plants the toxic principle is tremetol, which, being soluble in the fat of milk, may be transmitted from diseased cows through the milk to humans, causing the disease known as milk sickness. Some plants (*e.g.*, scouring rushes [*Equisetum* spp.] and locoweeds [*Astragalus* spp.]) may produce different types of diseases, acute or chronic, depending upon whether an animal eats a large quantity of the plants at one time or small quantities repeatedly for a considerable time.

Among cultivated plants the following poisonous species, originating mostly in the old world, are common and widely grown in the temperate regions: castor bean (*Ricinus communis*), daphne (*Daphne mezereum*), foxglove (*Digitalis purpurea*), lily-of-the-valley (*Convallaria majalis*), meadow saffron (*Colchicum autumnale*), monkshood (*Aconitum napellus*), larkspur (*Delphinium* spp.), narcissus (*Narcissus poeticus*), oleander (*Nerium oleander*).

Plants Poisonous by Contact.—Most cases of contact poisoning by plants occur in man; animals are rarely poisoned by contact alone. In man certain plants produce a skin poisoning or dermatitis consisting of minor or temporary irritation or a painful inflammation with vesicles or blisters lasting for days or weeks, depending upon the susceptibility of the individual or the severity of the infection. The toxic principle in these plants is often most concentrated in a resinous or milky juice. Among the species which cause many cases of dermatitis may be mentioned the following:

Cashew Family.—Poison ivy and poison oak (*Toxicodendron radicans*) and related forms, common in North America; poison sumac (*Toxicodendron vernix*), eastern North America; poison wood (*Metopium toxiferum*), of southeastern United States and West Indies; Japanese lacquertree (*Toxicodendron vernicifluum*), eastern Asia; cashew (*Anacardium occidentale*), widespread in tropical regions.

Spurge Family.—Manchineel tree (*Hippomane mancinella*), common in the West Indies and Central America; sandbox tree (*Hura crepitans*), native to Central American lowlands; spurges (*Euphorbia* spp.), many species, especially some native to Africa and Asia, very toxic; snow-on-the-mountain (*Euphorbia marginata*), an annual native to western North America, widely introduced as an ornamental. A few species of primrose, notably *Primula obconica*, a favourite house plant, several kinds of lady-slipper (*Cypripedium reginae* and *C. parviflorum*), native to eastern North America, the garden parsnip (*Pastinaca sativa*), often escaped as a weed, and several species of milkweed (*Asclepias*)

are responsible for dermatitis in many susceptible persons.

Photodynamic Plants.—Several plants appear to contain substances that sensitize domestic animals to light. If animals with white fur or unpigmented skin eat these plants and are subsequently exposed to strong sunlight they may develop a disease with characteristic symptoms that may result in death. Animals that are not exposed to sunlight subsequent to eating these plants do not develop any symptoms. Some of the widely distributed photosensitizing plants are buckwheat (*Fagopyrum esculentum*), St. Johnswort (*Hypericum perforatum* and *H. crispum*), bur clover (*Medicago denticulata*) and puncture vine (*Tribulus terrestris*).

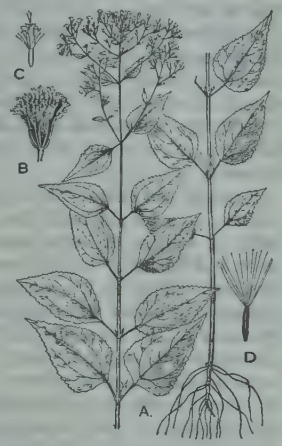


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FIG. 1.—WHITE SNAKEROOT (EUPATORIUM RUGOSUM). (A) PLANT SHOWING GENERAL HABIT; (B) HEAD OF FLOWERS; (C) FLOWER; (D) SEED (ACHENE) WITH PAPPUS ATTACHED

Seleniferous Plants.—Several species of plants when growing on certain soils from Cretaceous or Eocene shales take up enough selenium compounds to make them toxic. In several regions in western North America, cattle and horses have been poisoned by eating such seleniferous plants, resulting in alkali disease and blind staggers. Selenium absorbed from seleniferous shales by these plants upon their decomposition is returned to the soil and becomes available and may be taken up by other native plants or by crop plants that are unable to absorb inorganic selenium. By such action crops such as wheat may become poisonous. The locoweeds (*Astragalus bisulcatus, A. pectinatus, A. racemosus*), wild aster (*Aster commutatus* and *A. xylorrhiza*) and princes plume (*Stanleya bipinnata* and *S. pinnata*) are examples of seleniferous plants of western North America.

Principal Stock-Poisoning Plants.—Several forms of bracken or brake-fern (*Pteridium*) occurring in widely distributed places throughout temperate regions from Eurasia to Australia and North America, when eaten fresh or in hay over a prolonged period, are the cause of poisoning of cattle and horses. Horsetail (*Equisetum arvense*) of Eurasia and North America causes an acute or chronic disease, equisetosis. Arrowgrass (*Triglochin maritima*) of Eurasia, North Africa and North America produces prussic acid which poisons cattle and sheep. Darnel (*Lolium temulentum*), native to Europe and introduced in North America, contains a poison in its grains. Death camas (*Zygadenus venenosus*) and related species, all native to North America, contain toxic alkaloids and cause considerable losses among sheep and cattle grazing on ranges in the spring. False hellebore (*Veratrum viride*), widespread in North America, and the European *V. album* contain toxic alkaloids.

Fly poison (*Amianthemum muscaetoxicum*) causes losses among cattle and sheep in the eastern United States. Lily-of-the-valley (*Convallaria majalis*), native to Europe and the eastern United States, widely cultivated as an ornamental, contains toxic alkaloids. Star-of-Bethlehem (*Ornithogalum umbellatum*), native to Europe and naturalized in North America, and other species of *Ornithogalum* native to South Africa cause poisoning of cattle and sheep. Meadow saffron (*Colchicum autumnale*), native to Europe and widely introduced in North America, contains toxic alkaloids. Lechuguilla (*Agave lecheguilla*), native to southwestern United States and Mexico, contains a photosensitizing agent and causes poisoning, chiefly of sheep and goats.

Pokeweed (*Phytolacca americana*), native to eastern North America, contains a toxic alkaloid chiefly in the root. Corn cockle (*Agrostemma githago*), native of Eurasia and widely naturalized in most regions where winter wheat is grown, contains a toxic glucoside in its seeds. Monkshood (*Aconitum napellus*), a native of Europe, and *A. columbianum*, native of the mountain ranges of western North America, both contain toxic alkaloids. Larkspurs (*Delphinium* spp.) contain toxic alkaloids; several species native to western North America cause heavy losses when grazed by cattle.

Hellebore (*Helleborus niger* and *H. viridis*), native to Europe and introduced in North America, contain toxic glucosides. Opium poppy (*Papaver Somniferum*), of Asiatic origin and widely introduced in warmer parts of the world, contains several alkaloids. Dutchman's breeches (*Dicentra cucullaria*) and squirrel corn (*D. canadensis*), native to eastern North America, contain toxic alkaloids and cause blind staggers in cattle and sheep. Wild cherry (*Prunus serotina*), a common native tree in eastern North America, chokecherry (*P. demissa*) of western North America, the cherry laurel (*P. laurocerasus*) of Europe and other species contain a glucoside that may yield prussic acid upon hydrolysis. When the leaves of these plants are eaten by cattle or sheep, death may result quickly.

Several European and North American species of lupines (*Lupinus* sp.) contain toxic alkaloids. In western North America losses among cattle and sheep grazing on lupine seed pods may be large. A number of species of locoweeds (*Astragalus* sp. and *Oxytropis* sp.) native to North America in the region from the Great Plains westward to the Rocky mountains are poisonous and when eaten cause loco disease in cattle and horses. The plants appear to be habit forming, and animals may develop a habit of seeking out locoweeds in preference to other vegetation. The disease may be acute from eating large amounts at one time, or chronic from eating small amounts over a long period. Some, but not all, locoweeds owe their toxic properties to selenium compounds absorbed from the soil.

Precatory bean (*Abrus praecatorius*), a native shrub of India, is widely introduced in subtropical regions.

Its seeds contain a toxic substance, abrin, and may poison cattle and sheep. In India immunity has been developed in animals by feeding them very small amounts of the abrin and gradually increasing the dose. Black locust (*Robinia pseudo-acacia*), a native tree of eastern North America and widely introduced in Europe, contains a toxic substance in its bark. Horses are sometimes fatally poisoned by eating the bark. Puncture vine (*Tribulus terrestris*), a more or less cosmopolitan weed in the warmer parts of the world, contains a photosensitizing agent and causes a disease, tribulosis, when eaten by animals.

China tree (*Melia azedarach*), a native tree of India widely introduced in many warm regions of the world, including the southern United States, contains a narcotic poison, especially in its fruits. Many species of spurges (*Euphorbia* sp.) native to Africa, Europe and America contain toxic substances in their latex. These plants are not only poisonous when eaten but many of them are poisonous to touch Coyotillo (*Karwinskia humboldtiana*), a shrub native to Mexico and the southwestern United States causes a paralytic disease, "limberleg," when the leaves are grazed by cattle. St. Johnswort (*Hypericum perforatum*), native to Europe but widely naturalized in North America, Australia and North Africa, contains a photosensitizing agent. This species and also *H. crispum* cause the disease osteoporosis or bighead in cattle and sheep.

Water hemlock (*Cicuta virosa*), native to Europe, and *C. maculata* and *C. douglasi*, native to wet lands in eastern and western North America, contain a resinous substance, cicutoxin, especially in their roots. Only a small piece of root may kill a cow. Poison hemlock (*Conium maculatum*) and fool's parsley (*Aethusa cynapium*), both native to Europe and naturalized in North America, contain alkaloids in their roots and seeds. Mountain laurel (*Kalmia latifolia*) and sheep laurel (*K. angustifolia*), two native evergreen shrubs of eastern North America, frequently cause death of cattle and sheep when they eat the leaves. Indian hemp (*Apocynum cannabinum*) and dogbane (*A. androsaemifolium*), native North American herbs, produce a resinous material with toxic substances responsible for poisoning cattle and horses. Oleander (*Nerium oleander*) native to Asia but widely introduced in the warmer parts of the world, contains toxic glucosides. Various domestic animals have been poisoned by eating the leaves.

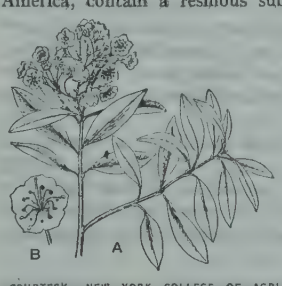

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FIG. 2.—MOUNTAIN LAUREL (KALMIA LATIFOLIA). (A) FLOWERING BRANCH; (B) FLOWER

Whorled milkweeds (*Asclepias galioides, A. mexicana*) and related species native to western North America have caused death of sheep and cattle grazing on the tops. Black nightshade (*Solanum nigrum*) and European bittersweet (*S. dulcamara*) contain the alkaloidal glucoside solanine in the leaves and berries. Thorn apple (*Datura stramonium*) and related species, native to warmer parts of the world but now widespread, contain toxic alkaloids. Belladonna (*Atropa belladonna*) and henbane (*Hyoscyamus niger*), European species introduced into North America, are poisonous and are also grown as medicinal plants for their powerful alkaloids. Foxglove (*Digitalis purpurea*), native to Europe and naturalized in western

North America, contains several glucosides, mostly in the leaves. Animals, and rarely people, are poisoned by eating the leaves. White snakeroot (*Eupatorium rugosum*), native to eastern North America, causes the disease trembles in cows and milk sickness in people. Cockleburs (*Xanthium* sp.), widespread in warmer parts of the world, are poisonous in the seedling stages. Ragworts (*Senecio jacobaea* and other species) cause a disease of the liver in cattle and horses in North America, South Africa, parts of Europe and New Zealand.

FROM "POISONOUS PLANTS OF U.S." BY W. C. MUENSCHER. THE MACMILLAN CO.

FIG. 3.—WOOLLY LOCOWEED (ASTRAGALUS MOLLISSIMUS)

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(W. C. M.)

POISSON, SIMÉON DENIS (1781–1840), French mathematician, was born at Pithiviers in the department of Loiret on June 21, 1781. He studied medicine but gave it up in favour of mathematics. In 1798 he entered the École Polytechnique at Paris, where he attracted the notice of Lagrange and Laplace. Until his death on April 25, 1840, he was almost entirely occupied in mathematical research and in teaching. He was made *professeur suppléant* at the École Polytechnique in 1802, and full professor in succession to Fourier in 1806. In 1808 he became astronomer to the Bureau des Longitudes; and when the Faculté des Sciences was instituted in 1809 he was appointed *professeur de la mécanique rationelle.* He was the author of more than 300 memoirs and papers. His most important work was on the application of mathematics to physics, and in particular to electrostatics and magnetism. In the field of pure mathematics, his most important works were his series of memoirs on definite integrals, and his discussion of Fourier's series, which paved the way for the classical researches of Dirichlet and Riemann on the same subject.

Besides his many memoirs, Poisson published a number of treatises: *Traité de mécanique,* 2 vol., (1811 and 1833), which was long a standard work; *Theorie nouvelle de l'action cappillaire* (1831); *Theorie mathématique de la chaleur* (1835); *Supplément* to the same (1837); *Recherches sur la probabilité des jugements,* etc. (1837).

See F. Arago, *Biographie de Poisson,* read before the Académie des Sciences on Dec. 16, 1850. It contains a list of works.

POISSY, a town of northern France, in the department of Seine-et-Oise, 17 mi. W.N.W. of Paris, on the railway from Paris to Rouen. Pop. (1946) 13,375. Poissy was the ancient *Pinciacum.* The ancient church, dating from the 12th century and restored under E. E. Viollet-le-Duc, affords one of the earliest and best examples of transition from the Romanesque to the Pointed style. The old bridge of Poissy was widened and modernized. The painter J. L. E. Meissonier lived in the town.

POITIERS, a town of western France, formerly capital of Poitou (*q.v.*) and now the chief town of the department of Vienne, 61 mi. S.S.W. of Tours on the railway to Bordeaux. Pop. (1946) 48,546. Called *Limonum* at the time of the Roman conquest, Poitiers afterward took the name of its Gallic founders, the Pictones or Pictavi. Christianity was introduced in the 3rd century, and the first bishop of Poitiers, from 350 to 367, was St. Hilarius. Fifty years later the city had fallen into the hands of the Arian Visigoths and became one of the principal residences of their kings. Alaric II was defeated by Clovis at Vouillé, not far from Poitiers, in 507, and the town became a part of the Frankish dominion. This was the first occasion on which the peoples of northern and southern Gaul met in conflict near the town which was to see them so often join battle. By his victory in 732 over the Mohammedans at Moussais-la-Bataille in this region, Charles Martel proved the saviour of Christendom. Eleanor of Guienne frequently resided in the city and in 1199 entrusted it with communal rights. After the battle of Poitiers in 1356 (*see* below), Poitou was recognized as an English possession by the treaty of Brétigny (1360); but by 1373 it was recovered by Bertrand du Guesclin.

Between the northwest of the plateau central and the Gâtine, both heights of old rock, lies the relatively low land called the Seuil du Poitou, giving a historic connection between the Paris basin and the basin of the Garonne. In this lowland streams have dissected valleys in the Jurassic rocks, and Poitiers stands on a promontory above the junction of the Boivre and the Clain (a tributary of the Loire by the Vienne); its situation has given it a peculiar importance in military and political history. The town is picturesque, and its streets are interesting for their remains of ancient architecture, especially of the Romanesque period, and the memories of great historical events. Till 1857 Poitiers contained the ruins of a Roman amphitheatre more extensive than that of Nîmes; remains of Roman baths, constructed in the 1st and demolished in the 3rd century, were laid bare in 1877; and in 1879 a burial place and the tombs of a number of Christian martyrs were discovered on the heights to the southeast, the names of some of the Christians being preserved in paintings and inscriptions.

The cathedral of St. Peter was begun in 1162 by Henry II of England and Eleanor of Guienne on the ruins of a Roman basilica. It was completed by 1379 in the Romanesque and Early Gothic styles. The choir stalls (1235–57) are among the oldest in France. The church of St. Jean near the cathedral is the most ancient Christian monument in the country. Built as a baptistery in the first half of the 4th century, it was enlarged in the 7th century.

The church of St. Radegonde, a great resort of pilgrims, commemorates the consort of Clotaire (d. 587), preserving in its crypt the tomb of Radegonde, who founded at Poitiers the abbey of the Holy Cross, and two others reputed to be those of St. Agnes and St. Disciola. The choir and tower above the entrance are of the 11th century, while the nave (late 12th century) was built in the Angevin style. Notre-Dame la Grande (late 11th century) represents a much older collegiate church and has a richly sculptured Romanesque façade. The church of Montierneuf (*Monasterium Novum*) was begun in 1077 by William VI, duke of Aquitaine and count of Poitiers, who was buried within its walls; and the choir (13th century modified by the erection of a "lantern") was solemnly consecrated by Urban II in 1096. Restorations were effected in the 19th century. The beautiful 11th-century tower of St. Porchaire was restored in the 19th century.

Poitiers has a university with various faculties. Trade is in farm produce, wine, wool, honey, goose quills and leather. The industries include the preparation of goose and swan skins, printing and the manufacture of hosiery, brushes, oil, paint and candles.

Counts of Poitiers.—In the time of Charlemagne the countship of Poitiers, then part of the kingdom of Aquitaine, was represented by a certain Abbon. Renoul (Ranulph), created count of Poitiers by Louis the Pious in 839, was the ancestor of a family distinguished in the 9th and 10th centuries for its attachment to the Carolingian dynasty. One of his successors, Ebles the Bastard (d. 935), took the title of duke of Aquitaine, and his descendants retained the hereditary name of William. In accordance with the dying wishes of William X his daughter Eleanor was married in 1137 to Louis, the son of Louis VI of France. Sole heiress, she brought her husband Poitou, Saintonge, Aunis, a part of Touraine and Berry, Marche, Angoumois, Périgord, Auvergne, Limousin,

Bordelais, Agénois and Gascony. After a divorce in 1152, Eleanor married the count of Anjou, Henry Plantagenet, who became king of England as Henry II. The west of France thus passed into the hands of England. Philip Augustus reconquered Poitou in 1204. When Charles VII ascended the throne he united the countship of Poitiers to the crown.

BATTLE OF POITIERS

The battle of Poitiers, which was fought on Sept. 19, 1356, between the armies of King John of France and of Edward the "Black Prince," was the second of the three great English victories of the Hundred Years' War. From Bordeaux the Black Prince had led an army of his father's Guienne vassals, with which was a force of English archers and men-at-arms, into central France and had amassed an enormous booty. King John, hitherto engaged against the army of John of Gaunt, duke of Lancaster, in Normandy, hurried south to intercept the raiding army and to bar its homeward road. After an unexpected encounter with the French rear, the Black Prince, by forced marching, was able to slip past the French, but reaching Maupertuis, 7 mi. S.E. of Poitiers, with the king's army in chase, he found himself compelled to choose between fighting and abandoning his spoil. He chose the former course, in spite of the enemy's great superiority in numbers (perhaps 16,000 to 6,500), and in order to give his trains time to draw off took up a defensive position on Sept. 18 with a slight hollow in front and a wood behind, between the Poitiers-Bordeaux main road and the Maussion river.[1] John, instead of manoeuvring to outflank the English, allowed the cardinal Hélie de Talleyrand-Périgord to attempt to negotiate a peace. This proving vain, the French army attacked without any attempt at manoeuvre or reconnaissance, and on a front so narrow that the advantage of superior numbers was forfeited. Moreover, King John ordered all but the leading line to dismount and to attack on foot (tactics suggested by the success on the *defensive* of the dismounted English men-at-arms at Crécy and the Scots at Bannockburn), and thus condemned the best part of his army to a fatiguing advance on foot across difficult country in full armour.

The French crossbowmen, who might have crushed the relatively few English archers present, were mingled with the mounted men in first line, but, as the latter charged, their advance masked the fire of the crossbowmen in the first few seconds, besides leaving the others, dismounted, lines far in rear. Thus the first attack on the Black Prince's line, which was greatly strengthened by trees and hedges in front of it, was promptly brought to a standstill by the arrows of the archers lining a hedge which overlooked the hollow in front; and the earl of Oxford, hastily drawing out a body of archers beyond the defenders' left, into the marshy valley of the Maussion, completed their rout by firing up the hollow into their flank. But it was not so easy to deal with the second line of dismounted men-at-arms, led by the dauphin, which was the next to arrive on the French side. The hedge indeed was held, and the assailants, unable to advance beyond the hollow, gave way, but to achieve this the prince had to use all but 400 of his men. Had the third body of the French advanced with equal spirit the battle would probably have ended there and then, but the duke of Orleans, who commanded it, was so demoralized by the retirement of the dauphin's division that he led his whole force off the field without striking a blow.

Thereupon the king himself advanced furiously with the fourth and last line, and as it came on, the situation of the English seemed so desperate that the prince was advised to retreat. But his determined courage was unshaken; seeing that this was the last attack he put his reserve into line, and, rallying around this nucleus all men who could still fight, he prepared not only to repulse but to counterattack the French. He dispatched 60 men-at-arms and 100 archers under the Captal de Buch to ride round the flank of the enemy and to appear in their rear at the crisis of the fight. Though a mediaeval knight, he knew as well as Napoleon at Arcole that when the moral force of both sides has passed its culminating point even a materially insignificant threat serves to turn the balance. And so it fell out. When both lines were fighting hand-to-hand, the 60 horsemen of the Captal de Buch appeared in the rear of the French. The front ranks fought on, but the rearmost Frenchmen melted away rapidly, and at last only a group of the bravest, with King John and his son Philip, a boy of 14, in their midst, was left. This band continued their hopeless resistance for a time, but in the end they were killed or captured to a man. The rest of the French army, totally dispersed, was pursued by the victors until nightfall. Two thousand five hundred of the French, 2,000 of them knights and men-at-arms, were killed, including the constable, one of the marshals, the standard bearer and six other great lords. The prisoners included the king and his son Philip, the other marshal and 25 great lords, and 1,933 knights and men-at-arms as well as 500 others. The Black Prince then resumed his march to Bordeaux, making no effort to exploit his military ascendancy. And in this he was justified, for he had now in his hands a political key which could yield him all the possible profits of victory, without their military cost.

[1]The view adopted is that of Sir Charles Oman, *Art of War in the Middle Ages*, A.D. 378–1485, p. 631 (1924).

POITOU, a former province of France, roughly corresponding to the modern departments of Vienne, Deux-Sèvres and Vendée. The Seuil du Poitou is a low-lying zone of sedimentary rocks, about 60 mi. wide, separating two higher countries of older rocks (Limousin in the east, the southern part of the Massif Armoricain in the west) and forming the easiest natural passage between northern and southwestern France.

Poitou, which takes its name from the Gallic Pictavi or Pictones, was incorporated by the Romans into Aquitania and was for centuries the northern part of Aquitaine (*q.v.*) and, as such, a border country and a battlefield (Vouillé, 507; Poitiers, 732 and 1356; Moncontour, 1569) as well as the meeting place of northern and southern cultures. Its golden age (11th–12th centuries) is represented by a great school of Romanesque architecture, sculpture and painting (Saint-Savin). Philip Augustus occupied it in 1204; and the treaty of Paris (1259) recognized the French conquest, after which Poitou was subject to the royal authority (except for a few years after the treaty of Brétigny). From 1417 it was a stronghold of the dauphin Charles, who made Poitiers his capital much more than Bourges. Poitou suffered much in the Wars of Religion; its later history was much quieter, apart from the insurrection of the Vendée against the Revolutionary government.

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POKEBERRY or POKEWEED, the popular name (from the American Indian *pocan*, applied to any plant yielding a red or yellow dye) of *Phytolacca decandra*, a strong-smelling perennial herb, a native of North America, with ovate-lanceolate sharp-pointed leaves, racemes of small greenish-white flowers and flattish berries nearly ½ in. in diameter, which contain a crimson juice. The young asparagus-like shoots are sometimes used as a potherb, but the roots are poisonous. The plant is often cultivated in Europe, and has become naturalized in the Mediterranean region.

POKER, a card game played in various forms throughout the world. In the English-speaking countries it is exceeded in popularity only by contract bridge and, in the United States, rummy.

In principle poker is an ancient game, almost as old as playing cards themselves, but its name and present form originated in the United States early in the 19th century. R. F. Foster, Scots-born U.S. student of games, cites an 1834 reference to poker, and no earlier one is known. There has since been gradual but continuous change in the form of the game.

Poker has countless variants and probably in no two poker games is exactly the same procedure followed; but the fundamentals are constant and one who knows them can easily play in any game.

A standard pack of playing cards is used, consisting of 52 cards divided into four suits: spades (♠), hearts (♥), diamonds (♦) and clubs (♣), the suits having no relative rank; each suit has 13 cards ranking ace (high), king, queen, jack, 10, 9, 8, 7, 6, 5, 4, 3, 2 (low). From two to eight players ordinarily participate, taking their seats at random around a table.

The object of the game is to win money (or chips or other tokens), for which poker is invariably played, by having the highest-ranking "hand" of five cards, or by "bluffing"—making the other players believe one's hand is best even though it is not. The rank of poker hands is based upon the relative infrequency of the combinations which have value. These are, from highest to lowest:

Straight flush: five cards of the same suit and in sequence. The ace, king, queen, jack and 10 of one suit are a "royal flush." The ace may also rank low in the sequence 5-4-3-2-ace.

Four-of-a-kind, as, all four 6s and any fifth card.

Full house, or full hand: three of one kind and two of another, as 10-10-10-3-3.

Flush: five cards of the same suit.

Straight: five cards in sequence, but of two or more suits. The ace ranks either high or low, as in a straight flush.

Three-of-a-kind, or *triplets,* with any two other cards.
Two pairs, as, A-A-9-9 and any fifth card.
One pair.

As between two hands having combinations in the same category, the winner is determined as follows:

Straight flushes, flushes, straights or *no pair:* the one containing the highest card wins; if these cards are identical in rank, the next highest decides, and so on. *Four-of-a-kind* or *three-of-a-kind:* the one composed of the higher-ranking cards. *Full house:* the higher three of a kind. *Two pairs:* the highest pair; if these are identical, the higher of the second pairs; if these are identical, the higher of the two unmatched cards. *One pair:* the higher pair; if these are identical, the highest of the unmatched cards, and so on.

If two hands are identical they tie.

The better of these combinations occur infrequently. There are 2,598,960 possible poker hands, of which 40 are straight flushes, 624 fours-of-a-kind, 3,744 full houses, 5,108 flushes, 10,200 straights, 54,912 threes-of-a-kind, 123,552 two pairs, 1,098,240 pairs and 1,302,540 with no pair or better. To increase one's chance of holding a good hand, in some games value is accorded to one or more of the following special hands, ranking as follows:

Big tiger, or *big cat:* king high, 8 low, no pair.
Little tiger, or *little cat:* 8 high, 3 low, no pair.
Big dog: ace high, 9 low, no pair.
Little dog: 7 high, 2 low, no pair; any tiger or dog beats a straight but loses to a flush.
Skip straight, as 2–4–6–8–10, or *round-the-corner straight,* as queen–king–ace–2–3; beats three-of-a-kind, loses to a straight.
Blaze: five "face cards"—kings, queens and jacks. Beats two pairs, loses to three-of-a-kind.
Four-flush: (played only in stud poker): four cards of the same suit; beats a pair, loses to two pairs.

As between two skip or round-the-corner straights or two four-flushes, the highest card decides. As between special hands in any of the other categories, ties are not broken.

The Shuffle and Deal.—Any player deals the cards in rotation to his left, one at a time face up, until a jack shows; the player receiving the jack becomes the first dealer. Any player may then shuffle the cards, the dealer last; the player at the dealer's right may cut or not, as he pleases; and the dealer serves the cards, one at a time, face down, in clockwise rotation beginning with the player at his left. The right to deal will then pass from player to player to the left.

The most popular variants of poker are:

Draw poker, the game as played in Great Britain and to some extent in the United States, where it originated: Five cards are dealt to each player. The "age"—player at the dealer's left—must make the first bet, called an "ante." All bets go into the centre of the table and form a "pot." A limit is placed on the size of bets; the ante is commonly 10% to 25% of this limit. The next player in rotation may "straddle" (put up double this ante) but must do so "blind" (without looking at his cards). Each player in turn after the ante or straddle may then "call" or "see" by betting the same as the player before him; or may "raise" by calling the previous bet and adding an additional bet to it; or must "drop" out of the pot and discard his hand.

When every player has exactly called the last previous bet or raise, or has dropped, each active player in turn beginning with the age may discard one, two or three cards, which the dealer replaces, face down, from the top of the deck. This is the "draw." A player who does not wish to draw is said to "stand pat." The dealer may not serve the last card. If necessary the discards must be shuffled and cut to complete the draw. To avoid this, most draw poker games are limited to seven players.

The active player nearest the left of the age (or of the straddler, if any) must now bet or drop, and so on around until the last previous bet or raise has been exactly called by every player still in the pot. There is then a "showdown," in which the player who made the last bet and each player who called it must place his five cards face up on the table. The highest-ranking hand wins the pot. If no one called the last bet, that bettor wins and need not show his hand.

Jack pots is the favourite U.S. draw-poker variant. Each player antes before the deal. The ante usually is about 5% of the limit. Five cards are dealt, face down, to each. Beginning at the dealer's left, each player in turn may pass or open. To open, a player must have a pair of jacks or any better hand. If no one opens, everyone antes again and the deal passes. If the pot is opened, each player in turn (whether or not he previously passed) may either call, raise or drop. (In other poker variants, however, the term "pass" is equivalent to "drop," and a player who once passes may not re-enter the pot.)

After the draw, any active player, beginning with the one who opened, may bet or may "check"—stay in the pot without betting—until a bet is made; thereafter, each player in turn must either call, raise, or drop. If everyone checks, or when everyone has called the last bet or has dropped, there is a showdown. The opener, to win the pot, must demonstrate that he had "openers." A penalty is usually prescribed for a false opening—usually that the offender must ante for everyone on the next deal.

Stud poker is the most popular of the poker variants played for high stakes in the United States. As many as 14 have been known to participate in a single stud-poker game, but 7 to 9 make the best game. The dealer gives each player one face-down card, called the "hole card," and then one card face up, whereupon the deal is suspended for a round of betting. The player dealt the highest card must make a bet; of identical cards the one dealt first (*i.e.,* nearest the dealer's left) ranks higher. Each player in turn thereafter must call, raise or drop. (To drop, he turns down his face-up card or cards.) When this round of betting is completed, each active player receives another face-up card, and there is another round of betting; and this process is repeated until each player has in all five cards, one of them his hole card. On each of the last three rounds of betting, the player having the highest-ranking combination showing bets first, and may bet or check as in jack pots. After the last round of betting there is a showdown in which the hole cards are shown and the highest-ranking hand of five cards takes the pot.

Seven-Card Stud.—Each player receives two hole cards face down, then four cards face up, with a round of betting after each; then one more card face down and another round of betting. At the showdown each player selects five of his seven cards as his hand.

High-Low Poker.—The highest-ranking poker hand and the lowest-ranking poker hand divide the pot equally. If there is an odd chip the high hand gets it. If two or more hands tie for high or low, they split their half of the pot equally.

High-low seven-card stud became a fad game in the United States in the early 1930s, and is perhaps the most scientific of the poker games. Seven-card stud is played, and at the showdown the high and low hands are to split the pot; but each player may select five of his cards as a high hand, and five as a low hand, and perhaps thus win the entire pot. Some play that the ace may count as either the high or the low card in this game, so that the lowest possible hand is 6–4–3–2–ace of two or more suits. "Table stakes" are usually played in this game, as in any poker game for high stakes; the limit for each player is the amount he has on the table at the time.

Wild Cards or "Freaks."—A "wild" card may stand for any card its holder wishes to name. A 53-card pack, including a joker as a wild card, is often used; or the four deuces (2s) may be called wild (in which case the game is called "deuces wild"). "Naturals" are usually played to beat equivalent wild-card combinations, so that three aces will beat one ace and two wild cards. When wild cards are played, the highest possible hand is five-of-a-kind. Serious players scoff at most wild-card variants, but some use the "bug"—the joker used either to represent an ace or to fill a flush or straight. Thus, A–A–bug–6–5 represent three aces, and 8–7–6–bug–4 are a straight, but K–K–bug–6–5 are only a pair of kings.

Irregularities in Poker.—There are no official poker rules. The following remedies are more or less generally applied to irregularities in serious games:

Misdeal: None. If a player at any time has more than five cards or fewer than four, his hand is dead. If a player is dealt four cards, and

does not look at any of them, the dealer must complete his hand after finishing the regular deal. An error in the draw may be corrected only before the next player in turn has drawn.

Betting rules: Money once put in the pot may not be removed. A bet out of turn remains in the pot, and when the player's turn comes he may increase it enough to make it constitute a call or raise. An announced bet is not valid until the money is in the pot.

Exposed card: During the deal, a player must take it. During the draw, an exposed card is dead and is replaced after the regular draw is completed.

Announcements out of turn: If a player announces out of turn that he intends to drop, but keeps his hand, or announces an intention to bet, but does not put the money in the pot, the announcement is meaningless and in turn he may act as he pleases.

Skilful Play.—Poker better rewards skilful play than any other card game. Psychology and the "poker face" do not, however, play so great a part in its science as is generally supposed. Patience—the ability to drop time after time until a good hand comes along—is a prime ingredient of the successful poker player. Even more important is the good player's insistence on receiving proper "odds" for every bet he makes. It is 8½ to 1 against improving three-of-a-kind by drawing two cards, and 11 to 1 against improving two pairs by a one-card draw, but these hands are so often good enough to win without improvement that it is generally wise when holding them to raise before the draw. It is 2½ to 1 against improving a single pair by drawing three cards; a pair lower than queens should usually be dropped and no single pair justifies a raise. The odds are 38 to 9 against making a flush by drawing one card to a four-flush, and 39 to 8 against "filling a bob-tail straight" (open at both ends, as 10–9–8–7); so these hands should be dropped unless there is at least five times as much in the pot as it would cost to stay in. An "inside straight" (such as 10–9–7–6) should not be played in any circumstances. In stud poker it is unwise to stay unless one's cards, including the hole card, will "beat the board" (that is, are better than any showing combination of cards); and in no case should one stay against an "open pair" (a pair showing in another player's face-up cards) unless holding a higher pair.

See *Oswald Jacoby on Poker* (1940) for the game as played in the U. S.; Maurice Ellinger, *Poker* (1944), for the game as played in England. (A. H. Md.)

POKOMAM, a group of Indians speaking a Maya dialect who live in southern Guatemala. Their territory runs from the upper part of the Motaqua river to the border of Salvador. They inhabit the departments of Chimaltenango (in part), Guatemala, Amatitlán and Jalapa in Guatemala, and at the time of the conquest they extended to Chalchuapa in Salvador. The principal towns where this tongue is spoken are San Martín Jilotepeque, Mixco, Petapa, Jalapa, Jilotepeque and Asunción Mita. They number about 50,000, of whom more than half speak their native tongue. The ancient capital of the Pokomam was the fortress of Mixco situated on a steep hill in the valley of Xilotepeque.

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POLA, a seaport of Italy, the capital of the province of Pola, in the district of Venezia Giulia, 86 mi. S. of Trieste by rail. Pop. (1936) 34,090 (town); 42,259 (commune). It was the principal naval harbour and arsenal of the Austro-Hungarian monarchy until 1918, and is situated near the southern extremity of the peninsula of Istria. It lies at the head of the Bay of Pola, and possesses a safe and commodious harbour almost completely landlocked. An extensive system of fortifications, constructed on the hills which enclose the harbour, defends its entrance, while it also possesses a good roadstead in the large channel of Fasana.

The modern town of Pola lies round the base of a hill formerly crowned by the Roman capitol, and now by a castle of the 17th century. Besides the castle the chief buildings are the cathedral, burned down in 1923 and reconstructed on the lines of a 6th-century Ravenna basilica; the new garrison church, completed in 1898 in the basilica style, with a marble façade; and the Franciscan church dating from the 14th century. To the southwest, along the coast, extends the marine arsenal, which has been dismantled; the large barracks are equally deserted. The chief interest of Pola centres in its fine Roman remains. The most extensive of these is the amphitheatre built in A.D. 198–211 in honour of the emperors Septimius Severus and Caracalla, which is 79 ft. high, 400 ft. long and 320 ft. wide, and could accommodate about 23,000 spectators. It is remarkable as the only Roman amphitheatre of which the outer walls have been kept intact. The history of Pola begins with its capture by the Romans in 178 B.C. It was destroyed by Augustus because of its espousal of the cause of Pompey, but was rebuilt under the name of Pietas Iulia and was mainly important as a harbour. Later it became the capital of the margraves of Istria, and was captured by the Venetians in 1148. In 1379 the Genoese, after defeating the Venetians in a great naval battle off the coast, took and destroyed Pola, which disappears from history for the next 450 years. It remained under Venetian supremacy to 1797, and fell under Austria in 1815.

See T. G. Jackson, *Dalmatia, the Quarnero and Istria,* vol. iii (1887).

POLABS (*Po*=on, *Laba*=Elbe), the Slavs (*q.v.*) who dwelt upon the Elbe and eastward to the Oder. Except the Lithuanians they were the last Europeans to be Christianized; their chief sanctuary was at Arcona on the Isle of Rügen. They were converted and conquered in the 12th century and germanized. By the 17th century Slavonic survived only in a tiny patch in the east of Hanover about Lüchow; its scanty remains are corrupt.

POLAND (Polska), a country of eastern Europe lying between the Baltic sea to the north and the Sudeten and the Carpathian mountains to the south and bounded, from 1945, on the east by the U.S.S.R., on the south by Czechoslovakia and on the west by Germany. (For population, *see* below.)

PHYSICAL GEOGRAPHY

The main morphological features have been moulded by two great influences: the northward thrust of the alpine fold mountains against the Hercynian plateaus (represented there by the Bohemian massif and the submerged Polish platform which reaches the surface in the Lysagora) and the southward sweep of the Scandinavian ice-sheet. Conditioned by these influences the natural regions tend to form zones running broadly east and west across the country.

In the extreme south, the mountain frontier zone is divided into two sections. The first, composed of the older, much peneplained rocks of the Sudeten mountains, reaches its highest point in Mt. Sniezka (5,260 ft.); the second, formed by the young fold mountains of the Carpathians, assumes a truly alpine appearance in the High Tatras, the highest point of which, Gerlachovka (8,737 ft.), lies across the frontier in Slovakia. The submontane zone of southern Poland, consisting of upland-rimmed river basins interconnected by narrow gateways, is again capable of subdivision. Thus Silesia, drained northwestward by the Oder, forms a unity centring upon Wroclaw (Breslau); bounded on the north by the Trzebnica hills, this basin represents an extension of the great carboniferous deposits of northwestern Europe. The sub-Carpathian basins, on the other hand, occupy a tectonic hollow running from the Moravian gate through the small Oswiecim basin and the Cracow gate to the wider Sandomierz basin drained by the Vistula and San, with the Przemysl gate separating the latter from the headwaters of the Dniester, within the Soviet frontier. The Little Polish tableland which separates the Silesian and sub-Carpathian basins, consists of the Cracow-Czestochowa limestone plateau (1,653 ft.), opening southeastward to the Tertiary deposits of the Nida basin, and the Holy Cross (Swietokrzyskie) mountains (Lysagora, 2,004 ft.). The southeastern edge of the latter, the level Sandomierz tableland, is noted for its fertile loess deposits. Finally, east of the Vistula the upland rim is represented by the Lublin tableland, with its rich soils derived from chalk marl, and the Roztocze ridge.

The remainder of Poland is dominated by glacial features. The characteristic east-west sectors of the great rivers and their tributaries (*e.g.*, the lines formed by the Bug-Vistula-Notec-Warta and the Warta-Obra-Oder) mark stages in the successive northward retreat of the ice sheet, when drainage was forced toward the west. Central Poland, an undulating country crossed by the great valleys, is subdivided into the Great Polish and Kujavian lowlands around Poznan and the Mazovian Podlasian lowlands

around the capital city, Warsaw. The soils are based on fluvioglacial and fluvial deposits. Further north, breached by the Oder and Vistula in their lower courses, lies the Baltic lake zone, Pomorze (Pomerania) to the west and Mazuria to the east of the Vistula. It is a region of classic morainic topography: the boulder clay, sands and gravels form hummocky ridges, reaching often more than 650 ft. in height and interspersed with numerous lake-filled, peaty hollows. The morainic hills descend to a low sandy plain along the Baltic coast. The half-formed deltas of the Oder and Vistula are classic examples of the lagoon-and-bar coastal formation, where the sea currents and prevailing winds drag the river deposits and coastal sands eastward along shore. Modern methods of port maintenance and navigation enabled the old ports to continue their ocean-going trade.

Flora and Fauna.—The natural forests of Poland are transitional between the mainly coniferous stands of northern Europe, closely associated with the podsols, and the deciduous woodlands of central and western Europe growing on the more fertile brown soils. The fauna is that associated with the temperate forests which once covered most of the country apart from the alpine zone of the high mountains. The reindeer, sable and wild horse, however, survive only in tradition; the bear is restricted to the Carpathians, the elk was found in the former northeastern provinces and the beaver in the Polesian marshes, which became Soviet territory.

About 70% of Poland's forests are coniferous, with the pine dominant, followed by spruce. There are few firs, while larches and yews appear only sporadically. The deciduous trees, more characteristic of the southern provinces, are mainly birch, beech, wych-elm, aspen, ash, oak and alder. One of the best-known forests is that of Bialowieza, famed for its ancient trees and, up to 1918, its herd of aurochs or European bison (later crossbred with animals of Canadian origin). The main timber products are deal boards, building timber, pit props and fuel. Losses incurred in World War II made it necessary to import certain types of timber, whereas before that war the export of timber accounted for one-fifth of the active foreign trade balance.

Climate.—Climatically, Poland belongs to the major zone which includes eastern Germany, most of Finland and western U.S.S.R. It is open to the influence of the prevailing, variable westerly winds, except when these are replaced during winter by the heavy masses of cold air cushioning the interior of the continent. The summers are warm or very warm, according to distance from the sea and latitude, although the latter is offset by the increasing height of the land toward the south. The winters are cold and are particularly unpleasant when pressure conditions are right for the influx of strong winds from the Russian plains. Temperatures are everywhere below freezing point for at least two winter months in the west and three months in the east. The Oder, for example, is frozen for an average of 80 days, the Vistula 80–100 days; and the Baltic harbours, especially where distant from the open sea, are icebound for a considerable period every year —Swinoujscie for 20 days on the average, Szczecin for 61 days. The open Baltic itself is frequently impeded by drift ice, but navigation usually continues along the sea lanes connecting the favourably placed docks of Gdynia-Gdansk (Danzig). The following figures for the mean January and July temperatures, in degrees Fahrenheit, are typical: Szczecin, 30.4 and 64.9; Warsaw, 26.8 and 65.5; Tomaszow Lubelski, 23.9 and 64. Sniezka, with a range between 19.2 and 46.9 and below freezing point for six months, is typical of conditions in the highest mountain regions; even in the Tatras, however, there are no permanent snows.

Precipitation, in winter mostly in the form of snow, is moderate, 20–27.5 in., except along the southern highland fringe. More falls in the summer half-year, because of the development of thundery conditions in early summer and of the passage of depressions in autumn. The skies are on the whole cloudy, mean cloudiness averaging somewhat less than seven out of ten points; the summers are brighter and less humid, although more rainy, than the winters. Wroclaw is representative, with a mean annual rainfall of 23.3 in. and cloudiness of 6.8 points; precipitation is distributed seasonally, in percentages of the total, beginning with winter, as follows: 16, 24, 38 and 22. Sniezka has a mean annual precipitation of 45.6 in., typical of the narrow mountain fringe.

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HISTORY

Polish history begins in the year 963 when a German border knight came into contact with Mieczyslaw or Mieszko I, who was prince of Poland till 992. The unity of the Polish state, surrounded as it was by other pagan and mostly Slavonic tribes, had been achieved under the descendants of Piast (said to have been either of peasant origin or an official at the court of an older dynasty), who founded the dynasty which gave his people strong and valiant rulers down to 1370. Mieszko's predecessors had succeeded not only in uniting a number of tribes but in establishing a highly developed political community which had neither enjoyed the benefits nor suffered the disadvantages of contact with the high civilizations of western and southern Europe. To meet the dangers that arose when the Germans began to penetrate the barrier formed by the western Slavonic tribes, Mieszko conceived that policy of deliberately adopting western civilization which was the chief object of the rulers of Poland for several centuries. He secured his state from the aggression of his new neighbours by acknowledging himself a tributary of the western emperor Otto I, and removed all danger of a hostile crusade by accepting Christianity for himself and for his people in 966 with the help of the Czech princess Dubravka or Dabrowka, whom he had married a year before. Finally he placed all his lands in the hands of the pope, thus inaugurating a close relationship that gave Poland the special protection of the Holy See. He seems to have been successful in gaining Pomorze (Pomerania; *i.e.*, the seaboard), but lost part of his eastern territory to Vladimir the Saint.

THE PIAST KINGDOM

Mieszko's son Boleslaw I the Mighty (*see* BOLESLAV I) (992–1025) was one of the great soldiers and statesmen of his time. From the congress of Gniezno (Gnesen) (1000) with his friend the emperor Otto III, where he secured for Poland an independent church, organized in a number of bishoprics under a metropolitan at Gniezno, to his coronation as king (1024), he achieved the transformation of his father's principality into a powerful and independent kingdom. His wars of defense and expansion against Germany and Bohemia ended successfully in 1018; then he turned east and occupied the Russian capital, Kiev, thus recovering the territory lost in the preceding reign. His younger son Mieszko II (1025–34) succeeded him as king, but the power of the kingdom waned in spite of its partial revival under Mieszko II's son Casimir (Kazimierz) I the Restorer (1038–58) and the strong rule of Casimir's son Boleslaw II the Bold (*see* BOLESLAV II) (1058–79). But under Boleslaw III Wrymouth (*see* BOLESLAV III) (1102–38), a nephew of Boleslaw II, Poland made great advances. Boleslaw maintained the independence of his country when the emperor Henry V invaded Silesia in 1109 by a victory at Glogow. His reign saw a considerable cultural advance, and an anonymous chronicler recorded the earlier history of Poland. He collaborated with Otto, bishop of Bamberg, in converting the Pomeranians to Christianity and occupied the greater part of that province.

The Period of Division, 1138–1314.—Boleslaw III divided Poland among his sons, so that Poland, like its neighbours Germany and Kievan Russia, ceased to be a united state for two centuries. The capital was established at Cracow, the ruler of which held the central provinces of Poland together with Pomorze and had "seniority" over his brothers, who ruled over Silesia, Mazovia, Great (or western) Poland and Sandomierz. In each of these principalities there grew up round the Piast prince a powerful upper class consisting of the officials and the clergy headed by the local bishop, a process which modified the *jus ducale* of the monarchical system. This period of divided loyalties laid the country open to many dangers; while the empire remained strong, a ruler like Frederick I Barbarossa in 1157 could assert his claim to Polish allegiance, and a major disaster like the Mongol

invasion in 1241 found the chivalry of Little (or southern) Poland unsupported and the heroic efforts of Prince Henry of Silesia made in vain. Worst of all were the incessant raids of the barbarian neighbours, notably the Lithuanians and Prussians. To avert these, Prince Conrad of Mazovia called in the Teutonic Order, a purely German crusading organization that had lost a sphere for its activities in Palestine. Well established on the northern border, the order was helped by the Poles to occupy not only the borderland but the whole of Prussia, which was speedily colonized mainly by German immigrants. By a brilliant piece of diplomacy the grand master Hermann von Salza persuaded the emperor Frederick II to accept his homage as ruler of the newly acquired lands (1226). The divided Polish states found themselves face to face with a powerful German state on their northern border.

In spite of the political weakness of Poland, of the great Mongol disaster and of the menace from Germany, this age was one of great importance to the development of Poland. In the process of decentralization, each province was able to assert its own individuality, helping its prince and bishop to enlarge its capital city and to intensify their efforts to develop the resources of its small territory. The petty princes were able to imitate western Europe by encouraging the immigration of German peasants, townsmen and artisans, who helped them to raise the level of economic life. The ideal of the 13th-century Polish prince, especially in Silesia, was *melioratio terrae,* to achieve which he was prepared to sacrifice both part of his own sovereign power and vague national ideals. This lack of a Polish patriotism resulted in the loss to Poland of some areas: Lower Silesia and western Pomorze were gradually colonized by Germans. But the economic and cultural advance of the country as a whole was worth the sacrifice. The community thus strengthened was able to maintain its ethnical frontier in spite of political disaster for six centuries. In most of Poland the Germans were ultimately absorbed. The princes further reduced their sovereign power by the granting of charters to different groups and individuals. The Jews, whom crusading zeal had expelled from nearly every country, were granted the right to settle in Poland, to maintain their own schools and to practise their religion. For the Poles they were skilled middlemen who made an important contribution to the economic life of the country but who were never absorbed as the Germans were and hampered the formation of a Polish middle class. The achievements of this period of division, in spite of its difficulties and weaknesses, can be appreciated through a comparison of the low social and economic situation in the 12th century with the resources available to the revived monarchy after 1305, whereby the rulers were able to reunite the divided principalities and to preside over the rapid development of a state that had no need to copy the social and economic life of its neighbours.

Wladyslaw I, 1314–33.—The idea of reuniting the Polish principalities in one state first appears in the experiments of the princes of Silesia, especially in those of Henry I the Bearded. These princes failed partly because they gradually succumbed to the attraction of German civilization and joined the empire under Czech auspices. Przemyslaw II of Great Poland actually assumed the royal title in 1295; but the real task of reunion was undertaken, at a time when Poland had come under the rule of Czech kings, by the hard-fighting Wladyslaw Lokietek (Ladislas the Short) (*see* WLADISLAUS) of Kujavia. The idea was strongly supported by the ecclesiastical leaders. These men had represented for a long time the links that bound Poles together and led the enlightened magnates who realized that a divided Poland would suffer extinction at the hands of such powerful neighbours as Bohemia, Brandenburg, Hungary and the Teutonic Order. Wladyslaw cleverly availed himself of the support of Hungary and of the traditional protection of the Holy See. After occupying Little Poland in 1305 and Great Poland in 1314, he was crowned king of Poland in 1320 as Wladyslaw I (1314–33). He had many disappointments: the Teutonic Order seized Pomorze in 1308; his country long continued to suffer from the raids of the pagan Lithuanians; and he never reigned over Silesia or Mazovia, which preferred to do homage to John of Bohemia. But he held his own against the order in the battle of Plowce (1331), strengthened his position by his diplomatic friendship with Hungary (which was sealed in 1320 by his daughter Elizabeth's marriage to the new Angevin king Charles I) and ended for a time the Lithuanian raids by marrying his son Casimir to Anne (Aldona), daughter of the grand duke Gedymin, in 1325.

Casimir III the Great, 1333–70.—Unlike his father, Casimir was born in the purple and was a man of peace. A realist and a shrewd diplomatist with a zest for the Latin culture that he learned at the court of his sister in Hungary, he was ready to make great sacrifices to secure the independence, unity and prosperity of his kingdom. Happily for Poland the decline of the empire, the disunity of Germany, the weakness of Russia and the death of the last great khan of the Tatars lessened the dangers on the western and eastern frontiers. Poland had to face in the south the powerful kingdom of Bohemia, whose king in 1355 was crowned emperor as Charles IV, and in the north the great military strength of the Teutonic Knights. Basing his foreign policy on a close alliance with Hungary, he was content to allow Charles IV, another lover of peace, to hold Silesia, and to give up his claim to Pomorze and the border districts held by the order. As compensation for this loss of Polish territory, he found himself able by inheritance and diplomacy to annex Halicz and to begin that policy of conciliation with the Lithuanian princes which was to bring such important results later on. His own prestige grew abroad, and he made Poland a full member of the European community. By thus gaining for Poland a long period of peace and security, he was able to make great changes in the internal relations of the country. He codified the laws of Great and Little Poland and succeeded in persuading these two rival states to co-operate, while the local officials of Little Poland became national ministers. The princes of Mazovia were persuaded to acknowledge Casimir as their king. He acquired great wealth, reformed the currency and introduced western methods in town and country. He befriended the Jews, improved the position of the peasants and encouraged the immigration of Germans and Armenians, so that the cities grew in size and prosperity, especially Cracow and Lwow. He was a great builder and was said to have "found a country of wood and left a country of stone." The administration was made more efficient, and it was mainly to train young men in law that Casimir founded the University of Cracow in 1364. He encouraged learning and was able, through the Italian influences at the court of Hungary and the French connections of Prague, to raise the level of learning among the Poles to western European standards. By his foresight, his patience and genius for creation and adaptation, this great statesman made possible the strong and prosperous position of the Polish kingdom during his lifetime and its great development in the next two centuries.

Louis I of Hungary, 1370–82.—Having no sons, Casimir III bequeathed his kingdom to his sister Elizabeth's son Louis I of Hungary (1370–82), already one of the leading rulers of central Europe, who continued the co-operation of his two realms in the spirit of his predecessor. Like Casimir, he left no sons, and the future of central Europe depended to some extent on the fate of his two daughters. After an interregnum of two years the Poles accepted his younger daughter Jadwiga as their queen (1384–98) and consummated the efforts of Casimir III to conciliate the pagan rulers of Lithuania by arranging the marriage of Jadwiga to Jagiello, grand duke of Lithuania, who became king of Poland as Wladyslaw II (1386–1434).

Social and Constitutional Development, 1138–1384.—The social structure of the Polish state at the time of the dynastic union with Lithuania was very different from what it had been under the early kings. In the period of division there had grown up round each prince a class of ecclesiastical and lay magnates whose function was at first to advise and later to share with the prince the government of his principality. In addition to this privileged class, the general mass of the gentry, organized in their clans, each with its coat of arms and slogan, was becoming conscious of its own importance as a social and political element in the country. As the prince gradually lost his monopoly of political and legal power by the grant of charters to various groups, this

body, which came to be called the *szlachta*, began to share political privileges with the magnates. The extinction of the Piast dynasty gave them the opportunity by the pact of Koszyce (Kosice) in 1374 to obtain from Louis a number of privileges, the *magna carta* of Poland. The chief of these was the right to pay no taxes beyond a certain sum, unless they had expressly consented to them. During the period of division the church, which had established its position at the synod of Leczyca in 1180, played a leading part, not only in the social and moral life of the community but also as the sole factor of unity between the numerous principalities. The inhabitants of the towns had received charters mainly under Magdeburg law to encourage the settlement of Germans. Besides Wroclaw (Breslau) and Poznan, the two great cities Cracow and Lwow grew to prosperity on the great eastern trade route. These towns, though at first largely foreign in race, became integral members of the community, able to aid and to advise the prince and to attain political importance. The peasants, with the rise of the gentry, lost in social standing but gained economically by the rights granted under Magdeburg law in the reign of Casimir III—a situation that only slowly worsened as serfdom grew up a century later. From the small body of educated men who made the court of Boleslaw III superior to that of the early kings (with the famous Otto, later bishop of Bamberg, and the anonymous scholar who wrote the first history of Poland), through the spread of western social and moral ideas (at first chiefly by the Cistercians) to the writing of a real historical work by Wincenty Kadlubek (d. 1223), the great progress of learning in the Polish community can be followed, only temporarily interrupted by the Mongol invasions. The great problem of the Poles was to seek and assimilate western institutions and ideas while retaining and cherishing their own native civilization. They were forced to learn mainly from the Germans. But the political exploitation of this position by the latter led to the rise of strong anti-German feeling and to the practice of seeking models in Italy, France or the Low Countries in preference to Germany. The union of Poland and Lithuania was a mortal blow to the position of the Teutonic Order, the greatest German power on the Polish border.

THE JAGIELLON DYNASTY

Jadwiga and Wladyslaw II Jagiello.—The magnates of Cracow, Casimir III's pupils and successors, were able to instruct the girl queen and the pagan king in the arts of government. One of the first acts of the new king was to receive Christianity for himself and his people. The Lithuanians, unlike the Ruthenian members of their grand duchy who were Orthodox, joined the western Catholic Church. So the Poles gained by peaceful agreement what the German Knights had sought by violence during a century and failed to win: the conversion of the last great body of pagans in Europe. The very reason for the existence of the order had gone, and it would have to struggle to preserve its territories which included Pomorze with Danzig (Gdansk) and the whole of Prussia. But the settlement was delayed for some time, partly because of Jadwiga's religious scruples against fighting a crusading body, and partly because Wladyslaw Jagiello had to solve the difficult problem of Lithuania, where he had a rival in his cousin Vytautas (Witold). The order exploited this situation so adroitly that the king was forced to recognize Vytautas as grand duke of Lithuania. This arrangement was successful for a time, and in 1409 the aggression of the order provoked the two cousins to join their forces against their common enemy. Advancing into Prussia they completely defeated the Knights in the great battle of Grunwald (Tannenberg) in 1410. Unfortunately, though the victory was followed by the union of Horodlo (1413), which established in Lithuania institutions based on those of Poland, the two cousins did not always agree; and Poland was exposed in the south to the hostility of Sigismund of Bohemia, who had succeeded to the possessions of Louis of Hungary in 1387 and to the German kingdom in 1410. Jagiello lost his wife Jadwiga in 1398 and remained without male issue by his next two wives; but his fourth, whom he married in 1422, the Lithuanian princess Sophia Holszanska, gave him what Poland needed: two sons. Throughout his long reign he continued to collaborate amicably with the Polish leaders or, occasionally, to oppose them, knowing well that the union with Lithuania depended on his own person. He suffered great anxiety from the ambitions of Vytautas, who was a great warrior and statesman and planned to conquer the Tatars and to annex Moscow. Beloved by the Lithuanian people, Vytautas died in 1430. Wladyslaw Jagiello died in 1434, after a reign of 48 years, at a great age. He was, like most of his family, a prudent, tolerant and tenacious ruler, and he founded a dynasty that was to be one of the greatest in Europe.

Wladyslaw III, 1434–44.—Jagiello was succeeded by his ten-year-old son Wladyslaw III, the chief position in the realm being held by the most eminent of the Cracow magnates, Zbigniew Olesnicki, bishop of Cracow and one of the previous king's chief advisers, who became a cardinal. Olesnicki had to deal with a number of urgent problems: the spread of Hussitism among the gentry; the threat to European civilization from the Turks on the Danube; the possibility of the recovery of Silesia from the Czechs and of Pomorze from the Teutonic Order; and the dangerous rise of rebellion in Lithuania among the Orthodox Ruthenians. A highly cultured scholar, a great orator and diplomatist, he played a leading part in the council of Basel. The Lithuanian rebels, though supported by the master of Livonia (the Knights of the Sword had been amalgamated with the Teutonic Order in 1237), were decisively defeated in 1435 near Wilkomierz (Vilkomir, Ukmerge). A churchman, Olesnicki was, like Queen Jadwiga, prepared to conciliate the Teutonic Order and to concentrate the national forces against the heretical Czechs (so as to recover Silesia) and against the Turk in the south. He failed in the first project, and his great crusade, which involved securing the throne of Hungary for Wladyslaw III (who thus became Ulaszlo I of Hungary), was brought to a disastrous end by the defeat at Varna (1444), where Wladyslaw was killed and his supporter John Hunyadi routed. Until his death was certain, Poland remained without a ruler for three years (1444–47), when Wladyslaw II Jagiello's second son, Casimir, who had made himself popular in Lithuania, ascended the Polish throne. (A. B. Bo.)

Casimir IV, 1447–92.—The difficulties which confronted Casimir were great. He recognized not only the vital necessity of the maintenance of the union between the two states but also the fact that the chief source of danger to the union lay in Lithuania. For political reasons, during the earlier years of his reign, Casimir was obliged to reside for the most part in Lithuania, and his interest in the grand duchy was always resented in Poland, where, to the very end of his reign, he was regarded with suspicion. In particular, he could never rely on adequate Polish support in the struggle, which he inherited from his predecessors, with the Teutonic Order.

The struggle assumed a new form in 1454, when Casimir accepted the suzerainty offered to him by the Prussian league, which had repudiated the authority of the order and needed a protector. The acquisition of the Prussian lands was vital to the existence of Poland. It meant the command of the principal rivers of Poland, the Vistula and the Niemen, and the acquisition of a seaboard with its corollaries of sea power and commerce. Yet, except in the border province of Great Poland, which was interested commercially, the king received little support, military or financial, and it was only with his victory at Puck (Sept. 17, 1462) that he obtained any decisive success against the order. The war was ended in 1466 by the second treaty of Torun (Oct. 14), by which Poland recovered the provinces of Pomorze, Chelmno and Michalow, with the bishopric of Warmia (Ermeland), numerous cities and fortresses, including Marienburg, Elbing, Danzig and Torun. The territory of the Knights was now reduced to Prussia proper, embracing, roughly speaking, the district between the Baltic, the lower Vistula and the lower Niemen, with Königsberg as its capital. For this territory each grand master within nine months of his election was in future to render homage to the Polish king, who undertook not to make war or to engage in any important enterprise without Prussian consent. Prussia had now become a Polish province, and Poland had acquired a seaboard.

The whole foreign policy of Casimir IV was influenced by the

Prussian question. At the beginning of the war both the empire and the papacy were against him. He therefore allied himself with George of Podebrad, whom the Hussites had placed on the throne of Bohemia. On the death of George (1471), Casimir's eldest son, Vladislav (*i.e.*, in Polish, Wladyslaw), was elected king of Bohemia by the Utraquist party, despite the determined opposition of Matthias Corvinus (Matthias I Hunyadi), the king of Hungary, who thenceforward deliberately set about traversing all the plans of Casimir. He encouraged the Teutonic Order to rebel against Poland; he entertained at his court anti-Polish embassies from Moscow; he encouraged the Tatars to ravage Lithuania; he thwarted Casimir's policy in Moldavia. His death in 1490 came, therefore, as a distinct relief to Poland, and all danger from the side of Hungary was removed when Vladislav, already king of Bohemia, was elected king of Hungary also.

It was in the reign of Casimir IV that Poland first came into direct collision with the Turks. The Jagiellons, as a rule, prudently avoided committing themselves to any political system which might irritate the still distant but much-dreaded Turk, but when their dominions extended so far southward as to embrace Moldavia the observance of a strict neutrality became exceedingly difficult. Poland had established a sort of suzerainty over Moldavia as early as the end of the 14th century, but at best it was a loose and vague overlordship which the hospodars repudiated whenever they were strong enough to do so. The Turks themselves were too much occupied elsewhere to pay much attention to the Danubian principalities till the middle of the 15th century, and it was not till 1484 that they became inconvenient neighbours to Poland. In that year a Turkish fleet captured the strongholds of Kilia and Akkerman, commanding, respectively, the mouths of the Danube and Dniester. This aggression seriously threatened the trade of Poland, and induced Casimir IV to accede to a general league against the Porte. In 1485, after driving the Turks out of Moldavia, the Polish king, at the head of 20,000 men, proceeded to Kolomyja on the Pruth, where Bayezid II, then embarrassed by an Egyptian war, offered peace; but as no agreement concerning the captured fortresses could be arrived at, hostilities were suspended by a truce. During the remainder of Casimir's reign the Turks gave no trouble.

John Albert and Alexander.—The death of Casimir was followed by the temporary separation of Poland and Lithuania and by a strong aristocratic reaction in Poland itself. Casimir's third son, John Albert, was elected king of Poland, and his fourth son, Alexander, became grand duke of Lithuania. On the death of John Albert in 1501, Alexander succeeded him as king, and the union of Poland and Lithuania assumed a more definite character, the senate of each country agreeing that in future the king of Poland should always be grand duke of Lithuania. The acquiescence of Lithuania was essentially the result of a new danger which had arisen in the east. Till the accession of Ivan III in 1462 Moscow had been a negligible factor in Polish politics. During the earlier part of the 15th century the Lithuanian princes had successfully contested Muscovite influence even in Pskov and Great Novgorod. Many Russian historians even maintain that, but for the fact that he had simultaneously to cope with the Teutonic Order and the Tatars, Vytautas would have extinguished struggling Moscow altogether. But since the death of Vytautas (1430) the military efficiency of Lithuania had sensibly declined, and the natural attraction of the Orthodox Greek element in Lithuania toward Moscow threatened the integrity of the grand duchy. During the reign of Alexander, who was too poor to maintain any adequate standing army in Lithuania, the Muscovites and Tatars ravaged the whole country at will and were prevented from conquering it altogether only by their inability to capture the chief fortresses. In Poland, meanwhile, Alexander had practically surrendered his authority to an incapable aristocracy, while the dependent states of Prussia in the north and Moldavia in the south made strenuous efforts to break away.

Sigismund I, 1506–48.—Fortunately for the integrity of the Polish state, the premature death of Alexander in 1506 brought upon the throne his capable brother Sigismund, the fifth son of Casimir IV. Eminently practical, Sigismund I recognized that the first need of Poland was a standing army, that Poland, in order to hold its own, must in future follow the example of the west and wage its warfare with trained mercenaries. The great financial and military liberties of the Polish gentry for long prevented both the organization of an adequate national army and the development of a modern fiscal system. Much of the internal history of Sigismund's reign turns on the various proposals made toward these ends, most of which were defeated or mutilated by the aristocratic opposition in the *sejm*. The long, open frontiers of the Polish kingdom invited invasion, and the misfortunes which fell on Poland at a later time largely resulted from the failure of the defensive measures proposed by Sigismund and his advisers. Throughout his reign, the king was hampered by lack of resources. In 1525 he was compelled to grant autonomy to the province of Prussia instead of annexing it; he was unable to succour his unfortunate nephew, Louis II of Hungary, against the Turkish peril, or to prevent the occupation of one Lithuanian province after the other by the Muscovites.

To this period belong the first attempts to provide for the defense of the *dzikie pola*, or "savage steppe," as the vast plain was called which extended from Kiev to the Black sea. In the reign of Alexander, the fugitive serfs who had escaped into this wilderness (they were subsequently known as Kazaks, or Cossacks, a Tatar word meaning "freebooters") had been formed into companies (*c.* 1504) and placed at the disposal of the frontier *starostas*, or lord marchers, of Kaniow, Kamieniec Podolski (Kamenets-Podolsk), Cherkask on the Don and other places. But these measures proved inadequate, and in 1533 the lord marcher Ostafi Daszkiewicz, the hero of Kaniow, which he had successfully defended against a countless host of Turks and Tatars, was consulted by the diet as to the best way of defending the Ukraine permanently against such inroads. The veteran expert advised the populating and fortifying of the islands of the Dnieper. But nothing was done officially. The selfish prudence of Bona Sforza, Sigismund's second wife, did more for the national defense than the Polish state could do. To defend her immense possessions in Volhynia and Podolia, she converted the castles of Bar and Krzemieniec into first-class fortresses and placed the former in the hands of her Silesian steward, who acquitted himself so manfully of his charge that "the Tatars fell away from the frontier all the days of Pan Pretficz," and a large population settled securely beneath the walls of Bar, henceforth known as "the bastion of Podolia."

The most important political event in eastern Europe during the reign of Sigismund was the collapse of the ancient Hungarian monarchy at Mohacs in 1526. After the death of King Louis in the battle, the emperor Ferdinand and John Zapolya, voivode of Transylvania, competed for the vacant crown, and both were elected almost simultaneously. In Poland Zapolya's was the popular cause, and he also found powerful support in the influential and highly gifted Laski family, represented by the Polish chancellor and his nephews Jan and Hieronymus. Sigismund, on the other hand, favoured Ferdinand of Austria. He argued that the best way to keep the Turk from Poland was for Austria to incorporate Hungary, in which case the Austrian dominion would be a strong and permanent barrier against a Moslem invasion of Europe. History more than justified him, and the long duel which ensued between Ferdinand and Zapolya (*see* HUNGARY: *History*) enabled the Polish monarch to maintain to the end a cautious but observant neutrality. More than once, indeed, Sigismund was seriously compromised by the diplomatic vagaries of Hieronymus Laski, who entered the service of Zapolya (since 1529 the protégé of the sultan) and greatly alarmed both the emperor and the pope by his disturbing philo-Turk proclivities. As a result of Laski's intrigues, the new hospodar of Moldavia, Petrylo, after doing homage to the Porte, intervened in the struggle as the foe of both Ferdinand and Sigismund, and besieged the grand hetman of the crown, Jan Tarnowski, in Obertyn, where, however, the Moldavians (Aug. 22, 1531) sustained a crushing defeat, and Petrylo was slain. Nevertheless, so anxious was Sigismund to avoid a collision with the Turks that he forbade Tarnowski to cross the Moldavian frontier and sent a letter of explanation to Constantinople. On the death of John Zapolya, the Austro-Polish

alliance was still further cemented by the marriage of Sigismund's son and heir, Sigismund Augustus, with the archduchess Elizabeth. In the reign of Sigismund was effected the incorporation of the duchy of Mazovia with the Polish crown, after an independent existence of 500 years. In 1526 the male line of the ancient dynasty became extinct, and on Aug. 26 Sigismund received the homage of the Mazovians at Warsaw, the capital of the duchy and before long of the whole kingdom.

(R. N. B.; F. M. S.; X.)

Sigismund II Augustus, 1548–72.—Already in the 15th century the University of Cracow had brought forth humanist scholars of European repute and begun to attract distinguished lecturers and numerous students from abroad. Thanks to Sigismund I's marriage to a Sforza of Milan, the royal court at Cracow became the home of the highest Renaissance art of Italy, and the royal castle on Wawel hill at Cracow, rebuilt by Italian architects and their Polish disciples, became one of the finest monuments of Renaissance style north of the Alps. Under Sigismund II the third great spiritual factor of the age, next to humanist scholarship and Renaissance art—the doctrine of the Reformation—entered potently into Poland's intellectual life, uniting with Italian culture on the common ground of literature and helping to produce the first great age of Polish poetry and prose. There followed the clash between the New Learning and the strong tradition of Poland's chivalrous Catholicism; the difficulties with the Scandinavian powers and the rising empire of the Moscow tsars; the dilemma produced between the evolution of the Polish parliamentary system and the Renaissance tendency toward the strengthening of central government authority. Even a king of genius could be only partially successful in coping with all these tasks, and the reign of Sigismund II, in many respects one of the most brilliant in Polish annals, left the seeds of decay and failure behind it.

Reformation and Counter Reformation.—The new king having shown his temper by marrying a lady of the noble house of Radziwill without asking for the opinion of the senate, the reign began in a storm of demands for constitutional guarantees to secure the parliamentary "gentry democracy" against the powers of the crown and the nobility. The king resolutely allied himself with Austria abroad and with the bishops and the nobles at home, against a threatened revolt of the gentry. In doing so, he had to take the bishops' side in the issue between the Reformation and Catholic orthodoxy, and he affirmed this by an edict against heresy in 1550. But this act only opened up the long-maturing dispute about the creation of a national church after the recent example of Henry VIII of England. The king, a man of enlightened mind, the first Polish monarch who habitually used the vernacular language instead of Latin at public functions, showed in many ways a sympathetic understanding for the tendencies of the new era. The influence of the Bohemian Hussite movement of 100 years before combined with nascent modern nationalism to inspire definite programs for a Reformed Polish state church with Polish ritual, independent of Rome, and with a priesthood subject to government authority. The large Greek Orthodox element among the citizens of the eastern provinces of the monarchy furnished an additional stimulus, which gave strength to such demands as that for the abolition of clerical celibacy in the Lutheran fashion. The bishops resorting to highhanded measures of repression, the *sejm* of Piotrkow in 1552 voted, at the king's own suggestion, the suspension of clerical courts for a twelvemonth. This was extended afterward and solemnly renewed by another *sejm* in 1555, during which masses were actually said in Polish and the communion was administered in two kinds. A religious interim of about ten years followed, during which Protestantism in Poland flourished exceedingly. Presently reformers of every shade of opinion, even those who were tolerated nowhere else, poured into Poland, which speedily became the battleground of all the sects of Europe. Soon the Protestants became numerous enough to form ecclesiastical districts of their own. The first Calvinist synod in Poland was held at Pinczow in 1550. The Bohemian Brethren, expelled from their own country, ultimately coalesced with the Calvinists at the synod of Kozminek (Aug. 1555). In the *sejm* itself the Protestants were absolutely supreme and invariably elected a Calvinist to be their marshal. The king, however, perceiving a danger to the constitution in the violence of the gentry, not only supported the bishops but quashed reiterated demands for a national synod. The *sejm* of 1558–59 indicates the high-water mark of Polish Protestantism. From this time forward it began to subside, gradually but unmistakably, chiefly because of the division among the reformers themselves. From the chaos of creeds resulted a chaos of ideas on all imaginable subjects, politics included. The anti-Trinitarian heresy proved to be the chief dissolvent, and from 1560 onward the relations between the Lutherans and the Calvinists were fratricidal rather than fraternal; Jan Laski (*q.v.*) vainly strove to unite all Polish Protestants round the Helvetian standard, and a federation of all Poles of the Reformed faith—the "concord of Sandomierz," 1570, predominantly Calvinist in character—met resolute Lutheran opposition and led to nothing.

While the strong individualism of the Polish national character thus thwarted all endeavours at Protestant consolidation, the wars against Orthodox Moscow effectively united Poles round their old Catholic banners, and the vigorous Protestant propaganda conducted from Königsberg by Poland's vassal Albert, duke of East Prussia, appeared to the bulk of the nation under the guise of a German menace. These political factors told in favour of Catholicism; so did presently the wiser policy of Rome. Pope Pius IV, unlike his predecessor, adopted a conciliatory attitude toward the Polish crown in the matter of disputed appointments of bishops. The new bishops were holy and learned men, very unlike the creations of Queen Bona Sforza, and capable papal nuncios reorganized the scattered and faint-hearted Catholic forces in the land. From one of the ablest of them, Giovanni Commendone, the king, at the *sejm* of 1564, accepted the book of the decrees of the Council of Trent; immediately afterward he issued decrees banishing the more extreme heretics from the country. In 1565 the Jesuits, the vanguard of the Catholic Counter Reformation, appeared in Poland.

At their best, the various forms of Protestantism had never won more than a scanty noble and intellectual elite of the nation; they had never taken root among the peasantry or the petty *bourgeoisie*. While the gradual effacement of Reformed creeds removed a powerfully creative intellectual and literary factor from Poland's life, the re-establishment of Catholicism restored to the country that spiritual unity which was to be the chief source of national strength in the coming struggle against the aggression both of Orthodox Russia and of Lutheran Germany.

The Incorporation of Livonia.—Access to the Baltic had been a vital question since the dawn of the Polish state in the 10th and 11th centuries. Poland's expansion eastward, which began definitely in the 14th century through the acquisition of Halicz by Casimir the Great and was continued in the 15th through the dynastic union with Lithuania, made an extension of its foothold on the Baltic shore imperative. At the same time, the knights of the Teutonic Order (*q.v.*) had threatened to cut Poland off from access to the sea altogether. They had been beaten down by the earlier Jagiellons, and access to the sea was secured by way of Danzig. But in the 16th century the foe began to regain strength in the secular and Protestant duchy of East Prussia, formally owning allegiance to Poland. Sigismund II was naturally attracted by an opportunity to outflank this foe and to gain a separate outlet to the sea.

In the middle of the 16th century the Order of the Knights of the Sword (the Livonian Order), whose territory embraced Estonia, Livonia, Courland, Semigalliia and the islands of Dagö and Oesel, was tottering. All the Baltic powers were more or less interested in the apportionment of this vast tract of land, whose geographical position made it not only the chief commercial link between east and west but also the emporium whence the English, Dutch, Swedes, Danes and Germans obtained their grain, timber and most of the raw products of Lithuania and Moscow. Poland and Moscow as the nearest neighbours of this moribund state, which had so long excluded them from the sea, were vitally concerned in its fate. After an anarchic period of suspense, lasting from 1546 to 1561, during which Sweden secured Estonia while

Ivan the Terrible fearfully ravaged Livonia, Sigismund II, to whom both the master of Livonia and the archbishop of Riga had appealed more than once for protection, at length intervened decisively. At his camp before Riga in 1561 the last master, who had long been at the head of the Polish party in Livonia and had embraced Protestantism, and the archbishop of Riga gladly placed themselves beneath Sigismund's protection, and by a subsequent convention signed at Wilno (Nov. 28, 1561) Livonia was incorporated with Lithuania in much the same way as Prussia had been incorporated with Poland 36 years previously; that is to say, as a new Protestant duchy and as a fief of the Polish crown, with local autonomy and freedom of worship.

Union with Lithuania, 1569.—The danger to Lithuania, revealed in the Baltic wars with Ivan the Terrible, as well as the apathy shown in these matters by the Polish *sejm,* must have convinced so statesmanlike a prince as Sigismund II of the necessity of preventing any possibility of cleavage in the future between the two halves of his dominions. A personal union under one monarch had proved inadequate. A further step must be taken—the two independent countries must be transformed into a single state. The principal obstacle was the opposition of the Lithuanian magnates, who feared to lose their dominance in the grand duchy if they were merged in the *szlachta* (gentry) of the kingdom. When things came to a deadlock in 1564, the king tactfully intervened and voluntarily relinquished his hereditary title to Lithuania, thus placing the two countries on a constitutional equality and preparing the way for fresh negotiations. The death in 1565 of Nicholas Radziwill the Black, the chief opponent of the union, still further weakened the Lithuanians, but the negotiations, reopened at the *sejm* of Lublin in 1569, at first also led only to rupture. Then Sigismund executed his master stroke. Knowing the sensitiveness of the Lithuanians regarding Volhynia and Podolia, he suddenly, of his own authority, formally incorporated both these provinces with the kingdom of Poland, whereupon, amid great enthusiasm, the Volhynian and Podolian deputies took their places on the same benches as their Polish brethren. The hands of the Lithuanians were forced. Even a complete union on equal terms was better than mutilated independence. Accordingly they returned to the *sejm* and the union was unanimously adopted on July 1, 1569. Henceforth the kingdom of Poland and the grand duchy of Lithuania were to be one inseparable and indivisible body politic; all dependencies and colonies, including Prussia and Livonia, were to belong to Poland and Lithuania in common. The retention of the old duality of dignities was the one reminiscence of the original separation; it was not abolished till 1791, four years before the final partition of Poland.

The union definitely shifted Poland's political centre of gravity eastward; it created a common interest in the Russian menace to the long and naturally defenseless eastern frontier and in the millions of Greek Orthodox people living in the eastern borderlands. Warsaw was appointed one of the meeting places of the joint *sejm,* thus preparing the transfer of the capital from Cracow to Warsaw. The union was the last great historical act of the Jagiellon dynasty; it put the coping stone to the structure of a monarchy which, with growing consolidation, seemed to bear in it the promise of empire.

Political Development.—Simultaneously with the transformation into a great power of the petty principalities which composed ancient Poland, another and equally momentous political transformation was proceeding within the country itself.

The origin of the Polish constitution is to be sought in the *wiece* or councils of the Polish princes during the period of division. The privileges conferred upon the magnates of whom these councils were composed, especially upon the magnates of Little Poland (who brought the Jagiellons to the throne, directed their policy and grew rich upon their liberality), angered the less favoured *szlachta,* who, toward the end of the 14th century, combined for mutual defense in their *sejmiki* or local diets.

The first *sejm* to legislate for all Poland was that of Piotrkow (1493), summoned by John Albert to grant him subsidies; but the mandates of its deputies were limited to 12 months, and its decrees were to have force for only three years. John Albert's second *sejm* (1496), after granting subsidies the burden of which fell entirely on the towns and peasantry, passed a series of statutes benefiting the nobility at the expense of the other classes. These were followed by others of the same kind under his successor, Alexander, which, by facilitating import and crippling export trade in the interests of the gentry, enfeebled and degraded the middle class and thereby seriously disturbed the social equilibrium of the state. Nevertheless, so long as the Jagiellon dynasty lasted, the political rights of the cities were jealously protected by the crown against the usurpations of the nobility. The burgesses of Cracow, the most enlightened economists in the kingdom, supplied Sigismund I with his most capable counsellors during the first 20 years of his reign (1506–26). Sigismund's predecessor, Alexander, had been compelled to accept the statute *Nihil novi* (1505), which gave the *sejm* and the senate an equal voice with the crown in all executive matters. Under Sigismund I some of the royal prerogatives were recovered, but in his later years the influence of the gentry returned and the *sejm* succeeded in controlling all the great offices of state. The Polish parliamentary system, vesting supreme powers in the two houses of the *sejm,* was an established fact. Sigismund II knew that only a strengthening of the central authority could save the state. But his endeavours to manoeuvre his way between the two rival powers of the magnates and the lesser gentry were, on the whole, unsuccessful. A patriotic party of gentry democrats arose, veiling its program of democratic reforms under the conservative watchword of the "execution of the laws" and dealing further legislative blows at the trade of the towns and the social status of the middle class. The king, who at first sided with the great nobles against the "executionists," afterward allied himself with the latter to curtail the power of the magnates by a repeal of former royal grants of land and by the imposition of a tax on all tenants of crown lands for the maintenance of the army (1562–63). Beneficial as this was, it was obtained only at the price of further dependence of the crown on the *szlachta.*

THE ELECTIVE KINGS

The childless Sigismund II Augustus died suddenly in 1572. Fortunately for Poland, the political horizon was unclouded. Domestic affairs, however, were in an almost anarchical condition. The union of Lublin, barely three years old, was anything but consolidated, and in Lithuania it continued to be extremely unpopular. Worst of all, there was no recognized authority in the land to curb its jarring centrifugal political elements. Civil war was happily averted at the last moment, and a national convention assembled at Warsaw in April 1573 for the purpose of electing a new king. Five candidates for the throne were already in the field. Lithuania favoured Ivan IV. In Poland the bishops and most of the Catholic magnates were for an Austrian archduke, while the strongly anti-German *szlachta* were inclined to accept almost any candidate but a German. It was easy, therefore, for the adroit and energetic French ambassador to procure the election of the French candidate, Henry of Valois, duke of Anjou. Well provided with funds, he speedily bought over many of the leading magnates. Having been one of the instigators of the St. Bartholomew massacre, he was looked at askance by the Protestants; the religious difficulty in Poland, however, had meanwhile been adjusted to the satisfaction of all parties by the compact of Warsaw (Jan. 28, 1573), which granted absolute religious liberty to all non-Catholic denominations without exception—a far more liberal measure than the Germans had made in the religious peace of Augsburg 18 years before. Finally, early in April 1573 the election *sejm* assembled at Warsaw, and Henry was elected king of Poland.

Henry of Valois, 1573–74.—The election had been preceded by a *correctura iurum,* or reform of the constitution, which resulted in the famous "Henrician articles" which converted Poland from a limited monarchy into a republic with an elective chief magistrate. The king was to have no voice in the choice of his successor. He was to marry a wife selected for him by the senate. He was to be neutral in all religious matters. He was not to lead the militia across the border without the consent of the *szlachta,*

and then only for three months at a time. Should the king fail to observe any one of these articles, the nation was *ipso facto* absolved from its allegiance. Whatever its intrinsic demerits, the disastrous fruits of this reform were largely caused by the precarious geographical position of Poland, and it must be remembered to Poland's credit that it alone with England preserved the tradition of parliamentary government in the increasingly absolutist Europe of the time.

The reign of Henry of Valois lasted 13 months. The tidings of the death of his brother Charles IX determined him to exchange a thorny for what he hoped would be a flowery throne, and at midnight on June 14, 1574, he literally fled from Poland to become Henry III of France. In Nov. 1575 the senate elected the emperor Maximilian II to the throne; but the gentry democracy, at the suggestion of its new leader Jan Zamoyski (*q.v.*), chose a prince of Transylvania, Stephen Bathory, assigning him for husband to the last surviving princess of the Jagiellon dynasty, and enforced this election by arms.

Stephen Bathory, 1575–86.—The king elected by the "patriotic" party proved one of Poland's greatest kings. The glorious 11 years of his reign, too brief to be permanently effective, yet represent the high-water mark of Poland's international power, and the achievements of his genius both in foreign and domestic policy remain unsurpassed in Polish annals. (*See* STEPHEN [ISTVÁN] BÁTHORY.)

With the insight of a born statesman he focused his energy on two vital objectives: the maintenance of Poland's access to the sea by way of Danzig, and the defense of its newly gained further seaboard in the northeast against the rising power of Moscow. Danzig, on Bathory's election, began to intrigue against him with the emperor Maximilian (until his death in Oct. 1576) and with Russia and Denmark. In spite of a deplorable lack of understanding on the part of the Polish gentry for the issue at stake, Bathory, who had throughout the able and strenuous support of his chancellor Zamoyski, conducted a campaign against Danzig both by land and sea and finally enforced its complete submission to his rule.

Before peace was made with Danzig, Ivan the Terrible had raided Livonia once more. Bathory, for the first time in the history of Polish warfare using infantry rather than cavalry and calling peasants and burghers to arms together with the gentry, achieved in the operations against Russia the greatest military triumphs of his reign. In three successive expeditions he pushed his way northeastward as far as Pskov, and the tsar was fain to obtain the pope's intervention by a promise of making Russia Catholic. As a result of Bathory's victories, Poland pushed Russia entirely away from the Baltic for a long time and regained sway over nearly the whole of Livonia.

Brilliant as these foreign successes were, the greatness of Bathory's statesmanship was even more manifest at home. He conciliated, by concessions and privileges, two of the most important minority groups, the Ukrainian Cossacks and the Jews. The Cossacks were largely runaway serfs, who had organized themselves into a sort of military republic on the vast and scantily inhabited plains of the Ukraine or "borderland," stretching from the southeast of the monarchy toward the Black sea along the river Dnieper. The Cossack community had been drawn into the Polish military system under Bathory's predecessors by registration and pay and had already been granted exemption from taxation, as well as their own jurisdiction. Bathory, who needed them for his Russian wars, confirmed and enlarged these privileges. His successors used the Cossacks against the Russians, Turks and Tatars; but soon the Cossacks themselves were to grow into a factor of trouble for Poland, not without serious errors of policy on the Polish side.

The privileges which the Jews had obtained from former kings were augmented; from Bathory's day until 1764 the Polish Jews had a parliament of their own, meeting twice a year, with powers of taxation. It was also chiefly in the interest of the Jews that Bathory restricted, by special edict, the trading rights of Scottish pedlars, of whom as many as 30,000 were abroad in Poland in his time. Among other domestic measures, Bathory reformed the Polish judicial system by the creation of a supreme court of appeal for civil cases, and he founded, in 1579, the University of Wilno as a bulwark of western European culture in the east.

The growing imperial ambitions of the house of Habsburg had developed into a menace to Poland's international position; they now threatened to outflank and encircle Poland on the southern side. Bathory proposed to counteract them by the project of a union with Russia and a joint crusade against Turkey under the auspices of the pope. This grandiose plan would have given Poland again a firm footing on the shore of its "second sea"—the Black sea—which it had reached once before in the time of the Jagiellons. But the idea was carried with Bathory to his grave on his sudden death in 1586.

Sigismund III, 1587–1632.—The Vasa period of Polish history, which began with the election of Sigismund, son of John III of Sweden and of Sigismund I's daughter Catherine, was one of last and lost chances. The collapse of the Muscovite tsardom and the submersion of Germany by the Thirty Years' War presented Poland with an unprecedented opportunity of consolidating, once for all, its hard-won position as the dominating power between central and eastern Europe; it might even have wrested the best part of the Baltic littoral from the Scandinavian powers and pushed Russia back beyond the Volga. That this was not achieved was partly caused by the class spirit and blind selfishness of the Polish gentry. Apathetic toward vital problems of foreign policy and unwilling to make material sacrifices to the cause of national defense, they persisted in a doctrinaire defense of "republican liberty" at the very time when the need of a strong central executive was more urgent than ever.

But other grave causes of failure were not wanting. One of them consists in the very personality of the new foreign-bred king: the tenacity with which he clung to his hereditary rights to the Swedish crown involved Poland in unnecessary wars with Sweden at most inopportune times; and his bigoted devotion to the cause of Catholicism introduced a new spirit of religious fanaticism and persecution into the atmosphere of a country hitherto distinguished for toleration, while the same bigotry served Poland's interests very ill abroad. Poland's greatest statesman of the time, Jan Zamoyski, discovered in the earliest years of the reign that the king, who had married Anne, daughter of the Habsburg Charles of Styria, was willing to surrender the crown of Poland to an Austrian archduke and to return to his native Sweden in order to bring it back to the Catholic fold. Zamoyski, who had himself placed Sigismund on the throne by conquering a rival Austrian candidate, was naturally indignant, and the whole disgraceful affair of the king's secret negotiations with Austria culminated in his having to answer the charges of a special "court of inquisition" (1592)—the first time that the prestige of the crown in Poland was exposed to such an ordeal.

The Uniate Church.—It was only where the expansion of Catholicism served the interests of the Polish state that Zamoyski saw eye to eye with the king's Catholic zeal. Thus, he became instrumental in creating, at the synod of Brzesc in 1596, the Uniate Church as a halfway house for those of the republic's Greek Orthodox citizens who were willing to recognize the supremacy of Rome but desired to preserve their accustomed Eastern ritual and Slavonic liturgy. The Uniate Church served the purpose of drawing a large section of the population of the eastern border provinces out of the orbit of Moscow and into that of Polish influences; but by the antagonisms which soon began between Uniates and non-Uniates, it became in itself a source of new troubles for Poland. Besides this, the pride of Poland's Roman Catholic prelates, who looked down on the Uniate hierarchy, forced the Uniate Church into the position of a "peasant religion" and contributed to making it the social nucleus of anti-Polish Ukrainian nationalism which it henceforth remained. Even in Sigismund's time, Austria, competing with Poland for influence in the eastern Balkans, began to seduce the Ukrainian element (represented in organized form by the military community of the Cossacks) against Poland—a policy which the same Austria was to resume later in changed form and under different conditions when mistress of eastern Galicia.

Swedish, Muscovite and Turkish Wars.—The dispute over Sigismund's rights to the Swedish crown began, from the earliest years

of the reign, to drag its weary course of alternate victories and defeats. At first the areas that later became Estonia and Latvia were both the scene and the principal object of the strife; in the later stages, Gustavus Adolphus transferred the ground nearer to the heart of Poland by espousing the cause of the Calvinist elector of Brandenburg, who had come into possession of East Prussia and thus laid the foundation of a large Protestant power on the Baltic. The danger to Danzig and Poland's grain exports roused even the gentry from their apathy; but in spite of some brilliant victories by sea and land, an armistice toward the end of the reign was highly unfavourable to Poland.

Sigismund's persistent Swedish ambitions, his equally persistent Austrian sympathies, but, more than all, his absolutist leanings and cherished plans for a drastic and arbitrary constitutional reform on foreign models and on antiparliamentary lines occasioned in 1606 an armed revolt of the Polish gentry against their king—the *rokosz* (or insurrection) of Mikolaj Zebrzydowski, who was supported by the discontented Protestants. The *rokosz* was at last suppressed in 1607, but it left as its legacy such ruinous precedents as an enforced recognition of the doctrine of the subjects' right to depose their king (*de non praestanda obedientia*) and, being undertaken in justified defense of the native parliamentary tradition against wholesale foreign innovations, had the harmful effect of blocking the way toward any and every reform of the parliamentary system.

Soon after the constitutional cataclysm of the *rokosz*, Poland became embroiled in prolonged wars with Moscow. The motive was partly a vague conception of a Polish-Russian union as opposed to the king's Austrian propensities, but partly also the very real desire of some border magnates for more and more land east of the Dnieper. An occasion was furnished by the extinction of the dynasty of Rurik in Russia and the subsequent struggle for the throne, particularly the emergence of one candidate—the ill-fated Pseudo-Demetrius (*see* DEMETRIUS, PSEUDO-)—whom certain Polish nobles and finally also the king supported. The appearance of a second Pseudo-Demetrius after the fall of the first prolonged the strife. Throughout the campaigns against Moscow the king found himself at variance with some leading Polish statesmen and soldiers of the time, such as Zamoyski and, later, Stanislaw Zolkiewski; he thought of the problem only in terms of conquest, of the establishment of Catholicism in Russia and of strong monarchical rule over the united kingdoms, while Zolkiewski, even at the height of military successes against Russia, had a union like that of Poland with Lithuania in his mind and advocated tolerance of Russia's creed and social order. The Poles once actually held the Kremlin of Moscow for a time (1610) and once again laid siege to it (1617); Sigismund's son Wladyslaw was elected tsar, and his opponent did homage to Sigismund as a prisoner. But a national insurrection in Russia and the establishment of the Romanoff dynasty checked the Polish advance, and only certain territorial gains (including Smolensk), as well as a good deal of influence of Polish customs and institutions on the Russian nobility, were definite results of the struggle in Sigismund's time. It was to be continued under his successors.

The wars with Moscow temporarily ended in an armistice at the very moment (1618) when the Thirty Years' War broke out in central Europe. In this Poland remained officially neutral, but Sigismund's favourable attitude toward the Habsburgs entangled Poland in renewed and long wars with Turkey, which the later Jagiellons and their first successors had managed to avoid. A definite success was attained against the Turks at Hotin (1621), a year after Zolkiewski's heroic death at Cecora. But the Swedish trouble began anew in the same year, and Sigismund's long and unlucky reign ended 11 years later amid turmoil abroad and at home, setbacks to Polish power on all sides without and seriously increased constitutional disorder within.

Wladyslaw IV, 1632–48.—Sigismund's son, born in Poland and brought up as a Pole, enjoyed a popularity which had never been his father's lot. As crown prince, he had been successful in military operations against Moscow and Turkey; on his ascension to the throne he ingratiated himself with the gentry by some new concessions, including even exemption from income tax. The "wisest of the Polish Vasas," as he has been called, intended to create a basis of public favour and confidence for the constitutional reforms which he planned.

But the international difficulties inherited from his father diverted his energies largely into channels of foreign policy. The very first years of his reign are marked by new victories over Russia and the Turk and also by a new and much more advantageous truce with Sweden. He was less fortunate in a new conflict with Danzig, and with its supporter Denmark, over the tolls he intended to impose on the trade of the Baltic ports; no interest in these matters was to be awakened in the gentry, and the most powerful magnates—those of the eastern border—thought more of expansion into the fertile Ukrainian regions than of sea power. Accordingly, the Polish navy, which had begun to develop in a promising manner under Sigismund III, was allowed to fall into permanent decay, and Wladyslaw's plans for foreign action on a large scale were unrealized. He wavered in his diplomacy between Austrian and French influences, represented by his two successive queens; his tolerant and friendly attitude toward the Orthodox east caused serious trouble with the Vatican; and his project of a great crusade against the Turks, although encouraged by the Venetian republic and acclaimed by the south Slav nations, in the end came to nothing.

The Cossack Revolt.—The chief obstacle which prevented Wladyslaw's Turkish plans from maturing was the impossibility of winning the help of the decisive factor, the Ukrainian Cossacks, who had become too numerous and powerful to be willing instruments of Polish policy. Catholic intolerance toward this Orthodox population, in the time of Sigismund III, had combined with the proud and highhanded behaviour of Polish landowners to produce in the Cossacks a spirit of religious, racial and social enmity against the Polish element; the Polish parliament had not kept the financial terms of its compacts with the Cossacks; repressions inspired by the border magnates had infuriated them. Already in the earlier years of Wladyslaw's reign terrible Cossack revolts had flared up and been unwisely punished by the abolition of ancient privileges. Now, instead of letting themselves be made the tools of Wladyslaw's anti-Turkish plans, the Cossacks made common cause with the Tatars of the Crimea, who were the most immediate objective of the king's crusading plans; and the reign ended amid a wave of Cossack insurrection, engineered by the sultan, assisted by Tatar hordes and led by Bogdan Chmielnicki (*q.v.*), a country gentleman personally wronged by a Polish official, now the rising hero of Ukrainianism. It was only the resistance of the Polish burghers of Lwow that stemmed the Cossack and Tatar tide from flooding the inner provinces of Poland; the same patriotic town was to arrest two other invasions—a Russian and a Transylvanian one—in the next few years. But the defense of Lwow meant only a respite, and on Wladyslaw's death his brother and successor, the last of the Polish Vasas, found himself faced by a powerful renewal of Chmielnicki's attack on central Poland.

John Casimir, 1648–68.—John Casimir, summoned to the throne from France, where he had lived as a priest and become a cardinal, was obliged to begin his reign by negotiating with his rebel subject Chmielnicki. But Chmielnicki's conditions of peace were so extravagant that the negotiations came to nothing. It was only after a second invasion of Poland, in 1649, by a host of Cossacks and Tatars, that the compact of Zborow was concluded, by which Chmielnicki was officially recognized as chief (hetman) of the Cossack community. A general amnesty was also granted, and it was agreed that all official dignities in the Orthodox palatinates of Lithuania should henceforth be held solely by the Orthodox gentry. For the next 18 months Chmielnicki ruled the Ukraine like a sovereign prince. He made Czehryn, his native place, the Cossack capital, subdivided the country into 16 provinces and entered into direct relations with foreign powers. The Orthodox patriarchs of Alexandria and Constantinople were his friends and protectors. His attempt to carve a principality for his son out of Moldavia led to the outbreak of a third war between suzerain and subject in Feb. 1651. But fortune, so long Bogdan's friend, now deserted him, and at Beresteczko (1651) the

Cossack chieftain was utterly routed by John Casimir. All hope of an independent Cossackdom was now at an end, yet it was not Poland but Moscow which reaped the fruits of this great victory.

Chmielnicki, by suddenly laying bare the nakedness of the Polish republic, had opened the eyes of Moscow to the fact that its ancient enemy was no longer formidable. Three years after his defeat at Beresteczko, Chmielnicki, abandoned by his Tatar allies and finding himself unable to cope with the Poles single-

BY JOHN BARTHOLOMEW & SONS

FIG. 1.—SEVENTEENTH-CENTURY MAP PRESENTED TO CHARLES II

handed, very reluctantly transferred his allegiance to the tsar Alexius Mikhailovich, whose armies in the same year invaded Poland. The war thus begun is known in Russian history as the Thirteen Years' War and far exceeded even the Thirty Years' War in grossness and brutality.

In the summer of 1655, while Poland was still reeling beneath the shock of the Muscovite invasion, Charles X of Sweden, on the flimsiest of pretexts, forced a war to gratify his greed of martial glory, and before the year was out his forces had occupied the capital, the coronation city and the best half of the land. King John Casimir, betrayed and abandoned by his own subjects, fled to Silesia. Profiting by the cataclysm which, for the moment, had swept the Polish state out of existence, the Muscovites quickly appropriated nearly everything which was not already occupied by the Swedes. At this crisis Poland owed its salvation to two events—the formation of a general league against Sweden, brought about by the apprehensive court of Vienna, and a popular outburst of religious enthusiasm on the part of the Polish people. The first of these events, to be dated from the alliance between the emperor Leopold I and John Casimir (1657), led to a truce with the tsar and the welcome diversion of all the Muscovite forces against Swedish Livonia. The second event, which began with the heroic and successful defense of the monastery of Czestochowa by Prior Augustyn Kordecki against the Swedes, resulted in the return of the king from exile, the formation of a national army and the recovery of almost all the lost provinces from the Swedes, who were driven back headlong to the sea, where with difficulty they held their own. On the sudden death of Charles X, Poland seized the opportunity of adjusting all its outstanding differences with Sweden. By the peace of Oliwa (Oliva) (1660), made under French mediation, John Casimir ceded Livonia and renounced all claim to the Swedish crown. The war with Moscow was then prosecuted with renewed energy and extraordinary success. In 1664 a peace congress was opened, and the prospects of Poland seemed most brilliant; but at the very moment when it needed all its armed strength to sustain its diplomacy, the rebellion of Prince Jerzy Lubomirski involved the country in a dangerous civil war, compelled it to reopen negotiations with the Muscovites and practically to accept the Muscovite terms. By the truce of Andruszowo (1667) Poland received back from Moscow Vitebsk, Polotsk and Polish Livonia, but ceded in perpetuity Smolensk, Severia, Chernigov and the whole of the eastern bank of the Dnieper. The Cossacks of the Dnieper were henceforth to be divided between the dominion of the tsar and the king of Poland. Kiev, the religious metropolis of southwestern Russia, was to remain in the hands of Moscow for two years.

The "truce" of Andruszowo proved to be one of the most permanent peaces in history, and Kiev, though pledged for only two years, was never again to be recovered. Henceforth the political influence of Russia over Poland was steadily to increase, without any struggle at all, although influences of Polish culture and manners, exercised chiefly through the academy of Kiev, still continued to permeate Russia until the advent of Peter the Great.

The "Liberum Veto" in the 17th Century.—Poland had, in fact, emerged from the cataclysm of 1648–67 a moribund state, though its not unskilful diplomacy had enabled it for a time to save appearances. Its territorial losses, though considerable, were, in the circumstances, not excessive, and it was still a power in the opinion of Europe. But a fatal change had come over the country during the age of the Vasas. The period synchronized with and was partly determined by the new European system of dynastic diplomatic competition and the unscrupulous employment of unlimited secret service funds. This system, which dates from Richelieu and culminated in the reign of Louis XIV, was based on the rivalry of the houses of Bourbon and Habsburg, and very soon nearly all the monarchs of the continent and their ministers were in the pay of one or other of the antagonists. Poland was no exception to the general rule. To do them justice, the *szlachta* at first not only were free from the taint of official corruption but endeavoured to fight against it. But they themselves unconsciously played into the hands of the enemies of their country by making the so-called *liberum veto* an integral part of the Polish constitution. The *liberum veto* was based on the assumption of the absolute political equality of every Polish gentleman, with the corollary that every measure introduced into the Polish *sejm* must be adopted unanimously. Consequently, if any single deputy believed that a measure already approved of by the rest of the house might be injurious to his constituency, he had the right to exclaim *"Nie pozwalam,"* "I disapprove," the measure in question falling at once to the ground. Subsequently this vicious principle was extended still further. A deputy, by interposing his individual veto, could at any time dissolve the *sejm,* and all measures previously passed had to be resubmitted to the consideration of the following *sejm.* Before the end of the 17th century the *liberum veto* was used so recklessly that all business was frequently brought to a standstill. Later it became the chief instrument of foreign ambassadors for dissolving inconvenient sessions, as a deputy could always be bribed to exercise his veto.

Michael Wisniowiecki, 1669–74.—With the election of Michael Wisniowiecki in 1669 a new era began. A native Pole, he was freely elected by the unanimous vote of his countrymen; but he was chiefly chosen for the merit of his father, a great border magnate who had victoriously kept down the Cossacks, and he proved to be a passive tool in the hands of the Habsburgs. In view of this the French party rallied round John Sobieski, a military commander of rising fame. The dissensions between the two camps cost Poland a new defeat at the hands of the united Turks and Cossacks. Sealed by a shameful treaty of Buczacz (1672), this defeat was only wiped out by a brilliant victory of Sobieski's at Hotin, which also, after King Michael's early death, carried him to the throne against an Austrian candidate.

John III Sobieski, 1674–96.—Connected with France by marriage and by political sympathies, Sobieski, although he had half a lifetime of constant wars against the Turks behind him, stood at first, in accordance with French policy, for peaceful relations with Turkey and directed his eyes toward the Baltic, attempting

with French help to check the rising Hohenzollern power in that quarter. But his secret dealings with France turned his own subjects against him, while continuous Turkish invasions forced him into war, until an attack of unprecedented magnitude, aimed at the very heart of Europe, called forth that unprecedented outburst of Polish heroism—the gallant rescue of Vienna in 1683. That great act was the last noble reflex of the great crusading impulse of the middle ages; it was a unique service, rendered in the old chivalrous spirit by one nation to another in an age of Machiavellian diplomacy and growing national selfishness. It won Poland offers of friendship from all the great powers. But its positive gains for Poland proved little; cessions of territory to Moscow did not buy any active support in further campaigns against Turkey, nor did the delivered Austria assist Poland in its endeavour to re-establish the Rumanian outpost against the Turk.

Augustus II, 1697–1733.—On the death of John III no fewer than 18 candidates for the vacant Polish throne presented themselves. The successful competitor was Frederick Augustus I, elector of Saxony, who cheerfully renounced Lutheranism for the coveted crown and won the day because he happened to arrive last of all, with fresh funds, when the agents of his rivals had spent all their money. He was crowned, as Augustus II, in 1697, and his first act was to expel from the country his French rival, François Louis de Bourbon, prince de Conti, whose defeat was also partly caused by the growing Russian influence, which, from the accession of Peter the Great (1700), became a permanent factor in Polish domestic politics.

Good luck attended the opening years of the new reign. In 1699 the long Turkish war, which had been going on since 1683, was concluded by the peace of Karlowitz, whereby Podolia, the Ukraine and the fortress of Kamieniec Podolski were retroceded to the republic by the Ottoman Porte. But the permanent weakening of Turkey brought little good, for the power of Russia soon became a greater menace to Poland than Turkey had ever been.

Shortly after the peace of Karlowitz, Augustus was persuaded by the plausible Livonian exile Johann Reinhold Patkul to form a nefarious league with Frederick of Denmark and Peter of Russia, for the purpose of despoiling the youthful king of Sweden, Charles XII (*see* SWEDEN: *History*). This he did as elector of Saxony, but it was the unfortunate Polish republic which paid for the hazardous speculation of its newly elected king. Throughout the Great Northern War, which wasted northern and central Europe for 20 years (1700–21), all the belligerents treated Poland as if it had no political existence. Swedes, Saxons and Russians not only lived upon the country, but plundered it systematically. The *sejm* was the humble servant of the conqueror of the moment, and the leading magnates chose their own sides without the slightest regard for the interests of their country, the Lithuanians for the most part supporting Charles XII, while the Poles divided their allegiance between Augustus and Stanislaw Leszczynski (*see* STANISLAUS I), whom Charles maintained upon the throne from 1704 to 1709. At the end of the war Poland was ruined materially as well as politically. Augustus offered Courland, Polish Prussia and even part of Great Poland to Frederick William I of Prussia provided that he were allowed a free hand in the disposal of the rest of his kingdom. When Prussia declined this tempting offer for fear of Russia, Augustus went a step further and actually suggested that "the four eagles" (viz., the black ones of Austria, Prussia and Russia and the white eagle of Poland proper) should divide the other Polish territories between them. He died, however, before he could give effect to this shameless design.

Augustus III, 1733–63.—On the death of Augustus II, Stanislaw Leszczynski, who had, in the meantime, become the father-in-law of Louis XV, attempted to regain his throne with the aid of a small French army corps. Some of the best men in Poland, including the Czartoryski family, were also in his favour, and he was elected king for the second time. But there were many malcontents, principally among the Lithuanians, who solicited the intervention of Russia in favour of the elector Frederick Augustus II of Saxony, son of the late king. A Russian army appeared before Warsaw and compelled a phantom *sejm* (it consisted of but 15 senators and 500 of the *szlachta*) to proclaim Augustus III. Stanislaw and his partisans were besieged by the Russians in Danzig, and with its surrender their cause was lost. He retired to become duke of Lorraine and Bar, keeping the title of king of Poland but leaving Augustus III in possession of the kingdom.

Augustus III left everything to his omnipotent minister, Heinrich, count von Brühl, and Brühl entrusted the government of Poland to the noble family of the Czartoryskis, who had close relations of long standing with the court of Dresden. "The Family," as their opponents sarcastically called them, were to dominate Polish politics for the next half-century, and they were honourably determined to save the republic by a radical constitutional reconstruction which was to include the abolition of the *liberum veto* and the formation of a standing army.

Unfortunately, the other great families of Poland were obstinately opposed to any reform or, as they called it, any "violation" of the existing constitution. The Potockis, in particular, whose possessions in southern Poland and the Ukraine covered thousands of square miles, hated the Czartoryskis and successfully obstructed all their efforts. During the reigns of the two Saxon kings, every *sejm* was dissolved by the hirelings of some great lord or, still worse, of some foreign potentate.

It was against this primitive state of things that the Czartoryskis struggled and struggled in vain. First they attempted to abolish the *liberum veto* with the assistance of the Saxon court, but fear of foreign complications and the opposition of the Potockis prevented anything from being done. Then they broke with their old friend Brühl and turned to Russia. Their chief intermediary was their nephew Stanislaw Poniatowski (*see* STANISLAUS II AUGUSTUS), whom they sent, as Saxon minister, to the Russian court in the suite of the English minister Sir Charles Hanbury Williams in 1755. The handsome and insinuating Poniatowski speedily won the susceptible heart of the grand duchess Catherine, but he won nothing else and returned to Poland in 1759 somewhat discredited. Nevertheless, the Czartoryskis looked to Russia again for support on the death of Augustus III. They rejected with scorn and derision the pacific overtures of their political opponents, Prince Fryderyk Michal Czartoryski openly declaring that he preferred the tyranny of the Muscovite to the tyranny of his equals. He had in fact already summoned a Russian army corps to assist him to reform his country, which sufficiently explains his own haughtiness and the unwonted compliance of the rival magnates.

Stanislaw II Poniatowski and the Partitions, 1764–95.—The simplicity of the Czartoryskis was even more mischievous than their haughtiness. Their naïve expectations were very speedily disappointed. Catherine II and Frederick II had already determined (treaty of St. Petersburg, 1764) that the existing state of things in Poland must be maintained, and as early as 1763 Catherine had recommended the election of Stanislaw Poniatowski as "the individual most convenient for our common interests." The personal question did not interest Frederick; so long as Poland was kept in an anarchical condition he cared not who was called king. Moreover, the opponents of the Czartoryskis made no serious attempt to oppose the entry of the Russian troops.

Shortly afterward Stanislaw Poniatowski was elected king and crowned. But at the beginning of 1766 Prince Nikolai Repnin was sent as Russian minister to Warsaw with instructions which can only be described as a carefully elaborated plan for destroying the republic. The first weapon employed was the question of the dissidents. At that time the population of Poland was, in round numbers, 11,500,000, of whom about 1,000,000 were dissidents or dissenters. Half of these were the Protestants of the towns of Polish Prussia and Great Poland, the other half was composed of the Orthodox population of Lithuania. The dissidents had no political rights, and their religious liberties had also been unjustly restricted; but two-thirds of them being agricultural labourers and most of the rest artisans or petty tradesmen, they had no desire to enter public life and were so ignorant and illiterate that their new protectors, on a closer acquaintance, became heartily ashamed of them. Yet it was for these persons that Repnin, in the name of the empress, now demanded absolute equality, political and religious, with the gentlemen of Poland. He was

well aware that an aristocratic and Catholic assembly like the *sejm* would never concede so preposterous a demand.

Early in 1767 the malcontents, fortified by the adhesion of the leading political refugees, formed at Radom a confederation whose first act was to send a deputation to St. Petersburg, petitioning Catherine to guarantee the liberties of the republic. With a carte blanche in his pocket, Repnin proceeded to treat the *sejm* as if it were already the slave of the Russian empress. But despite threats, wholesale corruption and the presence of Russian troops outside and even inside the chamber of deputies, the patriots, headed by four bishops, offered a determined resistance to Repnin's demands. Only when brute force in its extremest form had been ruthlessly employed, only when two of the bishops and some other deputies had been arrested in full session by Russian grenadiers and sent as prisoners to Kaluga, did the opposition collapse. The *liberum veto* and all the other ancient abuses were now declared unalterable parts of the Polish constitution, which was placed under the guarantee of Russia. All the edicts against the dissidents were, at the same time, repealed.

Confederation of Bar.—This shameful surrender led to a Catholic patriotic uprising, known as the Confederation of Bar, which was formed in 1768 at Bar in the Ukraine, by a handful of small squires. It never had a chance of permanent success, though, feebly fed by French subsidies and French volunteers, it lingered on for four years, until finally suppressed in 1772. But, insignificant itself, it was the cause of great events. Some of the Bar confederates, scattered by the Russian regulars, fled over the Turkish border, pursued by their victors. The Turks, already alarmed at the progress of the Russians in Poland and stimulated by Charles Gravier, comte de Vergennes, at that time French ambassador at Constantinople, at once declared war against Russia. Seriously disturbed at the prospect of Russian aggrandizement, the courts of Berlin and Vienna conceived the idea that the best mode of preserving the equilibrium of Europe was for all three powers to readjust their territories at the expense of Poland. Negotiations led to no definite result at first; then Austria took the first step by occupying, in 1769, the county of Spiz (Szepes, Zips), which had been hypothecated by Hungary to Poland in 1411 and never redeemed. This act decided the other powers; in June 1770 Frederick surrounded with a military cordon, ostensibly to keep out the cattle plague, those of the Polish provinces that he coveted. Catherine's consent had been previously obtained.

First Partition, 1772.—The first treaty of partition was signed at St. Petersburg between Prussia and Russia on Feb. 6–17, 1772; the second treaty, which admitted Austria also to a share of the spoil, was signed on Aug. 5–16 the same year. The consent of the *sejm* to this act of brigandage was extorted by bribery and force in 1773. Russia obtained the palatinates of Vitebsk, Polotsk, Mscislaw: 34,616 sq.mi. of territory, with a population of 550,000. Austria got Little Poland without Cracow and also Lwow, Tarnopol and Halicz and, by corrupting the name of the last, called the new province Galicia: 32,045 sq.mi., with a population of 816,000. Prussia received the palatinate of Pomorze minus Danzig, the palatinate of Chelmno minus Torun, the northern half of Great Poland and the palatinates of Marienburg and Warmia, calling the new acquisition West Prussia: 14,025 sq.mi., with a population of 378,000. The total area of Poland before 1772 was about 283,200 sq.mi., with an estimated population of 8,750,000.

The partitioning powers presented Poland with a new constitution. The elective monarchy and the *liberum veto* were of course retained. Poland was to be dependent on its despoilers, but they evidently meant to make it a serviceable dependent. The government was henceforth to be in the hands of a permanent council of 36 members, 18 senators and 18 deputies, elected biennially by the *sejm* in secret ballot, subdivided into the five departments of foreign affairs, police, war, justice and the exchequer, whose principal members and assistants, as well as all other public functionaries, were to have fixed salaries. The royal prerogative was still further reduced. The king was indeed the president of the permanent council, but he could not summon the *sejm* without its consent and in all cases of preferment was bound to select one out of three of the council's nominees. Still, the new organization made for order and economy and enabled Poland to develop and husband its resources and devote itself uninterruptedly to the now burning question of national education.

The shock of the first partition had a certain salutary effect on national mentality. Already in the darkest days of Saxon rule, important educational reforms had been carried out in the schools of the Piarist order by Stanislaw Konarski. Now, the dissolution of the Jesuit order in 1773, putting its rich possessions and the system of schools conducted by it into the hands of the state, gave Poland opportunity to secularize as well as modernize the whole educational fabric of the nation. This huge task was admirably performed by the Commission of National Education, the first ministry of education in Europe. It reorganized both the program of teaching and the structure of the schools—including the decayed universities of Cracow and Wilno—in a thoroughly modern and truly enlightened way. Less progress was made with the cause of constitutional reform: the chancellor Andrzej Zamoyski indeed drafted a new comprehensive code of laws, in which a beginning was made with the emancipation of the peasant serfs and of the town population, but this was rejected by the gentry in the *sejm* (1780).

In the meantime, important events in the international field seemed to give Poland another chance of reasserting its independence against its despoilers. The death of Frederick the Great in 1786 loosened the bonds of the alliance between Prussia and Russia. Russia, drawing nearer to Austria, undertook, jointly with Austria, a war against Turkey which proved unexpectedly hard; and Russia was at the same time attacked by Sweden. Prussia, having changed its policy and concluded an alliance against Russia with England and Holland, was now emboldened by Russia's difficulties to go further: it invited Poland also to forsake the Russian alliance and offered to place an army corps of 40,000 men at its disposal.

The Constitution of May 1791.—It was under these exceptional circumstances that the "four years' *sejm*" assembled (1788). Its leaders, Stanislaw Malachowski, Hugo Kollontaj and Ignacy Potocki, were men of character and capacity, and its measures were correspondingly vigorous. Within a few months of its assembling it had abolished the permanent council, enlarged the royal prerogative, raised the army to 65,000 men, established direct communications with the western powers, declared its own session permanent and finally settled down to the crucial task of reforming the constitution on modern lines. But the difficulties of the patriots were commensurate with their energies, and though the new constitution was drafted as early as Dec. 1789 it was not till May 1791 that it could safely be presented to the *sejm*. Meanwhile, Poland endeavoured to strengthen its position by an alliance with Prussia. Frederick William II stipulated at first that Poland should surrender Danzig and Torun; but the Poles proving obstinate and Austria simultaneously displaying a disquieting interest in the welfare of the republic, Prussia in 1791 concluded an alliance with Poland which engaged the two powers to guarantee each other's possessions and render mutual assistance in case either were attacked.

But external aid was useless so long as Poland was hampered by its anarchical constitution. The most indispensable reforms had been frantically opposed; the debate on the reorganization of the army alone had lasted six months. It was only by an audacious surprise that Kollontaj and his associates contrived to carry through the new constitution. Taking advantage of the Easter recess, when most of the malcontents were out of town, they suddenly, on May 3, brought the whole question before the *sejm* and demanded urgency for it. Before the opposition could remonstrate, the marshal of the *sejm* produced the latest foreign dispatches, which unanimously predicted another partition, whereupon, at the solemn adjuration of Ignacy Potocki, King Stanislaw exhorted the deputies to accept the new constitution as the last means of saving their country and himself set the example by swearing to defend it.

The constitution of May 3, 1791, converted Poland into a hereditary limited monarchy, with ministerial responsibility and biennial parliaments. The *liberum veto* and all the intricate and

obstructive machinery of the anomalous old system were forever abolished. All invidious class distinctions were done away with. The towns, in a special bill confirmed by the new constitution, got full administrative and judicial autonomy, as well as a certain measure of parliamentary representation; the personal privileges of the gentry, such as possession of land and access to office in the state and in the church, were thrown open to the townsmen. The peasants were placed under the protection of the law, and their serfdom was mitigated with a view to its entire abolition. Absolute religious toleration was established. Provision was made for further periodical reforms by subsequent parliaments.

The constitution of May 3 had scarcely been signed when Stanislaw Feliks Potocki, Seweryn Rzewuski and Ksawery Branicki, three of the chief dignitaries of Poland, hastened to St. Petersburg and there entered into a secret convention with the empress, whereby she undertook to restore the old constitution by force of arms but at the same time promised to respect the territorial integrity of the republic. Entering Polish territory with Russian troops, the conspirators formed a confederation at the little town of Targowica in the Ukraine, protesting against the new constitution as tyrannous and revolutionary; at the same time the new Russian minister at Warsaw presented a formal declaration of war to the king and the *sejm*. The *sejm* met the crisis with dignity and firmness. The army was at once dispatched to the frontier; the male population was called to arms, and Ignacy Potocki was sent to Berlin to claim the assistance stipulated by the treaty of March 19, 1791. The king of Prussia, in direct violation of all his oaths and promises, declined to defend a constitution which had never had his "concurrence." Thus Poland was left entirely to its own resources. The little Polish army of 46,000 men, under Prince Joseph Anthony Poniatowski, nephew of King Stanislaw II, and Tadeusz Kosciuszko, did all that was possible under the circumstances. For more than three months they kept back the invader, and, after winning three pitched battles, retired in perfect order on the capital (*see* KOSCIUSZKO, TADEUSZ ANDRZEJ BONAWENTURA; PONIATOWSKI, JOSEPH ANTHONY). But the king, and even Kollontaj, despairing of success, now acceded to the confederation; hostilities were suspended; the indignant officers threw up their commissions; the rank and file were distributed all over the country; the reformers fled abroad; and the constitution of May 3 was abolished by the Targowicians as a "dangerous novelty." The Russians then poured into eastern Poland; the Prussians, at the beginning of 1793, alarmed lest Catherine should appropriate the whole republic, occupied Great Poland; and a diminutive, debased and helpless *sejm* met at Grodno in order, in the midst of a Russian army corps, "to come to an amicable understanding" with the partitioning powers.

Second Partition, 1793.—After every conceivable means of intimidation had been unscrupulously applied, the second treaty of partition was signed at three o'clock on the morning of Sept. 23, 1793. By this *pactum subjectionis*, as the Polish patriots called it, Russia got all the eastern provinces of Poland, extending from Livonia to Moldavia, comprising a territory of 96,751 sq.mi., while Prussia got Dobrzyn, Kujavia, Great Poland, Torun and Danzig. Poland was now reduced to less than one-third of its original dimensions, with a population of about 3,500,000.

Kosciuszko and the Third Partition.—The focus of Polish nationality was now transferred from Warsaw, where the Targowicians and their Russian patrons reigned supreme, to Leipzig, whither the Polish patriots, Kosciuszko, Kollontaj and Ignacy Potocki among the number, assembled from all quarters. From the first they meditated a national rising, but their ignorance, enthusiasm and simplicity led them to commit blunder after blunder. The first of such blunders was Kosciuszko's mission to Paris in Jan. 1793. He was full of the idea of a league of republics against the league of sovereigns; but he was unaware that the Jacobins themselves were already considering the best mode of detaching Prussia, Poland's worst enemy, from the anti-French coalition. Kosciuszko received an evasive reply and returned to Leipzig empty-handed. In the meantime, certain officers in Poland had revolted against the reduction of the Polish army to 15,000, imposed upon the country by the partition treaty. Kosciuszko himself condemned their hastiness; but the march of events forced his hand, and in March 1794 he went to Cracow, proclaimed a national insurrection and assumed the powers of a dictator. He called the peasants to arms, and they responded nobly, in return for which he supplemented the provisions of the constitution of 1791 by a manifesto giving them complete freedom. At first, Kosciuszko's arms were almost universally successful. The Russians were defeated in more than one pitched battle; three-quarters of the

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FIG. 2.—PARTITIONS IN THE 18TH CENTURY

ancient territory was recovered, and Warsaw and Wilno, the capitals of Poland and Lithuania, respectively, were liberated. The first serious reverse at Szczekociny, was more than made up for by the successful defense of Warsaw against the Russians (July 9–Sept. 6). But even during that heroic defense mob lawlessness in Warsaw and violent dissensions in the supreme council and in the army began to frustrate the superhuman efforts of the unfortunate but still undaunted dictator. The appearance of overwhelming masses of Russian troops, together with the open hostility of Austria as well as Prussia, did the rest, and Kosciuszko's insurrection received its deathblow on the battlefield of Maciejowice, where he himself was wounded and taken prisoner. Warsaw was taken amid a terrible massacre of the population in the suburb of Praga, and the remainder of the troops capitulated a few weeks later.

The greed of the victorious powers nearly led to a rupture between Austria and Prussia, but, after some dissensions, the third partition of Poland was effected by successive treaties in 1795 and 1796. Austria had to be content with Lublin, Siedlce, Radom and Kielce, while Prussia took Suwalki, Bialystok, Lomza and Warsaw. Russia annexed all the rest and was afterward to tear even parts of their booty from the two others. Thus the name of Poland was wiped from the map of Europe, to reappear only after more than a century. (R. N. B.; R. Dy.; X.)

THE DUCHY AND FOREIGN RULE

After the third partition, the more high-spirited Poles, chiefly officers and soldiers of Kosciuszko's army, emigrated and formed, on Italian soil, the Polish legions, which, during the next ten years, fought the battles of the French republic and of Napoleon all over Europe and even outside it, from Egypt to the West Indies. They were commanded by Jan Henryk Dombrowski, one of Kosciuszko's ablest generals; but Kosciuszko himself stood aloof, distrusting Napoleon.

The Duchy of Warsaw.—In 1806 and 1807, when Napoleon

defeated Prussia and engaged in a war with Russia, Polish soldiers once more appeared on Polish soil, and the hopes of the nation seemed near fulfilment. In fact, the peace of Tilsit resulted in the reconstruction of a Polish state out of the central provinces of Prussian Poland; but Napoleon's anxiety to conciliate Russia effectually prevented him from making his new creation large enough to be self-supporting. The duchy of Warsaw, as it was called, consisted in 1807 of territories taken by Prussia in the second and third partitions, to which territory seized by Austria in the third partition was added in 1809. The total area of the duchy was then about 64,000 sq.mi., with a population of about 4,350,000. The constitution was dictated by Napoleon; it was framed on the French model and on very advanced lines. Equality before the law (implying personal freedom of the peasant), absolute religious toleration and highly developed local autonomy were its salient features. The king of Saxony, Frederick Augustus I (previously elector as Frederick Augustus III; grandson of Augustus III of Poland), whom Napoleon made duke, took the initiative in all legislative matters, but the administration was practically controlled by the French. In spite of being subject to most burdensome financial and military exigencies for the purposes of Napoleon's continuous wars, the small duchy contrived, during the few years of its existence, to do much peaceful, productive, organizing work, especially in the educational and economic spheres.

Poland's hopes for greater things revived once more when Napoleon announced his war against Russia (1812), as his "second Polish war." The duchy, by an immense effort, put an army corps of nearly 98,000 men into the field. But the calamity that overtook Napoleon in Russia also sealed the fortunes of the duchy. The remainder of the Polish troops faithfully followed Napoleon in his campaign of 1813–14, during which the heroic leader of the Poles, Prince Joseph Anthony Poniatowski, perished in covering the emperor's retreat from Leipzig. The duchy was occupied by the Russians.

The Congress Kingdom and Russian Rule.—Tsar Alexander I had been united by youthful friendship to the most eminent Polish noble of his time, Prince Adam Czartoryski, and had even made him, on his accession, foreign minister of the Russian empire. On Napoleon's downfall the Poles, to whom Alexander did not spare promises and flatteries, entertained the highest hopes.

It was not Alexander's fault, indeed, if the congress of Vienna, because of jealousy among the great powers and the entanglement of the Polish question with that of Saxony and other territories, did not lead to a reunion of Poland, even under the Russian sceptre, but confirmed the division of the country among the three partitioning powers. Cracow only, with a small surrounding territory, was erected into a free city republic. Great Poland, with Poznan for its centre and a population of 850,000, was left to Prussia. Austria remained in possession of Galicia with 1,500,000 inhabitants. The eastern borderlands, from Lithuania and White Russia to Volhynia and the Ukraine, continued to be incorporated in Russia. The remnant of central Poland only—about three-fourths of the territory of Napoleon's duchy of Warsaw—was constituted as the so-called Congress kingdom under the emperor of Russia as king of Poland. Guarantees of home rule in all parts of the divided country and of free communication between them were given by all powers concerned, only to prove soon more or less futile.

Alexander, who had a sentimental regard for freedom, so long as it meant obedience to himself, had promised the Poles a constitution. That constitution was soon duly drafted and signed. It contained 165 articles divided under seven heads. The kingdom of Poland was declared to be united to Russia in the person of the tsar, as a separate political entity. Lithuania and the Ruthenian palatinates continued to be incorporated with Russia as the Western Provinces and were divided from the Congress kingdom by a customs barrier till the reign of Nicholas I. The kingdom of Poland thus defined was to have at its head a lieutenant of the emperor (*namiestnik*), who must be a member of the imperial house or a Pole. The first holder of the office, Gen. Jozef Zajonczek (1752–1826), was a veteran who had served Napoleon. Roman Catholicism was recognized as the religion of the state, but other religions were tolerated. Liberty of the press was promised, subject to the passing of a law to restrain its abuses. Individual liberty, the use of the Polish language in the law courts and the executive employment of Poles in the civil government were secured by the constitution. The machinery of government included a council of state (at which the imperial government was represented by a commissioner plenipotentiary) and a *sejm* divided into a senate, composed of the princes of the blood, the palatines and councillors named for life, and a house of deputies elected for seven years. Poland retained its flag and a national army based on that which had been raised by and had fought for Napoleon. The command of the army was given to the emperor's brother Constantine, a man of somewhat erratic character, who did much to offend the Poles by violence (*see* CONSTANTINE PAVLOVICH).

The *sejm* met three times during the reign of Alexander, in 1818, in 1820 and in 1825, and was on all three occasions opened by the tsar. But the tsar and the *sejm* soon quarrelled. The third session of the *sejm* (May 13 to June 13, 1825) was a mere formality. All publicity was suppressed, and one whole district was disfranchised because it persisted in electing candidates who were disapproved of at court. All Europe at the time was seething with secret societies organized to combat the reactionary governments of the Holy Alliance. In Poland the National Freemasonry, or National Patriotic society as it was afterward called, had a large membership, especially among the students and the younger officers. Outside Congress Poland, a similar student movement arose in the University of Wilno. Severe measures—imprisonment, deportation and exile—were taken against students and graduates of Wilno (including the poet Adam Mickiewicz), and they added to the excitement in Warsaw.

No open breach occurred during the reign of Alexander I, nor for five years after his death in 1825. On the death of the unpopular Zajonczek in 1826, the grand duke Constantine became imperial lieutenant. His brother, the new tsar Nicholas I, soon became entangled in a war with Turkey. Austria, as usual, desirous of profiting by Russia's difficulties, began to court the favour of the Poles. Nicholas was crowned king of Poland in Warsaw in 1829 and personally opened the *sejm* in 1830. But the *sejm* already in 1828 had refused to sentence to death a group of Polish conspirators accused of dealings with the Russian "Decembrists" who had plotted Nicholas' overthrow, and in 1829 there was even an abortive Polish plot to murder him at his coronation in Warsaw. Fresh excitement was created in Poland by the outbreak of the Revolution in France in July 1830 and the revolt of Belgium; a rumour was current—not without justification—that Nicholas, acting in concert with the other autocrats of the Holy Alliance, intended to use the Polish army to coerce the French and Belgian revolutionaries.

The Rising of 1830.—On Nov. 29, 1830, a military revolt broke out in Warsaw. It was started by the young hotheads of the officers' training school and began with the murder of several senior officers loyal to the government. Regiments of the army and masses of the civilian population began to join the rising; the weakness of Constantine allowed it to gather strength. He evacuated Warsaw and finally left the country. The war lasted from Jan. till Sept. 1831. The Poles began with some chances of success; they had a well-drilled and well-equipped army of about 30,000 men, which they increased by recruiting to about 80,000. Against this, the Russians, with considerable difficulty, succeeded in putting only about 114,000 men into the field. Their ultimate success resulted partly from the friendly attitude of Prussia, partly from the fact that the Polish *sejm*, having proclaimed the deposition of the tsar at an early stage of the conflict, received no response to its appeal for western European protection. But to a large extent the defeat of the insurrection was caused by certain faults on the Polish side: want of ability and decision on the part of the generals; a succession of rapid changes in the command of the army; fierce party strife within the civil government in the capital; a deplorable outbreak of mob violence in Warsaw at a critical moment of the war; and, finally, an irresolute attitude of

the insurrectionary parliament toward the peasant claims.

After the suppression of the insurrection, certain remnants of a constitution were still granted to Russian Poland by the "organic statute" of 1832, but they were soon rendered illusory; the administration avowedly aimed at destroying the nationality and even the language of Poland. The universities of Warsaw and Wilno were suppressed, the Polish students compelled to go to St. Petersburg and Kiev. The recruits from Poland were distributed in Russian regiments, and the use of the Russian language was enforced as far as possible in the civil administration and in the law courts. The customs barrier between Lithuania and the former Congress Poland was removed, in the hope that Russian influence would spread more easily over Poland. A hostile policy was adopted against the Roman Catholic Church. But though these measures cowed the Poles, they failed to achieve their main purpose. Polish national sentiment was intensified. The Poles in Russia, whether at the universities or in the public service, formed an element which refused to assimilate with the Russians. In Poland itself the tsar left much of the current civil administration in the hands of the nobles, whose power over their peasants was hardly diminished and was misused as of old. The Polish exiles who filled Europe after 1830 maintained a constant agitation from abroad. The stern government of Nicholas was, however, so far effective that Poland remained quiescent during the Crimean War.

Alexander II and the Rising of 1863.—The reign of the new tsar Alexander II began with certain concessions to Poland in the political and educational field. Exiles were allowed to return, administrative pressure was lightened, the church was propitiated, an "agricultural society" was allowed to be formed and to discuss important affairs of the community, a medical faculty and, later on, a complete university were re-established in Warsaw. Finally, even a Polish council of state and a Polish administrative apparatus for the kingdom began to be organized. In their later stages these reforms were the work of Count Aleksander Wielopolski, who was installed in high office and stood for a national policy of loyal union with Russia. But his autocratic temper lost him the sympathies of the moderate elements of the gentry, while, on the ardent minds of the young, Wielopolski's methods acted like fuel heaped on fire. Religious ceremonies were used as the occasion for demonstrative political processions, there were collisions with the Russian troops and victims fell in the streets of Warsaw. Wielopolski had the unhappy idea of causing the revolutionary youth of the cities to be recruited en masse for the Russian army; the plan became known, numbers of the young people fled into the forests, and a revolutionary committee on Jan. 22, 1863, started an ill-prepared insurrection.

The struggle of the ill-equipped and ill-organized insurgent bands against the Russian garrisons dragged on in the form of guerrilla warfare throughout the country for nearly two years. A secret national government was set up in Warsaw, the movement spread successfully into Lithuania and the insurrection occupied the diplomatic attention of western Europe. But the assistance promised by Napoleon III never became effective; the rising was crushed; wholesale executions, confiscations and deportations followed its suppression; and Poland was now definitely turned into a Russian province.

Russification.—All self-government in Congress Poland was suppressed in 1863; all education was russified in 1869, justice in 1873. On the other hand, the abolition in 1851 of the customs frontier between Russia and Poland had laid the foundation for an extraordinary industrial expansion: Russian Poland, with its great textile factories at Lodz, became the chief industrial region for all Russia. Its vast market in agricultural Russia was protected against western competition by high tariffs; the Russian government took every possible measure (such as the introduction of specially favourable railway tariffs) to assist this expansion. The Poles, being excluded from state service in their own country, busied themselves with productive occupations, and the upper and middle classes achieved a well-being far superior to anything enjoyed by their cousins in Galicia. A second result of this expansion was the growth in Congress Poland of a large and radical proletariat which made common cause with the Russian Social Democratic movement. In the country districts, the agrarian policy of the Russian government was expressly calculated to stir up ill-feeling between the Polish peasants, whom the government demonstratively took under its protection, and the country gentry, whom it was determined to punish in every way for the leading part they had played in the insurrections. The peasant of Russian Poland officially got his freedom from the tsar in 1864. All peasants, whatever their tenure had been, and the mass of the landless proletariat became freeholders, on a far more generous basis than the Russian peasant in 1861. The landlords received compensation in the form of Russian treasury bonds, which stood far below par, and the peasants got the right to use the landlords' pastures and woods.

In the sphere of education, the most thoroughgoing system of russification set in after 1864. All the revived Polish schools of the Wielopolski period were made Russian again, including the University of Warsaw, and no effort was spared to produce in the minds of youth a distorted image of Poland's past. Secret patriotic education, however, counteracted this policy successfully both in town and country, and private Polish schools, struggling against great difficulties, kept the Polish cultural tradition alive.

The civil government of Russian Poland was reorganized strictly on the model of the rest of the Russian empire, the Poles being debarred, however, from certain liberal institutions which the Russians by that time possessed, such as municipal self-government and trial by jury. The Russian language was made compulsory in all official relations and at a later time even in the records of private institutions. A corrupt Russian bureaucracy filled all government offices, a severe censorship strangled every free utterance of the nation in the press and in literature, and a drastic police regime kept the prisons filled with political offenders.

After Russia's defeat in the Japanese war of 1904, the outbreak of a revolution in 1905 kindled all Polish hopes once more. A constitution was granted to the Russians, and 36 Polish deputies sat in the first Russian parliament (duma). A certain measure of freedom in the educational field was obtained and eagerly used for the foundation of new schools by a Warsaw society called the Mother of Schools (*Macierz Szkolna*). The peasants of Russian Poland spontaneously introduced the Polish language in their self-governing bodies. In the duma itself, the Liberals were not averse to granting Poland a large measure of autonomy within Russia. At the same time, persecution in Prussian Poland increased under Prince Bernhard von Bülow, while the Ukrainian national movement, developing in Austrian Poland especially since the grant of universal suffrage in 1907, was unwelcome both to Poles and Russians. Under these circumstances, Russian propaganda, reviving the pan-Slav ideals of 30 years ago, could count on some success even among the Poles. There were gestures of reconciliation at two Slav congresses, in 1908 and 1910, the Czechs willingly acting as mediators. The idea of uniting all Poles with autonomy within the Russian empire was widely preached; it became the program of the National Democratic, or all-Polish, party, led by Roman Dmowski, the head of the Polish representation in the duma.

Opposed to Dmowski and the followers whom he found even among Austrian Poles there stood the irreconcilable revolutionaries, led by Joseph Pilsudski. Both the insurrectionary movement started by Pilsudski in 1905 and the constitutional endeavour of Dmowski and his friends in the duma were soon stifled by the Russian reaction of the Peter Stolypin period. Pilsudski took refuge in Galicia and began to organize armed resistance to Russia from that base. In the duma, the Polish representation was lowered from 36 to 10 deputies. In the country, all the liberties gained after 1905 soon disappeared. The government's purchase of the railway line from Warsaw to the Austrian frontier resulted in the removal of all Polish railwaymen from the service and was a great blow to the Polish element. In 1912 the separation of the district of Chelm, in the southeast of Russian Poland, from the body of the province and its incorporation in Russia proper was received with indignant protests by Polish opinion as a new partition of Poland.

Prussian Poland.—The regime in Prussian Poland during the

first 15 years after the congress of Vienna had been endurable. A Polish nobleman related by marriage to the Prussian dynasty—Prince Antoni Radziwill—was appointed lieutenant governor of the province; there was a provincial assembly and local representative bodies both urban and rural. The landowners were allowed to organize for economic purposes, and the peasants were fully enfranchised in 1823. After the insurrection of 1830, a period of more oppressive government by a German provincial president, E. Flottwell, set in; he revived Frederick the Great's method of German colonization of the Polish province, and he began to germanize the administration and the school system. A period of new concessions to the Poles under Frederick William IV was interrupted by the revolution of 1846–48. The constitution with which Prussia emerged from the revolution put an end to the self-government of Prussian Poland. Another interval of relaxation, in the first years of William I, was soon succeeded by the period of Bismarck's and Bülow's resolutely anti-Polish policy—characterized by the *Kulturkampf*, the "Colonizing committee," the Wrzesnia scandal, the schools' strike, the Expropriation bill and the like, for an account of which *see* POZNAN. The result of the Prussian methods was to create a sturdy class of peasants and small *bourgeoisie*, disciplined and economically and culturally advanced; and a fellow feeling arose between the peasants and the landowning gentry such as was hardly known in other parts of Poland.

Austrian Poland.—After the insurrection of 1830–31, no remnant of Poland's independent political existence had been left except the minute city republic of Cracow, created by the congress of Vienna. For 30 years this miniature state led a flourishing existence. When the ferment of the approaching European revolution of 1848 was stirring most continental countries to their depths, there were active preparations for another rising both in Austrian and Prussian Poland. For Austria the menace was diverted by a peasant revolt in Galicia in Feb. 1846, which led to a massacre of about 2,000 landowners by the peasantry incited by the Austrian governor general Baron Krieg von Hochfelden. At the same time, Austria availed itself of the unrest among its Poles to obtain the consent of Russia and Prussia to the suppression of the city republic of Cracow. But it was not until 1848 that Cracow was finally occupied by Austria and incorporated into Galicia.

Austria under the old autocratic regime oppressed its Polish province politically and exploited it economically in the most ruthless fashion. The revolution of 1848 brought a change, but not until the defeat of Austria by Prussia in 1866 was it realized at Vienna that only a more liberal policy could hold the tottering, mixed monarchy together. The relation with Hungary having been placed on a federal footing, concessions had to be granted to the strong Polish element in Austria. The Poles began to be active in Austrian politics. The numerical strength of Polish deputies in the Vienna parliament was such that no Austrian government could be formed without it. Galicia (as Austrian Poland was officially called), containing a large Ukrainian element in its eastern half, was granted a special minister to represent its interests in the Vienna cabinet. It also got a provincial legislative assembly and a governor, who was invariably appointed from the ranks of the Polish aristocracy. With purely Polish administration, schools and courts of law, Galicia became indeed almost an independent Polish state within Austria and successfully defied the centralizing efforts of the Vienna bureaucracy. The Polish landowning class, which practically governed the country for the next few decades, managed its affairs in a one-sidedly agrarian spirit; the interests of the towns were not properly considered, hardly any attention was given to the development of industries, and Galicia remained economically backward. Even its oil fields were largely developed by foreign capital. On the other hand, political and cultural activities had more scope than in the two other parts of Poland; Galicia became the "Piedmont" of the Polish national movement, and Cracow, with its old university and new Academy of Sciences, an intellectual, artistic and literary centre for the whole nation. With the growth of a new educated class and the introduction of universal suffrage in Austria (1907) the social structure of the country began to change, its politics were strongly democratized, new economic tendencies got the upper hand, and Galicia was at last on the road of material advance when World War I began.

World War I.—World War I found the Poles estranged from one another and without a united national policy. "Brygadier" Pilsudski crossed the frontier from Galicia with a few hundred of his legion and engaged the Russian empire in battle as forerunner of the army of an independent and united Poland. But the Polish Supreme committee, formed in Cracow on Aug. 16, aimed at uniting Galicia and Congress Poland as a third party in the dual monarchy and required the Polish legion to take the oath to the emperor. In Warsaw the Polish National committee under Dmowski denied the right of the Cracow committee to speak in the name of the Polish nation, protested loyalty to the tsar and attempted to form a Polish legion on the side of Russia. Meanwhile the grand duke Nicholas issued a proclamation (Aug. 14) in which he promised to unite the three parts of Poland in an autonomous state with the Russian empire.

In the summer of 1915, however, the Central Powers conquered all Congress Poland. After the fall of Warsaw on Aug. 5, 1915, military governments were set up on behalf of Germany at Warsaw and of Austria-Hungary at Lublin. But fresh difficulties confronted the Austrian solution. The Polish Socialist party (P.P.S.) under Pilsudski declared that no recruiting should take place for Polish legions until an independent Polish government had been formed to conduct it. Meanwhile, Istvan Tisza, the Hungarian premier, had vetoed the Austrian trialist scheme, which was also opposed by Germany. Vienna again rejected the plans put forward by Germany of annexing Congress Poland to Germany or of forming an independent Polish buffer state in economic, military and political alliance with the Central Powers.

In Aug. 1916, however, after the defeat of the Austro-Hungarian troops at Luck, the German supreme command acquired complete control of policy on the eastern front. Erich Ludendorff believed it possible to gain a large Polish army if his ideas were adopted. Germany and Austria-Hungary issued a proclamation on Nov. 5, 1916, holding out a prospect of the restoration of an independent Congress Poland as a hereditary constitutional monarchy closely attached to the Central Powers. Francis Joseph promised Galicia increased autonomy within Austria-Hungary. The discussion of details was shelved; the military governments at Warsaw and Lublin continued to administer the country. On Nov. 26, 1916, a provisional council of state of 25 members was appointed; it was solemnly opened on Jan. 14, 1917. Pilsudski, who was one of the members of the council, began to work out the plans for a national Polish army. He refused, however, to raise it for German use, and the German plan of raising a Polish army failed completely.

In March 1917 the Russian dynasty fell. On March 30 the new Russian government recognized Poland's right to self-determination and promised the creation of a new Polish state. These events altered the attitude of the Allies toward Poland, particularly as they were now reinforced by the entry of the United States into the war. The answer of the Entente Powers to the peace proposals of the Central Powers issued on Jan. 10, 1917, had already declared their adhesion to the tsar's manifesto to his armies (Dec. 25, 1916) which had spoken of "the formation of a free Poland in all parts into which it is at present divided."

The danger still threatening Poland from Russia vanished with the breakdown of Alexander Kerensky's offensive (July 1917). The Central Powers were now the only enemy. In May 1917 the Polish members of the Austrian *reichsrat* unanimously demanded "an independent united Poland with an outlet to the sea," and declared that the Polish case was one for "international consideration." At the same time, the Polish council of state in Warsaw asked the occupants for a widening of its powers and split up over the German demand for a recruiting appeal and an oath of loyalty. Pilsudski resigned from the council with his adherents and set about turning his secret military organization against Germany.

On July 22 Polish discontent was increased by the arrest of Pilsudski. On Aug. 25 the council of state, now discredited with the people, resigned. On Sept. 12 Germany and Austria-Hungary introduced a new project of a regency of three, a cabinet and premier and council of state, elected but enjoying limited powers,

the German and Austrian military governments retaining the right of veto. The regency was appointed on Oct. 15; it consisted of the archbishop of Warsaw, Aleksander Kakowski, Prince Zdzislaw Lubomirski and Jozef Ostrowski, a large landowner. The first prime minister, Jan Kucharzewski, was appointed on Nov. 26 and formed his first ministry on Dec. 7.

While Polish affairs were taking this course under Austro-German occupation, Dmowski was making propaganda for the Polish cause in France and Great Britain and I. J. Paderewski was working tirelessly in the United States. In Nov. 1916 the so-called Polish National department in Chicago, Ill., had united all the organizations of the 4,000,000 Poles in the U.S.; and under Paderewski's influence, Pres. Woodrow Wilson, in his tentative peace message of Jan. 22, 1917, alluded to a "united, independent and autonomous Poland." In the course of 1917 a Polish corps was organized by Gen. Jozef Dowbor-Musnicki in Russia, and a Polish army began to be formed in France. The Polish National committee, founded by Dmowski and Paderewski at Lausanne in Aug. 1917 and later established in Paris, was gaining increasing influence in the councils of the Allies. Between Sept. 20 and Dec. 1, 1917, France, Great Britain, Italy and the United States had recognized it as the official representative of the Polish people. The 13th of President Wilson's Fourteen Points (Jan. 8, 1918) declared that a Polish state should be erected which should include the territories inhabited by indisputably Polish population "with an outlet to the sea and an international guarantee of its independence and integrity."

In the meantime, the utter collapse of the Russian army had led to peace negotiations between the Central Powers and the Bolsheviks. The Bolshevik delegates who arrived at Brest-Litovsk (*q.v.*) in Dec. 1917 recognized, in theory, the right of the Polish people to self-determination, but Polish delegates were not admitted to the deliberations. By the treaty as concluded on March 1, 1918, Soviet Russia renounced all claims over Poland; but the treaty (Feb. 9, 1918) between the Central Powers and the Ukraine allotted to the Ukraine the disputed province of Chelm, while Austria-Hungary further pledged itself in a secret clause to form East Galicia and Bukovina into a separate crownland. These clauses became known and Polish opinion was infuriated; the Polish club in the Austrian *reichsrat* went over to the opposition and the remnant of Pilsudski's legions still fighting for the Central Powers mutinied. Some were interned, some, under Gen. Jozef Haller, fought their way to the coast and joined the new Polish army in France. The council of state in Poland was opened in Warsaw on June 22. Little interest was taken in it, and general feeling in Poland tended to ignore this body in favour of the National committee in Paris. Even before the breakdown of the German offensive in July 1918, the prime ministers of Great Britain, France and Italy had declared in favour of an independent and united Poland at Versailles on June 3, 1918.

The Declaration of Independence.—On Oct. 6 the Polish regency council published a manifesto to the Polish nation declaring its intention of dissolving the council of state, forming a representative national government and summoning a *sejm* for a "free and united Poland." On Oct. 15 the Polish representatives in the Austrian *reichsrat* declared themselves to be "subjects and citizens of a free and re-united Polish State." On Nov. 10 Pilsudski, who had been released from imprisonment at Magdeburg on Oct. 7, arrived in Warsaw. The German troops of occupation were disarmed and expelled, and the Poles assumed the executive power in Warsaw on Nov. 11. The regency council declared on the same day that it appointed Pilsudski to the supreme command of all Polish troops and on Nov. 14 resigned in favour of Pilsudski.

On Nov. 14, too, the Polish members of the German *reichstag* and of the Prussian *landtag* met in Poznan and formed a supreme popular council. On Dec. 27 the Poznanian Poles rose against the Germans and turned them out of their province. Severe fighting broke out and went on till Feb. 16, 1919, when an armistice was concluded at Trier by Marshal Ferdinand Foch, acting on behalf of the Allies and Poland. Not until after the treaty of Versailles was signed did Poznan send deputies to the constituent assembly in Warsaw.

POLAND RESTORED

Of all the new or resurrected states of Europe, Poland was in many respects in the most difficult position. The territory of Congress Poland and Galicia had been devastated in the war. Most of the factories that had not been actually dismantled were closed for lack of raw material. The fields of the peasants had been laid waste, their livestock slaughtered, their farms burned. Many districts were actually famine stricken, others swept by epidemics. Communications were disorganized and rolling stock was in a deplorable state. Marks, roubles and crowns circulated freely, but their values were low and uncertain, and public and private finances were chaotic. Because of the past policy of Prussia and Russia, a Polish civil service existed only in Galicia. Thirty thousand German troops were still in the country.

Pilsudski, the old revolutionary, had begun by appointing a cabinet of the left, composed mainly of Galician Socialists and peasants' representatives, under the presidency of Jedrzej Moraczewski. But the propertied classes refused him their support, and his attempt to float an internal loan met with little response. In December Paderewski, the second man in Poland enjoying almost unlimited prestige, arrived in the country, composed his differences with Pilsudski and became premier on Jan. 17, 1919. Dmowski was appointed president of the Polish delegation to negotiate peace. It was possible to hold elections for a constituent assembly on Jan. 26, 1919. The constituent *sejm* met on Feb. 10. It passed a vote of confidence in Paderewski's cabinet and confirmed Pilsudski as head of the state. Paderewski proceeded to Paris to urge Poland's claims; Pilsudski raised an army to defend them. General Haller's 100,000 troops, returning in April from France overland across Germany, were a valuable addition to the 230,000 men then at Pilsudski's disposal. The unification of the army was celebrated on Oct. 19, 1919, the French system of instruction and organization was adopted and by the beginning of 1920 the Polish army grew to about 600,000 men in 21 divisions of infantry and 7 brigades of cavalry. (R. Dv.)

The Treaty of Versailles and Frontier Problems.—On June 28, 1919, on behalf of Poland, Dmowski and Paderewski signed the treaty of Versailles, which, however, left the major part of the country's frontiers undefined. Poland regained Pomorze and Poznan, but in East Prussia and Upper Silesia the Polish-German frontier was to be decided by plebiscite. Danzig (*q.v.*) was to be a free city under the protection of the League of Nations but was to be included within the Polish customs frontier in order to provide Poland with a free and secure access to the sea; in addition, Poland was to have free, unrestricted use of the port and to undertake the conduct of the free city's foreign relations. There was a Polish-Czechoslovakian dispute over Teschen (Cieszyn or Tesin) and also over the territories of Orawa (Orava) and Spisz. Of the eastern frontiers of Poland article 87 of the treaty stated that they would be "subsequently determined by the principal Allied and Associated Powers."

East Prussia.—Two plebiscite zones were established, that of Marienwerder (Kwidzyn), an area of 1,036 sq.mi. with 174,000 inhabitants, and that of Allenstein (Olsztyn), about 4,800 sq.mi. with 565,000. All Prussian civil servants were left in the plebiscite areas and the presence of German security police precluded freedom of speech. The vote was taken on July 11, 1920, when Soviet forces were at the gates of Warsaw. In the Allenstein zone 363,209 votes were cast for Germany and 7,980 for Poland, in the Marienwerder zone 96,923 for Germany and 8,018 for Poland. Making the utmost of a stipulation that not only residents but also persons born in the area had the right to vote, the Germans sent to the plebiscite zones 202,700 "emigrants," who constituted nearly half of the voters, while 40% of the qualified residents abstained from voting. Thus the plebiscite, lost by Poland, could scarcely be described as a fair expression of the popular will. (*See* also ALLENSTEIN-MARIENWERDER.)

Upper Silesia.—The plebiscite area of Upper Silesia was 4,250 sq.mi. with 1,942,200 inhabitants. Out of 706,820 votes cast for Germany on March 20, 1921, emigrant voters were responsible for 182,288; Poland obtained 479,414 votes. In all, 682 communes voted for Poland and 792 for Germany, but the Poles secured pre-

ponderance in the southeastern plebiscite area, which economically was the most important. Disregarding the treaty provisions for the partition of the area according to the wishes of the inhabitants expressed by communes, Germany claimed the whole of Upper Silesia, while Wojciech Korfanty, the leader of the Silesian Poles, demanded that 59% of the area, in which 673 communes voted for Poland and 230 for Germany, be awarded to Poland.

The Inter-Allied commission failed to agree on a unanimous proposal to the Supreme council of the principal Allied Powers, the British and Italian commissioners favouring cession to Poland of only the two southern agricultural districts of Rybnik and Pszczyna (Pless) while the French commissioner proposed a frontier less favourable than the Korfanty line but leaving the industrial basin to Poland. Learning of this basic disagreement, the Polish military organization, of which Michal Grazynski was the chief organizer, thought that only an insurrection could save the Polish cause. Korfanty agreed and gave the order for a rising, which broke out on May 3, 1921. In a few days almost all the area within the Korfanty line was occupied. Taken by surprise, the Germans were thrown back. After six weeks' fighting the Inter-Allied commission effected a cessation of hostilities on June 24, and both the belligerents withdrew their troops.

The Supreme council assembled in Paris on Aug. 8–12 failed to draw a new frontier across Upper Silesia because David Lloyd George was anxious to save for Germany as much of the industrial area as possible. The only way out of the deadlock was to submit the question to the council of the League of Nations, where Great Britain was represented by Arthur James Balfour. The council's verdict, given on Oct. 12, 1921, was endorsed by the Allied Powers eight days later. The new frontier divided the industrial area: Poland was awarded 1,241 sq.mi. with about 996,000 inhabitants, 76% of the coal production, 22 out of 37 blast furnaces and 9 out of 14 steelworks. Thus a basis for economic independence was assured. (*See* also SILESIA.)

Teschen.—On Nov. 5, 1918, close upon the final dissolution of the Habsburg monarchy, the Polish and Czech National council of Teschen Silesia concluded an agreement dividing the four districts of the province into two ethnographic entities. On Jan. 23, 1919, however, on orders from Prague, the Czech forces fell unexpectedly upon insignificant Polish forces in the area and occupied the greater part of the province. The government of Prague argued that Teschen was historically a Czech land and, moreover, that the new Czechoslovakia needed its coal.

The fighting was stopped by the Supreme council on Feb. 3, 1919. After a vain attempt to reach agreement by direct negotiation, the Supreme council decided on Sept. 27 that the dispute should be settled by plebiscite. On July 10, 1920, Poland, whose existence was menaced by the Soviet offensive, agreed at Spa that the Conference of Ambassadors should draw a final frontier. On July 28 less than half of Teschen Silesia was awarded to Poland (387 sq.mi. out of 858, with a population of 142,000 out of 435,000). Czechoslovakia secured all coal mines. No Czechs were left on the Polish side of the new frontier, but on the opposite side were 140,000 Poles. The decision relating to Orawa and Spisz was likewise disadvantageous to Poland, which kept 27 villages; the 44 villages awarded to Czechoslovakia had a Polish population of 45,000.

Eastern Galicia.—Of 4,743,000 inhabitants of Eastern Galicia (18,245 sq.mi.), Ukrainians formed 52.7%, Poles 39.3% and Jews 7.2%; there was, however, a considerable Polish majority at Lwow (64% of a population of 300,000) and in some other towns. Enabled by the Austrian authorities to assume control of the whole area, the Ukrainians on Nov. 1, 1918, proclaimed at Lwow (Lviv) an independent republic of the Western Ukraine. Thereupon the local Polish population organized military formations, which succeeded in freeing the city by Nov. 22. In May 1919, after the fighting had continued for six months, the Polish army occupied the whole of the disputed province.

In March 1919 the Commission on Polish Affairs at the Paris peace conference considered the following alternatives regarding the future of Eastern Galicia: (*a*) a Polish mandate over the whole territory for 25 years, after which its fate was to be settled by plebiscite; (*b*) partition between Poland and a Ukrainian state. There were alternative demarcation lines in connection with these schemes: line A (*see* fig. 3), to run east of Przemysl, if the whole territory were to be entrusted to Poland under a mandate; and line B, which would leave Lwow and the Drohobycz oil fields to Poland in the event of the creation of a Ukrainian state. On June 25 the Supreme council accepted line A and authorized Poland to occupy the whole area; on Nov. 21, it approved the draft of an autonomous statute for the area with a 25-year mandate; on Dec. 22, 1919, giving satisfaction to Polish demands, the Supreme council rescinded its previous decision and allowed Poland to incorporate the whole area (*see* also GALICIA).

FIG. 3.—POLAND'S FRONTIERS, 1919-51 (SEE TEXT FOR EXPLANATION)

The Soviet Frontier.—Under the terms of the armistice of Nov. 11, 1918, the German armies had to evacuate western Russia and Poland. As the Germans withdrew, the Soviet army was advancing westward. In Nov. 1918 it was still on the Dnieper, but by Feb. 1919 had moved forward to the Bug. "Militant international Bolshevism urgently required contact with revolutionary Germany, and this could only be won over the body of Poland," says Sir Bernard Pares in his *History of Russia* (Alfred A. Knopf Inc. and Jonathan Cape Limited, publishers), thus succinctly indicating the origin of the Polish-Soviet war. The Soviet government hoped, of course, that the Polish workers and peasants would greet its armies as liberators, and was greatly dismayed when they did not. (*See* also RUSSO-POLISH CAMPAIGN.)

A counteroffensive launched by the Polish army under Pilsudski brought the Polish-Soviet front, by the end of 1919, along the river Berezina in Byelorussia, and in the Ukraine Novograd-Volynsk, Starokonstantinov and Bar were in Polish hands. Although in no haste to decide on Poland's eastern frontiers, the Supreme council, on Dec. 8, 1919, authorized Poland to organize a regular administration within a temporary line of demarcation "on the territories of the former Russian empire"; *i.e.*, not encroaching upon the formerly Austrian territory of Galicia. The declaration of Dec. 8 stated explicitly that the line fixed was a provisional minimum frontier, without prejudice to later terms which might be designed to fix the final eastern frontier of Poland.

On Jan. 28, 1920, Nicolai Lenin, Georghy Chicherin and Lev Trotsky handed a peace proposal to the Polish government suggesting the actual front as the armistice line. Pilsudski doubted the sincerity of this offer because he had information that the Soviet command was concentrating new divisions on the front and Trotsky himself, in a letter to three prominent French Communists, had written shortly before: "When we have finished with Denikin, we are going to attack the Poles" (*Internationale Com-*

muniste, Dec. 15, 1919). When, however, on March 27, 1920, the Polish government decided to open negotiations the Soviet government's rejection of Borisov, near the front, as a suggested meeting place confirmed Pilsudski's suspicion of a threatened Soviet offensive. On April 22, 1920, he accordingly signed a treaty of alliance with Simeon Petlyura, head of a Ukrainian government at Kamieniec Podolski (Kamenets-Podolsk), and three days later a Polish offensive started in the Ukraine. On May 7 the Poles occupied Kiev, but on June 8 the Soviet cavalry under Simeon (later Marshal) Budenny broke through the Polish line southwest of Kiev, and on July 7 Mikhail (later Marshal) Tukhachevsky attacked north of Borisov. The military situation of Poland became critical. On July 10 Wladyslaw Grabski, the premier, went to Spa where the Supreme council was assembled to ask for immediate help in the shape of war supplies. With the assent of representatives of France and Italy, Lloyd George undertook to act as mediator. He suggested an armistice along the line of Dec. 8, 1919; in Eastern Galicia the armies were to stand on the line reached on the date of the armistice. Grabski agreed, and on July 11 Lord Curzon, the British foreign secretary, suggested an armistice to Moscow and the Polish army's withdrawal to the line of Dec. 8, 1919, and in Eastern Galicia to the line A (*see* above), an obvious discrepancy with the agreement reached the previous day. Thus was born the "Curzon line."

Meanwhile the situation on the front gradually changed. By mid-August Pilsudski's counteroffensive brought a decisive victory. Poland was saved, but not only Poland. "By attacking Poland," said Lenin in Moscow on Oct. 8, 1920, "we are attacking also the Allies. By destroying the Polish army we are destroying the Versailles settlement." A Soviet-sponsored government for "liberated" Poland, headed by Feliks Dzierzynski, Julian Marchlewski and Feliks Kon, which had already established itself at Bialystok, had to flee back to Moscow. A Polish-Soviet peace treaty, concluded on March 18, 1921, at Riga, added to Poland an area of 51,762 sq.mi. east of the line of Dec. 8, 1919.

The Wilno Dispute.—During the advance of their armies westward, the Soviet government "ceded" Wilno (Vilnius) to Lithuania by a peace treaty signed on July 12, 1920. The city was evacuated by the Russians during their general retreat following the Polish victory and on Aug. 26 was entered by Lithuanian troops. The Poles appealed to the League of Nations and a partial armistice was signed at Suwalki on Oct. 7. Pilsudski was strongly inclined toward a federal solution of the dispute, with Wilno and its region providing an independent link between Poland and Lithuania. Gen. Lucjan Zeligowski accordingly occupied Wilno on Oct. 9 and set up a local government. Pilsudski's scheme, however, was incompatible with the prevailing temper of the Poles and Lithuanians. On Feb. 20, 1922, therefore, the democratically elected regional assembly of 106 members voted the incorporation of the whole province in the Polish republic; 96 members voted for the incorporation, 6 abstained and 4 were absent. It remained only to obtain the approval of the principal Allied Powers. The Soviet government had declared in the Riga treaty its disinterestedness in the Polish-Lithuanian dispute. The council of the League of Nations was no longer interested and on Feb. 3, 1923, adopted a final resolution fixing the Polish-Lithuanian line of demarcation. On March 15, 1923, the Conference of Ambassadors, requested by both the Polish and Lithuanian governments to use their right to fix the frontier, recognized the demarcation line of Feb. 3 as the final frontier between the two states. (*See* also VILNIUS.)

By the same decision the Conference of Ambassadors recognized as final the Polish-Soviet frontier fixed by the treaty of Riga. On April 5, 1923, both Polish-Soviet and Polish-Lithuanian frontiers were recognized by the government of the United States. The long series of territorial disputes which handicapped Poland's foreign policy and its internal reconstruction was definitely settled, both legally and in fact. The new Poland had a total area of 150,052 sq.mi. with an approximate population of 27,200,000.

(K. SM.)

Constitution and Internal Affairs, to 1925.—Under the constitution of March 17, 1921, Poland was a republic. The legislative power was vested in a *sejm* and a senate, which were summoned, adjourned and dissolved, but not without their own consent, by the president. The *sejm* was composed of paid members elected for five years, upon a system of proportional representation. Suffrage was universal, all who enjoyed full civic rights and who were over 21 being qualified to vote; soldiers on active service were excluded. Citizens over 25 were eligible for election to the *sejm;* members of the civil service could not be elected for the district in which they held office. The minimum age for voting in senatorial elections was 30, while no one under 40 was eligible for election. Bills went to the senate after being passed by the *sejm,* and if no objection was raised within 30 days the bill became law. Taxes and customs duties could be established only by law and a supreme board of control superintended the management of state finance. The executive power was exercised by the president and a council of ministers who were responsible for his official actions. He was elected for seven years by the national assembly; that is, the *sejm* and senate acting together.

For purposes of administration Poland was divided into 16 palatinates, which again were subdivided into districts and urban and rural communes. The palatine or the *wojewoda* represented the executive government in the palatinate, the *starosta* in the district. Local legislation was to be exercised by *sejmiki* in the palatinates and by district councils in the districts. Economic autonomy was established by means of chambers of agriculture, commerce, industry, etc.; judicial control over the whole administration was vested in a supreme administrative tribunal.

Poland was reconstructed out of provinces of three empires in which widely different systems of law were operative. A codifying commission began to work out a body of uniform codes of law for the whole republic; in the meantime, Russian, German and Austrian codes remained in force in the different parts of the country. Gradually many domains of legal relations were covered by parliamentary legislation and, after 1926, by presidential decrees. A supreme court of justice in Warsaw was established at an early date, but it was not until 1928 that the country found itself in possession of a unified judicial organization and a uniform code of judicial procedure. Judges were nominated by the president and irremovable except by judicial decision. Justices of the peace were locally elected by the people. Over property in land, forests and mineral wealth, however, a certain amount of state control was extended by special provisions of the constitution. State protection was given to labour, and insurance against unemployment, illness and accident was guaranteed. The exercise of religion was free, as far as it was in accordance with the law. The Roman Catholic religion, the predominant denomination of the country, was placed by the constitution in a privileged position.

The constituent *sejm* had 13 political parties, as well as two independent members, and it was difficult to ensure a stable government. The resignation of Paderewski (Nov. 1919) was followed by a succession of quickly changing cabinets, always based on unstable coalitions—chiefly between the Peasant centre and either the Nationalist right or the mainly Socialist left. A coalition government of national defense under the peasant leader Wincenty Witos, with Ignacy Daszynski, the Socialist leader, as deputy premier, succeeded at a critical moment in rousing the country to resist the Bolshevik invasion.

Toward the end of 1922 the prolonged legislative period of the constituent assembly came to an end. An electoral law was passed on July 28, and in November elections for the upper and lower house of the first regular *sejm* were held. They ended by distributing power in the chamber between the Nationalists (161), the Peasant groups (124) and the Party of Labour (18); the Socialists obtained only 41 seats, but the national minorities, by organizing a bloc for electioneering purposes, got 81 (of whom 35 were Jews) and accordingly, in spite of the large abstention of the Ukrainian element from the elections, became an important and occasionally a decisive factor in the parliamentary system.

The first business of the two houses of the new parliament was jointly to elect a president of the republic. Marshal Pilsudski refused to stand. The parties of the left, supported by the national minorities and the Witos Peasant party, secured the election

of Gabriel Narutowicz, a friend of Pilsudski, who had acted as minister of foreign affairs in several cabinets. Polish nationalism was infuriated by the election of a president through the votes of the national minorities, and on Dec. 16 a fanatic assassinated Narutowicz. The new president was Stanislaw Wojciechowski, a former Socialist and father of the Polish co-operative movement. Gen. Wladyslaw Sikorski became premier.

Poland's position in the early part of 1923 was still very unsettled. The Polish mark, a provisional currency, was affected by the collapse of the German mark. A government formed in the spring by Witos, on the basis of an alliance between the Peasant party and the National party, had to struggle against the resolute opposition of the left and the national minorities; the government proved unable to cope with the continued, disastrous fall of the mark and there was serious unrest in the country, culminating in riots at Cracow on Nov. 6; the government was obliged to resign on Dec. 11. It was followed by a nonparty one under Wladyslaw Grabski, who, as prime minister and minister of finance, made financial reform his principal task. The political parties now at last agreed to subordinate all other problems to those of financial reconstruction. On Jan. 3, 1924, Grabski's government was granted emergency powers for the purpose. Fulfilling partly the recommendations of a British financial adviser, Edward Hilton Young (later Lord Kennet), Grabski strenuously reorganized the financial system of the country. A Bank of Poland was once more created on a basis of private subscription. The budget was balanced by Draconian reductions in expenditure, the printing of paper money stopped, the currency became stabilized at the rate of exchange which it had reached (1,800,000 marks to the gold franc), and finally a new currency unit, the zloty, was introduced and declared equal to the gold franc. The drastic manner in which this financial reform was accomplished inevitably brought about its revenge. The too-high level at which the value of the new currency had been fixed caused a period of heavy economic depression.

On Feb. 10, 1925, a concordat with the Holy See was signed. The Catholic Church was granted absolute freedom of execution of its authority and jurisdiction in Poland, the assistance and support of the state being assured it in this respect. The state's interests in connection with nominations for the higher ecclesiastical posts were adequately protected. In religious education, the competencies of church and state were exactly defined. The division of Poland into ecclesiastical provinces was carried out in such a way that no portion of Polish territory remained subject to the jurisdiction of a bishop residing outside the borders of the state. An autocephalous Orthodox Church also established in Poland received the blessing of the synod and of the ecumenical patriarchate in Constantinople on Nov. 11, 1924. The Protestant Church in Poland was likewise placed beyond reach of political influences from abroad.

Alliances and Security.—In the first years of Polish independence, France's support was Poland's greatest asset. At the end of 1920 the French premier, Alexandre Millerand, invited Pilsudski to visit Paris in his capacity of head of state. As a result of discussions during this visit a political agreement was signed in Paris on Feb. 19, 1921, by Aristide Briand and Prince Eustachy Sapieha, ministers of foreign affairs. It provided that the two governments should take concerted measures for the defense of their territory and the protection of their legitimate interests if either or both of the contracting states, in spite of sincere peaceful intentions, should be attacked without provocation. On March 3, 1921, a treaty of alliance with Rumania was signed at Bucharest by Sapieha and Take Jonescu. On March 26, 1926, the Polish-Rumanian alliance was renewed. It stipulated that the two countries should pledge themselves to defend their territorial integrity and political independence against any outside aggression.

A definite alliance between Poland and the Baltic states was attempted on March 17, 1922, when a political treaty was signed in Warsaw by the foreign ministers of Poland, Finland, Estonia and Latvia. It stipulated that in the event of aggression against one of the contracting parties all four governments should co-operate on measures to be taken. On May 12, however, the Finnish parliament refused to ratify the treaty.

By the end of 1921 Polish-Czechoslovakian relations became cordial enough, and Konstanty Skirmunt, the foreign minister, paid an official visit to Prague. On Nov. 6 he signed with Eduard Benes a political convention by which the two governments agreed to act in concert for the application of the treaties which they had signed in common. There was some talk at that time of closer collaboration between Poland and the Little Entente, but the latter's aim, directed against Hungarian revisionism, was from the Polish point of view too limited. In June 1923 Marian Seyda, the Polish foreign minister, suggested the transformation of the Little Entente into a quadruple alliance, providing all the members with a collective guarantee of security, but this idea met with a cool reception in Prague. Count Alexander Skrzynski, Seyda's successor at the foreign office, was less ambitious. Benes paid a visit to Warsaw in April 1925 and a Polish-Czechoslovakian treaty of conciliation and arbitration was concluded.

Great Britain's rejection of the so-called Geneva protocol and of the principle of collective security alarmed Poland, as did the German proposals to France, which treated separately the problems of Germany's western and eastern frontiers. The Polish thesis was that European security was indivisible. A not too satisfactory compromise formula was found. The treaties initialled at Locarno (*q.v.*) on Oct. 16, 1925, and signed in London on Dec. 1 included two agreements concerning Poland: a Polish-German arbitration treaty and a Franco-Polish treaty of guarantee. The former provided for the peaceful settlement of disputes; in the latter France guaranteed the Polish frontier with Germany. Polish opinion was not easily reconciled to the idea of the Locarno treaties. They were accepted, but for the first time the Poles felt that they were abandoned by France.

The Second Coalition Government.—Soon after the breakdown of his financial policy Grabski resigned. He remained in power for 23 months, a record in Polish parliamentary history. On Nov. 20, 1925, Skrzynski formed a coalition cabinet, the second of this kind since the restoration of the state. This time the frontiers were secure, but the country was again in danger. The treasury was almost empty, the shortage of private capital was acute, unemployment was rife and the zloty continued to fall. Another storm centre of embittered dispute was the question of reinstating Marshal Pilsudski in the position of commander in chief of the army. He had resigned the office of chief of staff in May 1923 when a government of the Nationalist-Peasant coalition was formed.

In foreign affairs the Skrzynski administration was under the shadow of a growing feeling of international insecurity for Poland. When, a month after the ratification of the Locarno agreements, the League of Nations proceeded to elect Germany a permanent member of the council, Skrzynski claimed a permanent seat for Poland as well. It was not till after a good deal of dramatic friction in the League that a solution was found, Germany getting a permanent and Poland a so-called quasi-permanent seat in the council.

Pilsudski's Rule, 1926–35.—Meanwhile internal dissensions intensified while the conclusion of a new Soviet-German treaty in Berlin (March 1926) increased the general nervousness. Pilsudski, in his retreat at Sulejowek, was looked up to by large masses of the people as the only man who could secure a better future for the country. His adherents and opponents formed two opposing camps in the army. In parliament, the right, since the days of his provisional presidency, had used every legislative device to limit his power and influence. Now, in the dispute over his commandership, the right desired to frame the Army Organization bill in such a way as to bring the army under the direct control of parliament, while Pilsudski insisted on complete independence of the commander in chief.

Matters came to a crisis when, because of the dissensions over the budget, the Socialist ministers left the cabinet, and Skrzynski himself resigned in consequence. After a prolonged period of negotiations Witos succeeded in forming a ministry. Rumours were current that he meant to rely exclusively upon the support of the right and to settle the question of the commandership in the

sense demanded by the Nationalists. Thereupon, on May 12, Pilsudski suddenly entered Warsaw at the head of troops. The government proclaimed him a rebel. The concentration of government troops in Warsaw, however, was hampered by a strong strike movement in the country, chiefly among the railwaymen; and after two days of heavy fighting in the streets of Warsaw, Pilsudski was master of the capital. The government resigned and the president of the republic abdicated. Maciej Rataj, the speaker of the *sejm*, became acting head of the state, in accordance with the terms of the constitution. A provisional cabinet under Kazimierz Bartel was appointed, pending the election of a new president. When the two chambers met on May 31 for the presidential election, there resulted a majority of 292 to 193 in favour of Pilsudski. He, however, refused the office in favour of his nominee, Ignacy Moscicki, a scientist not formerly engaged in politics, who was duly elected on June 1 by 281 votes to 200. Pilsudski himself became minister of war and a few months later officially assumed premiership in the cabinet.

Pilsudski met with little opposition when on Aug. 2, 1926, he proceeded to reform the constitution in the sense of limiting the powers of parliament with respect to the budget: if within a period of five months the budget was not passed, the finance bill acquired the force of law. Another provision gave the president the right to dissolve the parliament on a unanimous proposal of the government, the new elections taking place within 90 days.

A year and a half after Marshal Pilsudski's coup d'état, a new parliamentary election became due in Poland. He had left the outward structure of the parliamentary system intact. The practical impotence, however, to which his rule reduced the sometime all-powerful parliamentary parties had a profound effect on them. The largest groups began to disintegrate, and when the elections approached as many as 35 different factions appeared in the field with lists of candidates of their own. This "pulverization of the party system" was the result of splits in the larger groups on the one issue that remained dominant under the circumstances; viz., the question: *for* Pilsudski or *against* him. In the midst of this reshuffling of all former groupings, the government created a nonparty bloc of its supporters of various shades of opinion. From the elections held on March 4 and 11, 1928, only the Socialists emerged with a substantial increase in the number of their seats (64 as against 41); the other parties which had once been strong factors—the Peasant, the Party of Labour, the Christian Democratic and the Nationalist—dwindled from 230 to 150 seats. The government bloc obtained 135 seats. (R. Dy.; X.)

The opposition, however, remained strong, and a normal cooperation of the parliament with Pilsudski proved impossible. In the autumn of 1930 the growing tension resulted in the arrest of some of the party leaders, who were imprisoned at Brzesc and treated there very badly. New elections held on Nov. 16 and 23 gave the government bloc an absolute majority of 247 seats in a *sejm* of 444, the National Democrats winning 63 seats, the Centre-Left coalition 92 and the national minorities 33.

The Constitution of 1935.—After his electoral success Pilsudski said that the principal task of the new parliament was the revision of the constitution. A draft was introduced to the *sejm* on Dec. 20, 1933; it was passed by it on Jan. 26, 1934, and by the senate on Jan. 18, 1935. On March 23, 1935, the new constitution was definitely adopted by the *sejm* by 260 votes to 139; it became law on April 23.

It was based on the following principles: the state being considered as the "common good" of all the citizens, the executive became considerably strengthened at the expense of the legislature; the president appointed and dismissed the prime minister and the commander of the army, could dissolve the *sejm* and was responsible to none; the six "organs of the state"—government, *sejm*, senate, army, courts of justice and court of supervision—were accordingly under the president's control; the powers of the legislature were strictly limited and the number of its members reduced to 208 in the lower and 96 in the upper house, one-third of the latter being nominated by the president.

Foreign Relations.—During the first six years of Pilsudski's regime, August Zaleski being minister of foreign affairs, Poland's policy was chiefly based upon the League of Nations and the close alliance with France. Poland, which had proposed to the League's assembly of 1927 a resolution outlawing wars of aggression, not only signed the Kellogg pact of the next year but even anticipated its realization by a special agreement with Soviet Russia in 1929. On July 25, 1932, that protocol was developed into a pact of nonaggression. At the disarmament conference of the same year the Polish delegation had played an active part, submitting an elaborate plan of "moral disarmament"; but it became obvious that the idea of collective security had failed, and Poland sought better guarantees in bilateral agreements with its neighbours.

After 1932 this method was developed by the new minister of foreign affairs, Col. Jozef Beck, formerly Pilsudski's *chef de cabinet*, and found its strongest expression in another ten-year nonaggression pact, concluded on Jan. 26, 1934, with Germany. There was of course a reservation that the new treaty was not to affect Poland's previous engagements, particularly its alliance with France. Nevertheless, it seemed to involve a change in Poland's general attitude. Seeing that nobody in Europe was prepared to fight the new Adolf Hitler regime, Pilsudski found it necessary to accept a direct understanding with Poland's western neighbour also, holding the balance between the Soviet Union and Germany.

Moscicki and Smigly-Rydz.—After Pilsudski's death on May 12, 1935, the form of government which he had established continued without much change. The voting regulations, as applied at the elections of Sept. 8 and 15, 1935, without having been defined in the new constitution itself, again raised much discontent; but attempts were started to come to some co-operation with various groups of the opposition. The government bloc was dissolved and replaced by a Camp of National Unity. Both President Moscicki, who had been re-elected in 1933 for another seven-year period, and Marshal Edward Smigly-Rydz, Pilsudski's successor as commander of the army (who was styled "the second person" in the republic), exercised their authority with moderation and in a conciliatory spirit. Such an appeal to internal unity was indeed indispensable in face of the increasing danger of the international situation.

That danger resulted from the policy adopted by Germany. After the annexation of Austria and the destruction of Czechoslovakia, it was clear that Hitler wanted to isolate the eastern European states so as to be able to attack them one by one. Soon after Munich, when Poland had seized the opportunity to claim the contested Teschen territory (*see* above), there began a new tension with Germany. Yet on Jan. 30, 1939, Hitler reaffirmed the importance of the German-Polish nonaggression pact as a contribution to the peace of Europe; but he had already decided to annex the Free City of Danzig, and on March 27 he officially requested the Polish government to accept that solution as well as the construction of an extraterritorial motor road through the Polish province of Pomorze. Touched in its vital interest and realizing that it was a first challenge against its independence, Poland refused, making counterproposals which were never taken into serious consideration. As soon as Poland had exchanged with Great Britain reciprocal guarantees of independence and integrity, Hitler took it as a pretext to denounce, in his speech of April 28, the nonaggression pact of 1934.

During the next four months he tried to provoke Poland by various incidents in Danzig and started a propaganda campaign against an alleged ill treatment of the German minorities in Poland. But it was not until Germany had concluded, on Aug. 23, a new partition treaty with the U.S.S.R. that he finally decided to attack Poland. Two days later a close alliance was signed between Poland and Great Britain which made it absolutely clear that Great Britain, as well as France, would support its ally in case of war; but in spite of a patient conciliatory effort made by British diplomacy and proposals of a peaceful settlement put forward by various powers and accepted by Poland, Germany invaded Poland on Sept. 1, 1939.

WORLD WAR II

Poland, which had postponed the general mobilization to the last moment, was unable to stand against the overwhelming Ger-

man forces, the long open frontier stretching from East Prussia to Slovakia being already occupied by German troops; nevertheless, it made a courageous resistance in the centre of the country until Sept. 17, when the Soviet army invaded its territory from the east under the pretext that the Polish state was no more in existence. Even then in various regions desperate fighting was continued, and Warsaw, although severely bombed, like so many other open places, defended itself heroically until Sept. 27. The next day a second German-Russian treaty was signed in Moscow by Joachim von Ribbentrop and Vyacheslav Molotov redistributing the spoils; the eastern provinces, including purely Polish territories, were incorporated in the Soviet republics of Byelorussia and the Ukraine; the western part was left within the German sphere of influence.

Before leaving Polish territory, President Moscicki resigned and designated Wladyslaw Raczkiewicz as his successor. The new president appointed a new government, the former having been interned in Rumania. General Sikorski became prime minister, Zaleski minister of foreign affairs, and both president and government were established at Angers, Fr. The Polish army was also reconstituted in France to fight with the Allies, while some Polish warships, having escaped, joined the British navy.

Sikorski also became the commander in chief of the reorganized Polish army. This was possible because part of the army had passed into Hungary and Rumania and succeeded in assembling in France, where its ranks were swelled by mobilization among the prewar Polish emigrants in that country. The Polish army, numbering nearly 100,000, was ready by the spring of 1940. A Polish brigade fought in the Norwegian expedition of the Allies, especially in the battle of Narvik, and the Poles joined also in the defense of France.

The collapse of France was likewise a heavy blow for Poland. In spite of fresh losses and the capitulation of one of the Allies, the Polish army did not even then dream of ceasing to fight. About 15,000 who had heroically protected the retreat of one of the French armies had to cross into Switzerland, where they were interned. A part of the Polish army was transported to Great Britain, where, at the end of June 1940, the Polish government together with the president transferred itself. The Polish airmen began increasingly to distinguish themselves, acting with the royal air force, and simultaneously Polish divisions, dispersed through the world as of old in the Napoleonic wars, appeared in Palestine and on the Egyptian-Libyan battlefield. (*See* also WORLD WAR II.) (O. HA.; X.)

Germany divided the conquered Polish land into two zones. The provinces that had been ruled by Prussia from the Vienna settlement to 1918 and also part of central Poland with Lodz (renamed Litzmannstadt) and Plock were incorporated into the reich on Oct. 19, 1939. All the incorporated lands were destined for complete germanization. The remaining territory between the new German frontier and the Molotov-Ribbentrop line was organized as a *General Gouvernement*. It was divided into four districts: Warsaw, Lublin, Radom and Cracow. In Aug. 1941, shortly after the German attack on the Soviet Union, the province of Bialystok was incorporated into Germany, while Eastern Galicia, with Lwow, was added as the fifth district to the *General Gouvernement*. This territory was to be used mainly as a reserve pool of labour. All Polish elements were submerged, and it became for a time, as Hans Frank, the governor general, described it, "an intellectual desert."

Such a policy was countered by immediate reactions in the community. The professors of Cracow university, who were invited to co-operate in the administration of the *General Gouvernement*, preferred internment and death to assisting the Germans in any way. Polish property was confiscated, and continual deportations of workers into the reich enabled the Germans to solve their growing problem of manpower. Concentration camps were established, and Oswiecim (Auschwitz) became especially notorious for the deliberate and systematic torture and murder of its inmates. Unknown numbers of Poles perished there and it became the grave of a great part of the 3,000,000 Polish Jews. In opposition to this terror, the Poles organized a powerful underground movement which continued the cultural and social life of the people in secret schools, social services and an active press. A secret home army grew to considerable strength and carried out operations against German communications and institutions. The administration of the underground organization took its orders from the Polish government in London.

Far more complicated was the position of the Poles in the eastern areas occupied by the Soviet Union from Sept. 17, 1939, to late June 1941. There the problem was Ukrainian as well as Polish. All political leaders, Polish and Ukrainian, together with the bulk of the educated classes were deported, but less open violence and more subtlety were used than in the German zone and the annexation to the Soviet Union was effected only after a so-called plebiscite which was claimed to have justified the act. The growing terror under the Soviet police was checked by the German invasion, which made the position of Poles in the U.S.S.R. easier but offered a difficult problem to the Polish government in London. The great mass of the Poles abroad continued to regard the Italians, who had helped many of them to escape, as their friends, and to mistrust Soviet intentions toward their country. But political and military reasons led Sikorski to make an agreement with the U.S.S.R. The terms of this agreement, signed in London on July 30, 1941, ended the state of war between the two countries and raised hopes of an ultimate restoration of Poland in its former boundaries; but it was more immediately important in enabling Gen. Wladyslaw Anders to organize a Polish army in the Soviet Union. Sikorski visited Moscow and on Dec. 4 signed with Joseph Stalin a Polish-Soviet declaration of mutual assistance and collaboration. Stalin agreed that the Polish army in the U.S.S.R., originally projected as two divisions, should be increased to a strength of six divisions. About 75,000 of the men already recruited by Anders were allowed to leave for the middle east in March and Aug. 1942. Unfortunately, as the danger of defeat by the Germans was averted, the Soviet authorities began to adopt a more aggressive attitude to Polish claims.

It was possible to form a Polish army in the U.S.S.R. since there were more than 200,000 Polish prisoners of war taken by the Russians in Sept. 1939 and hundreds of thousands of Polish nationals deported. Securing a corps of officers for the new army offered a more serious problem. In Oct. 1939 about 14,300 Polish officers were segregated by the Soviet authorities into three prison camps at Ostashkov, Kozelsk and Starobelsk. The Polish authorities in the Soviet Union and the Polish underground in the homeland failed to find any trace of the missing officers after April 1940, although it was suggested by the Soviet government that they had been exchanged with their German allies in 1940. When in April 1943 mass graves were discovered in Katyn wood near Smolensk, containing the bodies of the men who had been imprisoned in the Kozelsk camp, the Germans accused the Russians of having murdered them. The Soviet government refused an investigation by an International Red Cross commission suggested by Sikorski and, on April 25, 1943, broke off diplomatic relations with the Polish government.

Sikorski was killed in an aeroplane accident at Gibraltar on July 4, 1943, and was succeeded as prime minister by Stanislaw Mikolajczyk, the leader of the Peasant party, and as commander in chief by Gen. Kazimierz Sosnkowski. As their military position improved and they began to reoccupy Polish territory, the Soviet authorities' new policy became more anti-Polish. They revived their claim to the eastern provinces and began to protect a group of Poles who were prepared to accept this claim. This group was joined by a number of Polish Communists including Boleslaw Bierut and came to be known as the "Lublin committee" and then to be a provisional Polish government. All attempts by the London government to co-operate with or oppose them came to nothing, and the Soviet authorities started a great campaign of propaganda to discredit the legal Polish government in London.

Another move was to smuggle Communists into German-occupied Poland ostensibly to help but really to displace the leaders of the underground movement. These leaders continued to carry on their heroic struggle in co-operation with the government in London. As at the end of July 1944 the Soviet army

reached the Vistula and neared Warsaw the underground was requested by broadcasts from Moscow to support it, and Gen. Tadeusz Bor-Komorowski, commander of the home army, under orders from the military headquarters in London, started an open struggle in Warsaw on Aug. 1, 1944. Despite the efforts of the western Allies to send arms and supplies by air, the sacrifice was made useless by the inactivity of the Soviet armies, which refused to send any support. The struggle continued for 63 days, after which further resistance was impossible.

Even before this tragic event the Soviet generals, as they advanced into Poland, had been disarming and deporting members of the home army which was helping them. Now that the main army of the underground had perished, the task of the Soviet political leaders was made easier. While the Polish forces in the west continued to fight the battle with their Allies on land, sea and in the air, especially in the great advance through Italy, and, after June 6, 1944, in northern France, Belgium and the Netherlands, the Russians did all they could to discredit the Poles fighting against the common enemy in Poland and the government in London to which they gave their allegiance.

The fate of Poland was now taken over by the Great Powers, which at the Yalta conference in Feb. 1945 tried to settle the difficult questions which had arisen. As a result, the Soviet Union was able to obtain recognition of the Lublin committee. Both the Polish government and the underground movement sank out of sight, and when World War II came to an end a Polish "people's republic" was established. (A. B. Bo.)

THE "PEOPLE'S REPUBLIC"

Pres. Franklin D. Roosevelt, Winston Churchill and Marshal Stalin decided at Yalta, on Feb. 11, 1945, that a "Polish provisional government of national unity" should be created; *i.e.*, that the Soviet-sponsored government formed at Lublin on Dec. 31, 1944, should be reorganized to include "other Polish democratic leaders from Poland and from abroad." The three powers jointly engaged that free and unfettered elections on the basis of universal suffrage and secret ballot should be held as soon as possible. After four months of diplomatic discussion among Moscow, London and Washington concerning the exact interpretation of the Yalta decision, a Polish round-table conference met in Moscow on June 17 to discuss the formation of a Polish government. Among leaders from within Poland and from abroad attending the conference were Mikolajczyk (who had until Nov. 24, 1944, been premier of the Polish government in London) and Wladyslaw Kiernik, both sent to Moscow by the aged Witos and representing the Polish Peasant party. On June 28, 1945, the composition of the government was announced. It showed that the Soviet interpretation of the Yalta declaration had prevailed: of the 21 members of the cabinet only 5 were newcomers, the most important being Mikolajczyk, who became second deputy premier; 16 ministers were former members of the Lublin government, including Edward Osobka-Morawski, leader of a split Socialist group, who remained premier. Bierut, who from July 22, 1944, had been chairman of the presidium of the so-called Polish national home council, became provisional president of the republic. Without waiting for the formation of the provisional government of "national unity," Stalin and Osobka-Morawski on April 21, 1945, signed in Moscow a Soviet-Polish treaty of friendship, mutual assistance and postwar collaboration. On July 5 the British and the U.S. governments recognized the new Warsaw government and withdrew recognition from the London government composed of representatives of the National, Christian Democratic and Socialist parties and presided over by Tomasz Arciszewski, a senior Socialist leader who until July 1944 was the chairman of the underground Council of National Unity in Warsaw.

Only on Nov. 13, 1946, under pressure of the British and the U.S. governments, Bierut signed a decree fixing Jan. 19, 1947, as the date for the Polish elections. The official figures stated that 11,413,618 voted out of 12,701,056 qualified electors: 9,003,682 (89.8%) voted for the Communist-controlled Democratic bloc and 1,154,847 for the Polish Peasant party. Out of 444 seats in the *sejm* the Democratic bloc secured 382 (118 Communists, 108 Communist-controlled Peasants, 118 left-wing Socialists and 38 Democrats), the Polish Peasant party 28, the proregime Party of Labour (allegedly Christian Democratic) 17, the proregime "New Liberation" peasant group 13 and the Independents 4. It was officially stated in both the United States and Great Britain that the elections were neither free nor fair. The new *sejm* on Feb. 5 elected Bierut president of the republic, and two days later he appointed a new government headed by Jozef Cyrankiewicz, a left-wing Socialist.

A striking political development took place within the ranks of the Polish Workers' (Communist) party on Sept. 3, 1948, when it was announced that Wladyslaw Gomolka, its secretary-general and first deputy premier, had been accused of "rightist and nationalist deviation" and been obliged to recant and to resign from both offices. Although the leadership of the split Polish Socialist party was already purged, there was still resistance against a proposed merger with the Communist party which, for the former, was equal to dissolution. Nevertheless, the merger congress assembled in Warsaw from Dec. 15 to Dec. 22, 1948. The new party was called the Polish United Workers' party, and Bierut became its chairman. Among the 11 members of the Politburo were three former Socialists, including Cyrankiewicz. Mikolajczyk, accused on Oct. 12, 1947, of being "an ally of foreign imperialists," escaped and arrived in London on Nov. 3, 1947. On Nov. 30, 1949, the rump of the Polish Peasant party and the two Communist-controlled peasant groups were fused under the name of United Peasant party. In July 1950 the Party of Labour was absorbed into the Democratic party.

The new constitution passed unanimously by the *sejm* on July 22, 1952, was modelled on the Stalin constitution of 1936. The supreme organ of state authority was the council of state (in the U.S.S.R. the presidium of the supreme soviet) elected by the *sejm* and composed of a chairman, four deputy chairmen, a secretary and nine members. The supreme organ of state administration was the council of ministers appointed by and responsible to the *sejm*, or to the council of state when the *sejm* was not in session.

The electoral law adopted by the *sejm* on Aug. 1 accorded the franchise to all citizens of 18 years, including members of the armed forces; citizens of 21 years were eligible for election. There was one deputy for every 60,000 inhabitants. The 425 members of the new *sejm* were elected on Oct. 26, 1952, in Soviet fashion; *i.e.*, there was only one list of official candidates in each of 67 constituencies and 99.8% of valid votes were allegedly cast for them.

The New Frontiers.—On Aug. 16, 1945, Molotov and Osobka-Morawski signed in Moscow a treaty demarcating the Soviet-Polish frontier. This demarcation, more or less identical with the so-called Curzon line, restored to Poland the province of Bialystok in the north and a smaller area in the south including Przemysl, which the Molotov-Ribbentrop line had assigned to the U.S.S.R. In a small exchange of territory on Feb. 15, 1951, the U.S.S.R. acquired a strip of land of 185 sq.mi. south of Hrubieszow containing part of the railway system feeding the strategic centre of Lwow, while a similar area south of Przemysl, including the town of Ustrzyki Dolne and a sector of the sub-Carpathian oil field, was returned to Poland. (*See* fig. 3.)

On Aug. 2, 1945, at Potsdam, Pres. Harry S. Truman, Clement Attlee and Marshal Stalin published a statement establishing a new *de facto* western frontier of Poland along the rivers Oder and Neisse. The former German territories east of this line, including the Free City of Danzig but excluding the portion of East Prussia incorporated in the U.S.S.R., were placed under Polish administration. The Polish government was also authorized to undertake the transfer to Germany of the German populations east of the Oder-Neisse line. On July 6, 1950, an agreement recognizing the Oder-Neisse line as the permanent frontier was signed at Zgorzelec (Görlitz) by Otto Grotewohl and Cyrankiewicz, premiers of the German Democratic Republic and of Poland, respectively. On Jan. 27, 1951, at Frankfurt-on-Oder, Georg Dertinger and Stanisław Skrzeszewski, ministers of foreign affairs of eastern Germany and of Poland, signed the act of frontier demarcation.

The Polish-Czechoslovakian frontier in its prewar half remained as fixed on July 28, 1920; that is to say, the disputed territories of Teschen (349 sq.mi.) and of Orawa and Spisz (70 sq.mi.), which had been seized by Poland in Oct. 1938, were left to Czechoslovakia.

As compared with its territory before World War II, Poland was shifted westward considerably. In the east it lost 68,667 sq.mi. and in the west it gained 38,974 sq.mi., its new area being 120,359 sq.mi.

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(K. Sm.)

POPULATION

At the beginning of the historical period the Poles lived between the Baltic sea and the Carpathian mountains and the Oder and Bug rivers. They were one of the western branch of the Slavonic group of peoples. The Polish nation originated from three main tribal groups, the Polanie, the Mazowszanie and the Pomorzanie. Because of their central position, the Polanie, or dwellers in the plains (*pole,* "field"), gave their name to the country, *Polska,* and to the people, *Polacy* (singular *Polak*).

The Polanie themselves were originally composed of many tribes, the most important of them being the Slezanie (now Slazacy or Silesians) who settled on both sides of the middle and upper Oder; the Kujawiacy (Kujavians) who lived between Lake Goplo and the Vistula; and the Wislanie, called later Malopolanie, on both sides of the upper Vistula.

The Mazowszanie or Mazovians lived on both sides of the middle Vistula, and their Baltic neighbours to the northeast were the Lithuanians and the Prussians. The Mazurians of East Prussia were descendants of Mazovian settlers who came there in the 15th century.

The Pomorzanie or Pomeranians, as their name indicates, were living along the seacoast (*po,* "toward"; *morze,* "sea") between the lower Oder and lower Vistula. They formed an element of transition between the Polanie and the Polabians (*po Labě,* "along the Elbe"). The Polabians were germanized between the 10th and the 18th centuries, as were also those Pomeranians who remained outside Poland after the treaty of Torun of 1466.

Linguistically, however, two local Pomeranian dialects remained until the 20th century, the Slovince (Slowinski) and the Cassubian (Kaszubski). Slovince was spoken until World War I along the Baltic coast line between Slupsk (Stolp) and Lebork (Lauenburg). At mid-20th century Cassubian was still spoken west of Danzig in the districts of Wejherowo and Kartuzy.

Preliminary figures published after the census of Dec. 3, 1950, gave 24,976,926 as the total population of Poland, composed of 11,912,514 males and 13,064,412 females. At the time of the summarized census of Feb. 14, 1946, the total was 23,929,757. The last pre-World War II census (1931) recorded a total of 32,107,252, while an estimate for Sept. 1, 1939, stated it to be 35,339,000 (excluding the Teschen disputed territory). Both sets of figures illustrated the high rate of natural increase which distinguished Poland from its western neighbours. The actual increase between 1946 and 1950, calculated by the authorities in Warsaw to be about 2,139,000, was greater than apparent, having been obscured by two-way movements of population. The rate of increase, estimated at 1% a year even after allowing for the aftermath of World War II, was expected to bring the total population in 1960 to about 27,000,000. This would mean an average density of 228 persons per square mile (212 in 1931).

No part of Europe was more profoundly affected by the great displacements of population which took place in and for some years after World War II. Polish citizens were deported by both occupying powers during the German-Soviet partition and by the Germans over the whole of Poland after June 1941. As the tide of war swept back across Poland in 1944 and 1945, heavy casualties were inflicted upon the local population, the Polish resistance being a mass movement.

The territories annexed by the Soviet Union had a population of about 10,768,000 in 1939; by June 30, 1949, only 1,503,800 persons of Polish nationality were transferred from Soviet territory to the new Poland. The recovered lands in the west (*i.e.,* former territories of Germany and the Free City of Danzig) had in 1939 a total population of about 8,300,000, including 1,012,000 Poles. The 1946 census disclosed a population there of 5,022,200, including 2,075,900 Germans. By 1950, in accordance with the decisions of the Potsdam conference, all the Germans had been transferred to Germany. After this evacuation most of the population of the recovered lands was composed of autochthonous Poles, who had formed a minority in Germany and had been subjected to gradual germanization. To these indigenous inhabitants were added Poles repatriated from the Soviet Union, Poles repatriated from the west (mainly from Germany, France and Great Britain) and Poles transferred from the central parts of Poland. Central Poland (territories Polish both before 1939 and after 1945) counted more than 23,000,000 persons in 1939 but fewer than 19,000,000 in 1945.

As a result of all these displacements and territorial changes, Poland was converted from a country with large ethnographic and religious minorities into one almost entirely Polish in language and Roman Catholic in faith. The situation in 1931 is summarized in Tables I and II.

TABLE I.—*Population According to Language (1931 Census)*

Language	Number	Percentage
Polish	21,993,400	68.9
Ukrainian*	3,222,000	10.1
Ruthenian*	1,219,600	3.8
Byelorussian	989,000	3.1
Russian	138,700	0.4
German	741,000	2.3
Yiddish and Hebrew	2,732,600	8.6
Miscellaneous†	878,600	2.8
Total	31,915,800‡	100.0

Sic the source; but Ukrainian and Ruthenian are two names for the same language.
†This rather high figure includes 708,200 "locals"; *i.e.,* Byelorussian inhabitants of Polesia. ‡Excluding about 191,500 troops in barracks.
Source: *Maly Rocznik Statystyczny* (Warsaw, 1939).

TABLE II.—*Population According to Religion (1931 Census)*

Religion	Number	Percentage
Roman Catholic		
Latin rite	20,670,100	64.8
Greek Catholic rite	3,330,200	10.4
Orthodox	3,762,500	11.8
Lutheran, Reformed, etc.	835,200	2.6
Other Christian	145,400	0.5
Jewish	3,113,900	9.8
Other non-Christian	6,800	0.0
Unclassified	45,700	0.1
Total	31,915,800‡	100.0

The loss of territories to the Soviet Union deprived Poland of the Ukrainian, Byelorussian and Lithuanian minorities as well as many Jews, who were regarded automatically as Soviet citizens and absorbed into the adjoining Soviet republics. The most terrible change, however, was brought about by the disappearance of the large Jewish minority. Scattered over the whole of Poland, but particularly numerous in the cities, nine-tenths of them speaking Yiddish, the Jews had been a characteristic feature of Poland. They numbered about 3,440,000 in 1939 but fewer than 100,000 in 1951. The Nazi racial policy, manifested at first in the creation of the Lublin reservation and then in the segregation of the Jews into ghettoes in all the larger towns, resulted in the systematic extermination of more than 2,000,000 Polish Jews. The massacre of the Warsaw ghetto in 1943 and the work of the extermination camps at Oswiecim, Majdanek, Belzec, Chelmno, Sobibor and Treblinka were extreme examples of Nazi brutality.

Roughly one-third of the former Polish Jewish minority lived in territories annexed by the Soviet Union, by whom they were

generally regarded as not eligible for the option of Polish citizenship in 1945. Jews were, however, repatriated to Poland; probably half the total of 300,000 Jews who had fled or were deported to the Soviet Union in addition to those in the annexed territories were permitted to return to Poland after the war. The American Joint Distribution committee sponsored the emigration of most of these to Palestine in 1946 and 1947. Subsequently, the Polish government's general ban on emigration was extended to the Jews also, although a few continued to receive exit permits.

Apart from the Jews, major dislocations of the population of Poland after 1939 were as follows: Poles expelled from areas incorporated in 1939 into Germany, more than 2,000,000; Poles sent to German camps and forced labour, more than 3,000,000; Poles deported to Soviet camps, 1939–40, more than 1,000,000; Ukrainians, Byelorussians and Lithuanians transferred from central Poland to the U.S.S.R., 1945–49, more than 518,000; Germans fled and repatriated from lands east of the Oder-Neisse (including 741,000 in prewar Poland), about 7,900,000.

TABLE III.—*Development of Major Towns, 1880–1950*
(To nearest thousand)

Town	1880	1910	1921	1939	1946	1950
Warsaw	383	781	937	1,289	479	650
Lodz	48	408	452	672	497	620
Cracow	66	143	184	259	299	330
Poznan	65	150	169	272	268	320
Wroclaw	268	506	528*	621	171	290
Danzig (Gdansk)	102	162	195	258†	118	193
Szczecin	92	232	233*	268	73	178
Katowice	13	43	50	134	128	141
Bydgoszcz	34	53	88	141	135	160
Chorzow	27	73	73	110	111	142
Zabrze	13*	63*	67*	126	104	133
Gliwice	15	65	69*	114	96	128
Bytom	23*	67	53*	101	93	121
Lublin	33	66	94	122	90	116
Czestochowa	21	73	80	138	101	111
Gdynia	—	1	1	120	78	103

*Including troops in barracks. †1935.

Table III illustrates the main trends of urban population after 1880. It shows clearly the sudden development of Polish cities after 1920 with the restoration of Polish sovereignty, and especially the transformation of Gdynia from a fishing village to a port of international significance—a development which was one of the more remarkable feats of pre-1939 Poland. The vast losses borne by Warsaw during World War II, the decline of the Silesian towns and the Baltic ports and the changes in other towns appear in the figures for 1946. Those for 1950 show to what extent the losses were reversed. The population of Warsaw, reduced to 153,000 in Jan. 1945, had recovered to 650,064 by Dec. 1950 and, within wider administrative boundaries, to 760,000 by 1951, which, however, was still below the figure for 1910. The rate of rebuilding devastated Warsaw was one of the controlling factors; another was the increasing attention given to the development of heavy industry, particularly although not exclusively in Silesia and the recovered lands. An example of the last trend was the development of a new town at Nowa Huta, near Cracow, planned to house 100,000 people.

Poles Abroad.—The Poles are one of the most widely dispersed of the European people. The lack of natural frontiers east and west encouraged at one period the great spread of Polish culture over a wide area but led at another to dismemberment by the neighbouring great powers, Austria, Prussia and Russia or Germany and the Soviet Union. Major European wars swept back and forth across the Polish lands and left devastation in their wake. Despite the effects of war and occupation, Poland, particularly in the fertile areas of ancient settlement in the southern provinces, felt the pressure of its own populations and provided colonists and foreign labour in most corners of the world.

Poles abroad, therefore, became divided into two categories: the autochthonous Poles inhabiting alien territory contiguous with the political frontiers of Poland and the emigrants and refugees. Between 1922 and 1939, the largest groups of autochthonous Poles were in eastern Germany, numbering 1,012,000 when brought under Polish control in 1945, and in the U.S.S.R., where, according to the Soviet census of 1926, there were 792,471 Poles, including 476,435 in the Ukraine and 97,948 in Byelorussia. Poles were estimated in Lithuania at 200,000, in Latvia at 75,000 and in Rumania at 65,000 (including 50,000 in Bukovina). The three last-named territories all formed part of the U.S.S.R. by 1945. To these were added the Poles in the Polish territories incorporated by the Soviet Union. Perhaps the major part of these eastern Poles were dispersed; some were deported to the east, a part of whom succeeded in joining the Polish army which left the U.S.S.R. in 1941–42; some were repatriated in 1945. Yet others found the claim to Polish nationality discounted, and an uncertain number perished. Finally, according to the Czechoslovakian census of 1930, there were 77,300 Poles living in the disputed Teschen area, which later again became part of Czechoslovakian territory; according to Polish official estimates these numbered 170,000. The exact number of autochthonous Poles was not accepted by all the states involved; estimates are complicated by the prolonged intermingling of cultures and tongues, by intermarriage, by rival political propaganda and forced assimilation and by the changing frontiers.

The largest number of emigrants before 1939 settled in the Americas. By 1951 they included about 180,000 in Canada (mostly in Ontario and the prairie provinces), 300,000 in Brazil (mostly in Paraná), 70,000 in Argentina and 18,000 in Paraguay; but the greatest single group was in the United States, where there were probably 4,500,000 persons of Polish descent. Official statistics for 1940 revealed that there were 2,416,320 persons in the United States whose mother tongue was Polish, the largest non-English-speaking group after the German- and Italian-speakers. Chicago was the largest Polish centre, with about 500,000 Poles; Detroit had 200,000, Buffalo, Cleveland and Milwaukee each more than 100,000 and New York city, Pittsburgh and Philadelphia each 50,000. Poles engaged in agriculture, about one-fifth of the total, were spread across the states of Michigan, Wisconsin, Missouri, North and South Dakota and Texas. Immigration was at its greatest up to about 1930, before the quota systems and the world economic depression had everywhere dried up the streams of settlers to the new world. Between 1921 and 1930 more than 200,000 Poles entered the United States. Steady assimilation ensued, of course, but these U.S. citizens maintained a strong interest in Polish culture and the homeland. They established innumerable social and cultural organizations, including the Polish National alliance, the Polish Roman Catholic union and the Polish-American congress—all with headquarters in Chicago. By 1950 there were about 800 Roman Catholic Polish parishes. The number of Polish-language schools and publications, although tending to decline, remained large; in 1950 there were 600 primary schools, with 300,000 pupils, and 20 higher schools. Out of a total of 96 Polish periodicals appearing in the United States there were 9 daily newspapers.

The largest group of emigrants in Europe went to France, settling for the most part in the northern mining areas. After the onset of the economic depression they declined from 800,000 to about 600,000 in 1939. In 1950 they probably numbered fewer than 500,000. In the Ruhr, the "Westphalian" Poles formed another considerable group but, like their compatriots in France and Belgium, were somewhat reduced in numbers by World War II and by postwar repatriation, numbering fewer than 100,000 in 1950.

Many thousands of Polish refugees were driven abroad by World War II, and smaller numbers continued to escape across the Polish frontiers, defying the general ban on emigration. Many of these refugees went to those countries where large colonies existed already, particularly the United States and France, Canada and Australia (where there were 2,000 Poles before the war). The greatest change brought about by the war was the establishment of a Polish colony in Great Britain, where the Polish government had its seat. The majority of the Poles in Great Britain was constituted by the 100,000 ex-servicemen and their families who were assisted by the Polish Resettlement corps in finding civilian employment. Most of the political *émigrés* settled in London. After the derecognition of the Polish government in London a shadow organization continued with president, government and national council. Most of the larger political parties in exile—the

Socialist, the National and the Freedom and Independence, with a peasant group—organized the Polish Political council, with its headquarters in London. A third political grouping, the Polish National Democratic committee, mainly Peasant party, was established in Washington, D.C. These various groups maintained contacts with the European movement, the International Confederation of Free Trade Unions, the Peasant International, the National Committee for Free Europe in the United States, etc. A special British-Polish committee under the ministry of education supervised the Polish schools in Great Britain. A Polish university college in London, a Polish research centre, the Sikorski Historical institute and many cultural, social, professional and trade organizations were established. There were numerous Polish publications in Great Britain at mid-20th century, including an independent daily paper, the *Dziennik Polski.*

The United States made special provision in excess of the usual quota to enable Polish ex-servicemen and displaced persons to enter the country. Various funds were established to assist the general relief work. The Paderewski foundation of New York did much to help the Poles, particularly in cultural matters, in which it supplemented the work of the Kosciuszko foundation (established 1925).

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GOVERNMENT, DEFENSE AND EDUCATION

Constitution.—The constitution of 1921 was based on the best democratic traditions of Poland and of the western nations. It was superseded by the constitution of 1935, which, reflecting the internal political disputes and the mood of the prevailing international situation, showed what the major political parties described as quasi-authoritarian tendencies. After the dismemberment of Poland in 1939 and the subsequent regrouping of military and political personalities, the exiled leaders signed the Paris agreement of 1939, by which the powers of the president under the constitution of 1935 were modified. To speak generally, the standpoints of the three major *émigré* groups were determined in relation to these constitutional changes, the Polish National Democratic committee supporting the constitution of 1921, the Polish Political council standing by the Paris agreement and the government in exile clinging strictly to "legal continuity" and the constitution of 1935 until such time as it could be constitutionally modified in the homeland.

The Communist party, which was illegal before 1939, introduced a barely disguised single-party system when it got control. The stages in this development were (1) the formation in the U.S.S.R. of the Polish National Committee of Liberation, representing the Communist-controlled groups which later formed the nucleus of the postwar government; (2) the elections of Jan. 19, 1947, to a single-chamber *sejm,* the elections being weighted entirely in favour of the Communist-controlled bloc of parties; (3) the Constitutional act of Feb. 19, 1947, which quoted freely from the constitution of 1921, passed immediately by the new *sejm* and known as the "small constitution." This *sejm* was to have a life of five years and was charged with the task of passing a permanent form of constitution.

Several subsequent constitutional amendments further confirmed the government in its power to rule by decree and reduced the *sejm* to a body merely registering approval. The Polish United Workers' (Communist) party exerted control over all governmental and administrative bodies, both national and local, by direct membership and by duplicate party organizations. The highest officials, the president and leading ministers such as those controlling defense, security, economics and justice became members of the Politburo.

According to the "small constitution" in force from 1947 to 1952, the supreme organs of government were (1) the president of the republic, elected for seven years; (2) the *sejm,* elected for five years; (3) the state council with the president as chairman, other members being the speaker and deputy speakers of the *sejm,* the commander in chief of the armed forces in time of war and up to three other members appointed by the *sejm* and unanimously approved by the state council; (4) the council of ministers under the chairmanship of the prime minister, the cabinet council consisting of the council of ministers under the chairmanship of the president of the republic; (5) the supreme chamber of control under a president elected by the *sejm,* functioning as a supreme auditing and control authority; (6) the courts of justice, theoretically independent but gradually remodelled into an instrument of the Communist party.

Defense.—Between the armed forces of pre-World War II Poland and those established after 1945 there was no continuity; personnel, organization, training and equipment were completely changed. The Polish army suffered catastrophically from the German and Soviet invasions, although certain naval, army and air force units escaped abroad and made an uninterrupted and important contribution to the Allied war effort from the Polish headquarters in Britain. The fate of the Polish units in the east, their imprisonment, release and recruitment into the Polish army under Gen. Wladyslaw Anders, their exodus from the U.S.S.R. through the middle east and their subsequent battle engagements in the battle of Britain (during which the Polish airmen shot down 14% of the enemy aircraft destroyed), at Narvik in Norway, at Tobruk in Cyrenaica, at Monte Cassino in Italy and at Falaise in France provided one of the great epics of World War II. Out of 215,000 Poles fighting with the Allies in the west, 150,000 chose to remain in exile, and those who returned were not allowed to form any part in the new defense organizations.

A Communist-dominated Polish army was organized in the Soviet Union in 1943 and 1944, eventually numbering ten infantry divisions, an armoured corps and an air force.

Between 1944 and 1947 the Communists were occupied with the liquidation of the Polish home army, the main fighting organization of the underground government, which was supported by the mass of the people and directed by the Polish government in London until its derecognition in 1945. By 1947, aided by the presence in strength of the Soviet army and by the Communist militia, a new "people's army" had been established around the nucleus formed in Russia. On Nov. 7, 1949, Marshal Konstantin Rokossovsky (thenceforward Konstanty Rokossowski) was transferred from his command of the Soviet army troops stationed permanently in the Polish recovered territories at Legnica (Liegnitz) to become Polish minister of defense and commander in chief; on May 8, 1950, he also joined the Politburo of the Communist party. Many other Soviet officers acquired key positions in the Polish forces, which were modelled on the Soviet prototypes.

Including the forces of the interior (frontier guards, security troops), the Polish armed forces were thought to have reached a total of more than 500,000 by 1950. There were then four military areas (Warsaw, Bydgoszcz, Wroclaw and Cracow) comprising 16 divisions. By 1952 it was believed that four more divisions had been formed. In addition, Soviet army and air force units were maintained in the recovered territories and naval units at Swinoujscie and the former Polish naval base at Oksywie; the extraction of uranium ore in the neighbourhood of Jelenia Gora (Hirschberg) in the Sudeten mountains was a strict Soviet monopoly. The Polish navy in 1950 consisted of 1 destroyer, 3 submarines, 2 motor-torpedo boats, 13 minesweepers and 12 submarine chasers.

Military service was made universal and compulsory between the ages 20 and 50. In 1950 active service was two years in the army, three years in the air force and the navy, two years in the anti-aircraft units and 27 months in the forces of the interior. Women were called up for six months' active service. Premilitary training was afforded by the youth clubs and the Service for Poland brigades.

Education.—Before 1939 the educational system was based on the principle of free and compulsory elementary education for all between the ages of 8 and 15 years, with nursery schools serving younger children from the age of 3. Secondary education, which was selective, was provided in two stages, the grammar schools for those aged 12–16 years and the lycea for those aged 16–18, the

latter being maintained by the state, the municipalities and private organizations. In addition, there was a great variety of trade and professional schools which afforded theoretical and practical professional training as well as general education. The universities, of which several were ancient foundations, preserved the independent traditions of the finest schools of Europe. The educational authorities had been faced with the great task of unifying the former German, Russian and Austrian components of the new republic, in the last two of which illiteracy was widespread. In the great release of Polish intellectual life which began in 1918, the needs of the various national minorities were not forgotten.

The Germans in World War II attempted to destroy the educational and cultural system which had been steadily fostered by the Polish republic. In the incorporated areas no Polish schools were permitted, the Polish tongue was forbidden and the University of Poznan was entrusted with the special mission of propagating German culture. In the area of the so-called *General Gouvernement,* a restricted number of elementary and technical schools was permitted, while the teaching of all subjects dealing with Polish affairs was strictly excluded. The losses in personnel and property were enormous, the damage to buildings and the destruction of libraries, collections, museums, archives and records almost incalculable. More than 1,500,000 orphans were left to be cared for. Only the strength and deep-rooted nature of Polish culture, instructed by its historic experiences and aided by the great progress achieved up to 1939, enabled it to survive the onslaught of the invaders.

The policy of the post-1945 Polish government was the gradual replacement of the old system by a Stalinist-Marxist one at every level. The state control and censorship of all organs of information rendered this policy more effective. The influence of the state and, therefore, of the Communist party became absolute; private and independent institutions (such as those organized by the Roman Catholic Church, the Lutheran Church, the religious orders and the scientific and historical societies) had by 1952 been closed down or subjected to governmental interference. The enormous task of postwar rehabilitation called for state support and opened the door to party control. The development of the new educational system proceeded most easily in the regained territories, where a clear field was presented to the Communist organization, the Society of the Friends of Children, to plan schooling and the training of teachers on lines excluding those aspects of the former system to which the party objected. Besides the steady imposition of Marxist uniformity, the government was confronted with the need to supply trained citizens to man the ambitious program of industrial expansion, maintain and if possible improve technical standards and fill the ever-increasing state services, civil, security and military, and the public utilities. At mid-20th century there was free, compulsory and universal education for the nursery, primary and intermediate stages, which covered the years from 4 to 6, from 7 to 15 and from 15 to 18 or 19. No member of the community, except those too young for the factory crèches or nursery schools or too infirm to attend one of the numerous adult classes (which included even elementary tuition), was far removed from one course or another. Political instruction permeated every other form of education, from highest to lowest, and all organized cultural and recreational activities as well; the classroom, lecture hall, factory workshop, tractor station, barracks room, sports club, press, radio, motion picture and theatre were all subject to it.

The work of education was therefore shared by the governmental organs and the party officials. In 1952 the ministry of education controlled the lower schools, nursery, primary and intermediate, both general and vocational; the technical and special schools and supplementary courses on the appropriate level; and the central office of vocational training. The ministry of higher schools and learning controlled the universities, colleges of engineering and the increasing number of institutions affording specialist training at the highest level. The Supreme Technical organization, embodying all the technical associations of Poland, also came under the ministry of higher schools. The organization of the medical, pharmaceutical, dental and nursing professions was the concern of the ministry of health. The medical faculties were detached from the universities, and 11 medical academies had been established by 1952.

The senior learned societies of pre-1939 Poland were the Polish Academy of Learning in Cracow, founded in 1872, which maintained stations in Paris and Rome, and the Warsaw Scientific society, reopened as a continuation of the erstwhile Royal Society of the Friends of Science, dating from the 18th century. Both were seriously affected by the depredations of war and postwar political conditions. At the first congress of Polish science, held in Warsaw in July 1951, a new Soviet-type Polish Academy of Sciences was initiated; this body, in collaboration with the various government departments and party committees, was created to ensure the conformity of all higher learning and research with Stalinist-Marxist dogma. Chairs of dialectical and historical materialism and Michurinian genetics had already been established at the Polish universities.

Schooling was assisted at every level by free tuition, and the granting of scholarships for those attending higher schools was theoretically automatic. Qualifying certificates had to be supplemented by approval from the Union of Polish Youth, which could prevent a student's passing from one stage to the next by describing him as unsuitable. Class origin was another important qualification, it being an advantage to emanate from a proletarian or peasant background. Finally, students were closely influenced in their permitted specializations by state requirements and in their subsequent employment by the general direction of labour.

In the year 1949–50 Poland had 5,860 kindergarten schools, with 343,000 pupils, and 22,417 primary, with 3,242,000. Secondary schools (1948–49) comprised 335 grammar schools, with 197,110 pupils, 486 lycea, with 140,893, and 1,131 vocational, with 183,440. Teachers' colleges numbered 149, with 32,570 students, in 1950–51.

Higher academic institutions had 96,762 students in Dec. 1949, distributed as follows: in Warsaw, 9,793 at the university, 5,733 at the College of Engineering, 2,113 at the College of Agriculture, 2,129 at the Academy of Planning and Statistics, 314 at the Gen. K. Swierczewski Academy of Physical Culture, 2,866 at the Academy of Political Science and 324 at the Academy of Fine Arts; in Torun, 3,139 at the Copernicus university; in Poznan, 8,809 at the university and 3,124 at the Academy of Commerce; in Lodz, 8,658 at the university, 2,065 at the College of Engineering and 745 at the Academy of Planning and Statistics; in Lublin, 3,327 at the Marie Curie-Sklodowska university and 2,030 at the Catholic university; in Gdansk (Danzig), 3,017 at the College of Engineering and 1,805 at the Medical academy; in Szczecin, 309 at the Gen. K. Swierczewski Medical academy and 2,060 at a branch of the Poznan Academy of Commerce; in Wroclaw, 8,385 at the university and 2,322 at the College of Engineering; in Bytom, 625 at the L. Warynski Medical academy; in Gliwice, 3,051 at the College of Engineering; and in Cracow, 11,301 at the Jagiellonian university, 4,758 at the Mining and Metallurgical academy and 404 at the Academy of Fine Arts.

The loss of the eastern territories deprived Poland of two of the oldest universities, the Stephen Bathory at Wilno (founded in 1578) and the John Casimir at Lwow (1668), although a part of the latter was transferred to the new university at Wroclaw. Three other universities were founded after 1945; viz., those at Torun and at Lodz and the Marie Curie-Sklodowska university at Lublin. The greatest development in higher schools was in the vocational sphere. By 1950, there were 39 institutions in this category, with 18,816 students. They were distributed in Warsaw (engineering, psychology, law, pedagogy, plastic arts, drama, music), in Poznan (engineering, music, plastic arts, operatics), in Lodz (agriculture, pedagogy, music, plastic arts, films, drama), in Gdansk (Danzig) (engineering, pedagogy), in Sopot (naval commerce, fine arts, music), in Szczecin (engineering), in Wroclaw (commerce, pedagogy, music, plastic arts), in Cieszyn (Teschen) (agriculture), in Czestochowa (engineering, commercial administration), in Katowice (economic administration, pedagogy, music, plastic arts) and in Cracow (social sciences, pedagogy, music, plastic arts, drama). The larger of these schools were the techni-

cal schools in Warsaw (the former Wawelberg and Rotwand), Poznan and Szczecin, with 1,182, 1,526 and 1,519 students, respectively; the Gdansk evening college of the supreme technical organization, with 886; the Sopot Higher College of Overseas Trade, with 777; the Wroclaw Academy of Commerce, with 2,376; and the state higher colleges, of economic administration in Katowice, with 1,941, and of social sciences at Cracow, with 1,061.

ECONOMIC CONDITIONS

There was a certain similarity between the problems facing the Polish government in 1918 and those in 1945. After World War I losses of national wealth had to be made good and the differing systems of the Austrian, Prussian and Russian zones unified into one viable whole. World War II, it was estimated, destroyed 38% of the total national wealth, more than three times as much as World War I. In addition, Poland had acquired important new territories and lost 45% of its former area. Apart from the work of reconstruction, however, the new state embarked upon an ambitious program of industrial development and was forced to set about transforming the old economy into one based on Stalinist-Marxist theories. The period 1945–51 was essentially a transitional one, the organization of industry, trade, finance, labour, trade unions, co-operatives and social welfare having been fundamentally changed from that of the prewar days. By 1952 the adoption of Soviet forms was practically complete.

The breach with prewar days was made more complete by World War II, for the German control of key industries paved the way for the transfer to state ownership, just as the tremendous scale of destruction called for state planning and reconstruction. The acquisition of the German part of the Silesian industrial complex and of additional Baltic ports further emphasized the changed conditions. Direct comparisons between the two Polands should be made only in the light of these changes. Comparisons are rendered difficult because Polish statistics after World War II were published in incomplete form or withheld altogether.

In conformity with all the other undertakings of the new state, the financial system of Poland after World War II was changed in accordance with Stalinist-Marxist theories. The most fundamental of these changes were as follows:

1. The power of the private individual was restricted by a variety of methods, such as the confiscation of property under the Land Reform and Nationalization of Industry acts; the licensing and tapering off of the private sector of industry; the liquidation of the independent functioning of banks, co-operatives, insurance companies, the retail, wholesale and distributive trades, the trades unions and the professions; revaluation and reform of the currency; enforced "social saving"; the manipulation of income tax and land tax to the disadvantage of the "class enemies"; the regulation of the rationing system and the price-wage relation to the same end and to increase the dependence of labour upon the state; the operation of the arbitrary, punitive powers of the Special Commission for the Investigation of Economic and Social Abuses, the head of which was a member of the Politburo of the United Workers' (Communist) party.

2. The liquidation of foreign (*i.e.*, excluding Soviet) ownership was achieved under the terms of the Nationalization of Industry act. Foreign investments before 1939 had been considerable and were officially estimated in 1947 to have been 52% of the total in mining, 87% in the petroleum industry, 66% in electrotechnical production, 60% in the chemical industry, 80% in power stations and 59% in insurance.

3. The state monopolized investment, banks, credit institutions, insurance, etc.

4. Poland was reduced to dependence on the U.S.S.R., under the general terms of the treaty of friendship and mutual assistance signed on April 21, 1945, and under the provisions of the subsequent trade and economic agreements, as well as by membership of the Moscow Council for Mutual Economic Aid.

Budgets for the years 1947–52 are shown in Table IV.

Planning and Administration.—The basis of the reorganization of industry was the Nationalization of Key Industries act of Jan. 1946, which expropriated without compensation all formerly German-owned property. All key industries and other enterprises with more than 50 workers per shift were nationalized, Polish nationals and non-German foreign owners being able to bring claims for compensation before the appropriate commission.

TABLE IV.—*Budgets, 1947–52*
(In million zlotys)

Item	1947	1948	1949	1950	1951*	1952*
Revenue	228,400	325,444	612,058	1,265,800	55,972	63,787
Expenditure	207,700	325,249	612,058	1,265,800	51,891	62,876

*In new zlotys. On Oct. 28, 1950, the zloty was revalued and brought at par with the Soviet rouble. The new exchange rates were (old in parentheses): £1=11.20 (280.00) zlotys; $1=4.00 (100.00) zlotys.

Compensation of foreign claimants was usually finally agreed upon with countries in great need of coal, Poland's most valuable asset.

Ministries of reconstruction and of recovered territories were formed temporarily to tide over the first period of rehabilitation. The first co-ordinated plan of development was embodied in the three-year plan of 1947–49, during which period productivity was to be restored and the level of 1939 regained. The six-year plan covering the period 1950–55 aimed at big increases over the level of 1949, with emphasis upon the production of capital goods and heavy industry; Poland in fact was being transformed from a predominantly agricultural to a mainly industrial country. The private sector of trade and industry, still important up to 1949, dwindled rapidly after 1950 under the influence of the government's licensing and fiscal regulations and political doctrines.

The economic administrative system was reorganized during 1950 to conform with that existing elsewhere in eastern Europe. The ministry of industry and commerce was subdivided, and eventually separate ministries were established for mining, heavy industry and power, light industry, chemical industry, agricultural and food industry, internal trade and foreign trade. Co-ordinating the work of these ministries was the chairman both of the economic committee of the council of ministers and the state planning commission who was, moreover, a member of the Politburo of the Communist party.

Industry.—The progress of industrialization can be seen in the proportion of persons engaged in nonagricultural occupations; it was 38.6% of the total in 1931 and 54.25% in 1951. The change was not brought about solely by postwar planning. The trend was already apparent before 1939, as the republic overcame the stagnation of earlier days and set about such projects as the building of the port of Gdynia and the development of the central industrial region in a wide area centring on Sandomierz. The German war machine also stimulated certain industries. Most of all, however, the change was brought about by the acquisition of the former industrial centres of German Silesia. The plebiscite of 1921 had left Beuthen (Bytom), Hindenburg (Zabrze) and Gleiwitz (Gliwice) on the German side of the frontier and Chorzow-Krolewska Huta and Katowice on the Polish side. Poland, which had had insufficient coal before 1921, then received a useful surplus; after 1945 the country had a superabundance.

One of the most serious problems before the Polish planners was the supply of an adequate labour force. The rural areas, especially the densely populated provinces of the south, were expected to provide a part, and agriculture could be further denuded through mechanization. Industries providing consumer goods were to give way to the requirements of heavy industry. Various other methods, apart from the general direction of labour so envisaged, were used: working hours were increased, and more women and juveniles were brought into employment; the fiscal policy and the system of rationing food and consumer goods were so conducted as to induce people into the factories and mines; "Stakhanovite" methods and labour competitions were applied according to Communist practices; in 1948 a compulsory labour service (Service for Poland) was introduced, by which young persons between 16 and 21 were employed on all manner of projects; in 1951 a decree raising the minimum age of employment from 15 to 16 also made it possible for industry to engage juveniles in training for work from 14 years of age, for not more than 6 hours daily

or 36 hours per week. Lastly, as in the other countries of the Soviet bloc, forced labour camps supplied prisoners, especially for work in the mines.

The relative importance of the various industries is illustrated in Table V. The great preponderance of coal, with iron and steel works and textile mills in the second place, is clearly seen. The largest single industries, each employing more than 30,000 workers, are the coal mines, cotton mills, ironworks and woollen mills of the larger towns, and the sawmills and sugar refineries of the forests and farmlands of the rural areas; these provide the characteristic industrial landscape of Poland. Most of the leading industries showed a considerable increase above the prewar level; but the timber, petroleum and natural gas industries lost many establishments in the sub-Carpathian areas incorporated into the U.S.S.R. Figures for 1950, though details were not published, show the general increase above the level of 1946 as given in Table V; out of a total of 1,763,000 wage earners in industry, 886,000 were employed in heavy industries and mining, 732,000 in light industries and 145,000 in foodstuffs and kindred industries.

TABLE V.—*Wage Earners in Industry*
(Annual averages, in thousands)

Industry	1937	1946	Industry	1937	1946
Mining	88	262	Agricultural machinery, etc.		9
Coal		182	Machinery and tools		6
Iron ore		5	Foodstuffs, etc.	86	117
Textiles	165	181	Sugar		34
Cotton		74	Building	48	86
Woollen		38	Stone, glass, cement, etc.	81	81
Bast fibre		26	Chemicals	42	66
Knitted		16	Wood and timber	68	62
Synthetic fibre		15	Clothing	15	44
Metallurgy	37	70	Paper	19	26
Ironworks		61	Electrotechnical	19	20
Metal	104	137	Printing	13	15
Rolling stock		21	Petroleum, etc.	14	11
Cast iron and steel		20	Total number of industrial workers	825	1,126
Wire, nails, etc.		10			

Heavy Industry.—Heavy industry was given first place in the post-World War II economic plans. It was based on possession of the Silesian coal fields and the iron ores, zinc and lead of Silesia and central Poland.

The main field is formed by the coal measures underlying Upper Silesia and reaching the surface near the pre-1939 German-Polish border. It is comparatively little faulted and is composed of thick seams which facilitate the use of mechanical methods of extraction. It is divided into the Silesian basin (cut by the pre-1939 German border), the Dabrowa basin and the Cracow basin, of which the first was by far the most important one developed at mid-century. The coal is of good general-purpose type. The second coal field, another valuable acquisition from Germany, is the smaller one of Walbrzych (Waldenburg), noted for fine metallurgical coking coal.

Coal is the greatest single Polish national asset, the basis of heavy industry and the most valuable export, enabling Poland to import the necessary supplementary raw materials and capital goods for industrial development. In 1938 output was 38,100,000 metric tons (excluding 26,000,000 in the German part of Upper Silesia), exports about 10,000,000. In 1948 output was 70,260,000 tons, exports 24,000,000, the biggest consumers being Sweden and the Soviet Union; in the same year the output of lignite was 5,000,000 tons and coke 3,000,000 tons. The output of coal had risen to 78,000,000 tons by 1950.

Iron ores are mined in the Jurassic limestones near Radom; other ores are found near Cracow and in Upper Silesia. The metal industry imports large quantities of ore from Sweden and some from the Soviet Union. The foundries, iron and steel plants and metallurgical industry generally are concentrated mainly in Upper Silesia. An entirely new iron and steel centre was under construction in the early 1950s at Nowa Huta near Cracow; with the Soviet assistance promised, this was expected to become one of the most important steel towns in central Europe. The six-year plan also provided for the extension of the existing works at Czestochowa. In 1947 the output of crude iron ores (mainly loamy and brown ores, 32%–34% metal content) was 544,000 tons, of zinc metal 75,000 tons, of lead 13,000 tons, of pig iron 867,000 tons and of raw steel 1,580,000 tons. The output planned for 1955 was fixed at 3,000,000 tons of iron ore, 198,000 tons of zinc metal, 3,500,000 tons of pig iron and 4,600,000 tons of raw steel.

Textiles.—In the days of the Congress kingdom a textile industry sprang into being, developing subsequently under the imperial Russian regime in the latter half of the 19th century into the great supplier of Russian and eastern markets. Partly destroyed in World War I, the industry was reconstructed in 1919. Lodz became the main centre, with cotton goods, woollen goods, hosiery etc.; Bialystok was noted for woollen rugs, haberdashery and garments; Bielsko for high-quality combed-wool fabrics; Warsaw for linens, knitted goods and hosiery; Zyrardow, Czestochowa and Cracow for linens. After 1945 war damage once more had to be made good and steady supplies of raw materials provided. New machinery and equipment were obtained from the Soviet Union, now in much the same relation as the Russian empire had been formerly, and from Great Britain. The output of yarn in 1947 (in metric tons) was cotton 59,000 (compared with 78,000 in 1937), woollen 24,000, linen 11,000, jute 9,000 and rayon 6,000. The output of fabric was cotton 47,000 (compared with 52,000 in 1937), woollen 17,000, linen 8,000, jute 8,000, rayon 3,000 and knitwear 5,000.

Electric Power.—An integral part of the three-year and six-year plans was the reconstruction, integration and expansion of the network of high-tension lines. The networks existing in 1945 were in well-defined regions, drawing their supplies mainly from thermoelectric power stations: (1) Silesia, primarily the Katowice area, which, however, linked up with Cracow to the east, and the former German concentrations in Wroclaw and Walbrzych —a region supplemented by hydroelectric stations in the Sudeten valleys and the uplands bounding Silesia to the north; (2) the central industrial region, with stations at Lublin, Radom, Stalowa Wola, Kielce and Rzeszow and a dam on the river Dunajec to the south; (3) the Warsaw, Lodz and Poznan systems; (4) the Piotrkow-Czestochowa system; (5) the lower Vistula and Gdansk, with both thermoelectric and hydroelectric sources; (6) the former German systems of Szczecin and Olsztyn. An important step was the linking of the Silesian grid with Lodz in 1947, the first stage in bringing the great resources of Silesia to the coast at Gdansk (Danzig). Dams being built on the upper Vistula not only would help to control the seasonal floods which follow the spring thaw but also would swell the electricity supplies.

Electric power production in 1938 was 3,900,000,000 kw.hr.; within the post-1945 boundaries, production would have been 7,000,000,000 kw.hr. In 1947 actual production reached 6,600,000,000 kw.hr. and the 1955 planned production was fixed at 19,300,000,000 kw.hr.

A necessary adjunct to electric power production was the electrotechnical industry, centred mainly in Warsaw, Wroclaw and other Silesian centres.

Oil.—Before 1939 Poland was one of the three major producers of petroleum in Europe. The fields, which were also associated with natural gas, were situated along the sub-Carpathian foothills. The wells centred mostly around Boryslaw and the refineries around Drohobycz. Most of these resources were acquired by the Soviet Union, although some oil was still produced and natural gas piped to the larger towns. Average yearly output of crude oil in 1936–38 was 508,300 metric tons; 40% of the refined products were exported, central Europe being the natural market. The home production was to be raised to 394,000 tons by 1955. Poland imported oil at mid-20th century.

Chemicals and Fertilizers.—A wide variety of chemicals is produced. The prewar fertilizer industry was centred in two state-owned factories, at Moscice near Tarnow and at Chorzow. Poland before 1939 was third in the European production of potassium salts, coming after Germany and France; the deposits were in the southeastern area at Kalusz, Holyn and Stebnik; but, as this region was incorporated into the U.S.S.R., Poland became an importer from eastern Germany. Salt is obtained in Poznan, Silesia, the Cracow basin and Warsaw province, mostly in the form of rock salt from the mines at Wapno, Wieliczka (worked since 1040) and

Bochnia. Production amounted to 643,000 tons in 1938 and 619,000 in 1947.

Industrial chemicals are produced in conjunction with the other main industries, coal, metallurgical and textile, and production and demand were stimulated by the acquisition of the new territories and the expansion of heavy industry. Large increases were planned during the period 1950–51, especially in the basic chemical, sulphuric acid. (*See* Table VI.)

TABLE VI.—*Production of Chemicals*
(In thousands of tons)

Chemical	1937	1947	1955*
Superphosphates	163	184	250
Cyanamide of lime	68	121	?
Nitrates	19	70	231
Burnt soda	89	89	389
Caustic soda	22	31	162
Dyes	2	2	8
Sulphuric acid, 100%	74	48	540
Rubber tires and tubes	?	4	?

*Planned.

Two new chemical factories were built, one at Dwory near Oswiecim and the other at Brzeg (Brieg) in Lower Silesia, the former for synthetic oil, the latter for synthetic dyes.

Building Industry.—The building trade in Poland was pressed to the uttermost to provide the wherewithal for the restoration and reconstruction of property damaged during World War II in every sector of the national life. Salvaged materials, volunteer labour and youth brigades were employed on a large scale. To cope with this and with the new work of construction under the six-year plan, the production of lime and cement, bricks and building stones and timber received special consideration. Cement production, one of the more important industries, is associated with the calcareous rocks of central Poland. Production of cement amounted to 1,719,000 tons in 1938 and to 1,522,000 tons in 1947; the aim for production in 1955 was fixed at 5,000,000 tons. To the previous supplies, those of the Opole (Oppeln) area were added; a new plant, the "Odra" at Opole, completed in 1951, was reputedly the largest in Poland (followed in size by the plant at Wierzbica, near Radom, and next by that built in 1951 at Rejowiec, near Lublin).

Miscellaneous.—Other industries are glass, ceramics and pottery, based on the sands, clays and kaolin deposits of central and southern Poland and widely exported; leather and footwear; and paper.

Rural Economy.—Farming and forestry (for the latter see *Physical Geography,* above) and the related foodstuffs and timber industries remained among the more important pursuits at mid-century. The farming population had, however, declined to a secondary position: from 70% of the total in 1918 and 65% in 1938 to 45% in 1950. The people in rural areas, as in all other sectors, suffered heavily from the effects of both World Wars I and II. The restocking of farms was not complete until about 1927, the war with the Soviet Union not ending until 1921; six years after 1945 the position was still far from being restored, a vital factor when it is considered that horses were still the main draught power in Poland. Figures for livestock are given in Table VII.

TABLE VII.—*Livestock*
(In thousands of head)

Livestock	1938*	1938†	1946	1950
Horses	3,016	3,100	1,730	2,797
Cattle	10,554	9,900	3,910	7,164
Pigs	7,525	9,700	2,674	9,928
Sheep	3,411	1,900	727	2,194

*Within pre-1938 boundaries.
†Within post-1945 boundaries.

Climate and soils combine to give Poland a mixed type of farming and a relatively high proportion of cultivable land. At mid-20th century the percentages of the total surface under cultivation, forest and lying waste (including fallows and water surfaces) were, respectively, 68, 22 and 10—roughly similar to those in 1939, except that the forest area was smaller by 2%. The main crops were grains (rye, oats, wheat and barley), potatoes, sugar beets and fodder crops (*see* Table VIII). Rye and potatoes are more characteristic of the poorer sandy soils (the podsols) of the glaciated regions, wheat and sugar beets of the more fertile brown and chocolate-brown soils (the *radzines*) of southern Poland. Vineyards were found only in favourable situations around Wroclaw, since the former area of warm fruits in the extreme southeast was incorporated within the Soviet Union. Hops and tobacco are located on favourable soils in the centre and south. Temperate fruits, dairy, poultry and pig products are part of the general farming in most districts of the country. Sugar production surpassed the prewar level of 506,000 tons and in 1950 was estimated at 955,000 tons.

TABLE VIII.—*Agricultural Production*
(In thousands of metric tons)

Product	1934–38*	1934–38†	1948	1949	1950
Wheat	2,064	2,210	1,620	1,781	1,854
Barley	1,411	1,690	1,010	1,028	1,077
Rye	6,467	7,970	6,304	6,759	6,503
Oats	2,558	3,430	2,402	2,333	2,126
Potatoes	35,006	37,110	26,756	30,900	36,835
Sugar beets	2,806	4,750	4,226	5,085	6,377

*Yearly average within pre-1938 boundaries.
†Yearly average estimated for post-1945 boundaries.

The tendency at mid-20th century was to concentrate upon crops of value to the export market, such as sugar, poultry products, bacon and hams, the Soviet Union and United Kingdom being chief customers. Although Poland's export of sugar was in 1947 double what it had been in 1937, other formerly noted exports were considerably down; for example, the export of eggs was only one-twelfth the prewar quantity. The demands of the export drive and the victualling of the steadily increasing military forces, coupled with the direction of labour into heavy industry, imposed heavy burdens upon the ordinary civilian consumer. Changes in the agrarian system also contributed to the difficulty of adequately feeding the Polish population. As a result, internal food shortages became once more apparent in 1948, grew worse in 1950 and 1951 and led to the re-introduction of food rationing at the beginning of 1952. In 1947 grains and flour were imported from the Soviet Union (310,000 tons), from the United States (139,000 tons) and from Hungary and Denmark.

Agrarian Reform.—As in industry, Stalinist-Marxist dogma was applied to the ownership of land and the system of production, although the change was less sudden because of the greater difficulties involved. The ultimate objective was the complete socialization of agriculture on the pattern of the Soviet Union. These aims had been realized only partly by 1952.

Agrarian reform had been in progress in Poland since the Agrarian act of 1920 and its modification in 1925, which set aside for parcellation among the peasants the vast state domains of the Russian, Prussian and Austrian governments, certain ecclesiastical and public property, as well as the largest of the privately owned estates. More than 8,000,000 ac. were reallocated in the period 1920–38, the former owners receiving compensation; the total number of people who received land through parcellation was 734,100. Small peasant farmers occupied more than half of Poland, especially in the then central and southern areas, while the large estates were mostly in the eastern and western borderlands.

The first step in the Communist plan for agriculture was taken in July 1944, when the Polish National Committee of Liberation (the Lublin committee which later formed the real nucleus of the postwar government) passed a decree on agrarian reform. A land fund was set up to receive the land taken over from the former republic of Poland or confiscated from German owners and from persons who had collaborated with them and also from all owners of estates with more than 123.5 ac. of cultivable land. Church estates in excess of those needed to support the parish priests were confiscated by a decree issued in 1950. The main purpose of the decrees was not so much the satisfaction of peasant claims to ownership, which was in effect only nominal, as the creation of state farms (the Soviet *sovkhozy*) and production co-operatives (*i.e.,* collective farms, *kolkhozy*); in short, a Stalinist-Marxist type of rural economy. Hand in hand with the gradual development of

collective farming went the development of the state-owned machine tractor stations or M.T.S. (virtually holding the monopoly of mechanical farming) and the replacement of the former internationally renowned co-operative system, as applied to wholesale, retail and distributive trades and the provision of credit, by one under state control. The rate of development of collective farming is illustrated by the following figures: in 1946 there were 9,500 tractors in the whole of Poland and no collective farms; in 1947, 12,050 tractors in 30 M.T.S. supplying 243 collective farms; by 1950, 18,000 tractors, 156 M.T.S. and 2,200 collective farms.

In connection with the planning of agriculture under the six-year plan, the Polish government in the autumn of 1949 carried out a survey of rural areas, termed a "social classification of the land." In Dec. 1949 there were said to be in Poland 1,252,000 farms of 5–7.5 ac., 650,000 of 7.5–12.4 ac. and 200,000 of "medium size" (presumably 12.4–123.5 ac.).

Commerce.—The transition from a mixed to a Communist economy was paralleled by important changes in the economic relations of Poland. The six-year plan was largely dependent upon a vast program of capital investment and the production of capital goods, requiring loans and equipment from abroad as well as an unprecedented internal effort. That Soviet influence was paramount was demonstrated by the conclusion of a five-year trade and economic agreement on Jan. 26, 1948; Poland was to pay principally with coal and goods to be manufactured by the industries developed, particularly iron and steel, shipbuilding and textiles. Poland was forced to reject co-operation with the European Recovery program and became instead a member of the Council for Mutual Economic Aid in Moscow. Trade with Yugoslavia was stopped at the bidding of the Cominform. Relations continued to develop with other states of the Soviet bloc, particularly with Czechoslovakia, whose exports went down the Oder to the Polish ports and shipping lines rather than down the Elbe to Hamburg as formerly. Financial integration with the eastern European system was completed on Oct. 28, 1950, when the Polish currency was reformed and the zloty equated with the rouble.

The Soviet Union was not the only source of assistance in the three-year and six-year plans. On Jan. 14, 1949, the United Kingdom signed a five-year agreement by which Poland was to receive a variety of goods, including machinery, machine tools, ships, etc., in return for food and other products. The Scandinavian countries, Switzerland, Austria, the Netherlands, Belgium, France and Italy, anxious to obtain Polish coal (which had little to fear from the competition of the pre-war British and German exporters), all made important contributions to Poland's planning. By 1951, however, increasing political differences induced the countries of the North Atlantic Treaty organization to curtail the export to Poland of goods classified as strategic.

TABLE IX.—*Volume of Foreign Trade*
(In thousands of metric tons)

Volume of export trade			Volume of import trade		
Leading exports	1937	1950	Leading imports	1937	1950
Minerals	11,751	32,781	Minerals, mainly iron ore	2,050	3,146
of which coal	11,004	26,514	Chemicals, etc.	256	1,072
Timber, etc.	1,696	748	Grains, plant products, etc.	209	425
Base metals, etc.	391	336	Base metals, etc.	729	337
Foodstuffs, etc.	138	271	Timber, etc.	19	305
of which sugar	52	231	Textile raw materials etc.	146	152
Products of plant origin	631	236	Machinery, etc.	23	85
Chemicals, etc.	220	118	Paper, etc.	56	75
Animal products, etc.	89	104	Transport facilities	10	71
Transport facilities	0.7	111	Rubber, natural and synthetic	8	20
Glass, ceramics, etc.	10	42	Total volume of imports	3,685	5,827
Textiles	41	23			
Paper, etc.	14	20			
Machinery, etc.	4	15			
Total volume of exports	14,997	34,879			

TABLE X.—*Direction of Trade*
(Value in percentage of total)

Country	Average, 1937–38	1947
Soviet Union	1.1	25.1
Germany	17.6	2.1
United Kingdom	12.3	8.6
Sweden	3.1	9.0
United States	12.0	16.0
France	3.7	4.0
Brazil	1.4	4.8

For the volume of imports and exports *see* Table IX; for the direction of trade, *see* Table X.

After 1945 and more especially during the period of the six-year plan, while relations reached a very low ebb with the United States and became strained with the other western powers, Poland developed trade contacts with the middle east, with Indonesia and with Communist China. With the establishment of new shipping lines, Polish ships became an important factor in the carrying trade of the orient. The two great Polish port authorities, Gdynia-Gdansk (Danzig) and Szczecin-Swinoujscie, achieved major importance, rivalling Hamburg and Trieste in the trade of central Europe. In 1950 of the total of 12,451,000 metric tons of exports overseas handled by Polish ports, Gdynia-Gdansk accounted for 7,894,000 and Szczecin-Swinoujscie for 4,217,000; and of the 3,214,000 metric tons of imports from abroad, Gdynia-Gdansk for 2,234,000 and Szczecin-Swinoujscie for 978,000. *See* also Table XI.

The rigorous export drive combined with rapid expansion of heavy industry, coming as it did immediately after a prolonged war, was borne at the expense of serious shortages in consumer goods of all kinds, including foodstuffs.

Transport and Communications.—Poland has been endowed with a general openness of topography; even in the south the mountain barrier is pierced, notably by the Moravian gate. The great northward-trending valleys have always provided routeways to the Baltic, the ancient seat of the Hanseatic league and the scene of a busy commerce down the ages. The havens of Gdansk and Szczecin (Danzig and Stettin, *qq.v*), with the advantages of estuary accommodation, tideless navigation and shelter from the open sea, are among the most favoured in Europe. Counter to the general north-south trend run the east-west valleys of the ancient ice-age rivers, occupied in part by tributaries of the main streams; they have been a factor in the siting of the towns of central Poland and in the development of latitudinal communications. Finally, in the south, the comparatively favoured sub-Carpathian belt, with its rich mines, fertile soils, forest wealth and mountain passes, provided the channel of ancient routes running from southern Russia across southern Poland into western Germany and the Low Countries; cities like Lwow, Cracow and Wroclaw (Breslau) have for centuries commanded this old thoroughfare and been noted for their trade and commerce as well as their culture.

TABLE XI.—*Ships Entered in Polish Ports, 1950*
(In thousands of net registered tons)

Origin	Tonnage	Origin	Tonnage
Swedish	119.6	German (Allied controlled)	48.9
Danish	101.4	British	14.3
Polish	94.1	United States	13.7
Finnish	81.2	Italian	13.1
Norwegian	76.8	Panaman	6.1
Soviet	65.0	Others	14.6

During periods of political tranquillity, these natural influences exerted themselves freely. Unfortunately, the period of modern industrialization started not long after Poland had forfeited its independence, and enforced reorientations prevented the natural adjustment of the country's economy; the potentially valuable resources of the Silesia-Dabrowa basin were split between Prussia, Austria and Russia, and as the territory of Poland then lay on the borders of three great rivals, its resources were indifferently developed, its wealth drained in opposite directions.

The restored Poland inherited in 1918 three differing systems of communications, of which the Prussian was most highly developed, the Russian least so. The damage resulting from the Polish-Soviet war was very great, and the Russian railway system was mainly broad gauge. Roads were singularly ill provided, a disadvantage from which the country was still to suffer despite continuous road building between 1921 and 1939 and after 1945. Upper Silesia, the economic heart of Poland, remained divided; and, although Danzig formed a customs union with Poland, the Baltic was not freely accessible until after the opening of the new port of Gdynia.

The shift of frontiers in 1945 enriched the system of communications by bringing in the industrial areas of German Silesia and their outlet through the Oder valley, a region well supplied with railways, canals, rivers and roads. War damage was, however, higher than after World War I, and the period 1945–52 was occupied mainly with the work of reconstruction and the improvement of existing facilities. Destruction was computed at 40% of main railway tracks, 70% of large railway bridges, 42% of locomotives, 92% of passenger cars, 96% of freight cars, 30% of road surfaces, 100% of motor transport and 80% of boats and barges on inland waterways. Among the more spectacular achievements after 1945 were the driving of an east-west thoroughfare through Warsaw and the electrification of the Warsaw suburban line to Zyrardow. A beginning was also made on a Warsaw underground railway. In addition, Polish workshops were turning out rolling stock in large quantities for export to the Soviet Union. The railways crossing Poland from the Soviet Union to Germany took on a new significance, in view of the Soviet transit traffic in military and commercial goods; and the greatly increased volume of Polish-Soviet trade brought new importance to the broad-gauge interchange points

on the Polish eastern frontier.

In view of the paucity of roads the inland waterways have always been of considerable importance to Poland. By far the greatest stretches of inland navigation are provided by the Vistula and Oder and their main tributaries. The low sandy banks, the fast-flowing streams and the tendency to flood after the spring thaw necessitated regulation and canalization. The interconnecting glacial valleys provided means of linking by short canals a whole series of east-west tributaries and so, eventually, the main river systems of Germany, Poland and the U.S.S.R. Thus the Oginski and Royal canals (built in the 18th century, north and west of Pinsk) and the Augustow canal (built in 1825) joined the Vistula and Bug with the Niemen, Pripet and Dnieper; they were used between 1921 and 1939 for drifting Polesian timber westward but became part of Soviet territory. The Bydgoszcz (Bromberg) canal, built in 1914–16, was used for barge traffic between Germany and East Prussia; it linked Memel (Klaipeda) and Königsberg (Kaliningrad) in Soviet territory, with the Oder and central Germany by way of the sheltered lagoons of the Baltic coast, the canalized Nogat distributary of the Vistula and the rivers Brda and Notec. This canal was linked in 1949 through Lake Goplo with the canalized river Warta; if this in turn were linked with Katowice, a prewar scheme for a north-south coal canal would be realized. Another related scheme, an east-west coal canal joining Katowice with the headwaters of the Dniester through Cracow, the Vistula and the San, also failed to materialize; but the former German Upper Silesian field is served by a canal leading into the Oder, which makes Gliwice the most important inland port of post-1945 Poland. The much-publicized scheme for an Oder-Danube canal, originally scheduled to be completed by 1950 but still under discussion by 1952, was to take off from a point on the Gliwice canal, cross the Czech frontier at Bohumin and, by using the Morava, join the Danube near Devin.

TABLE XII.—*Communications*
(Lengths in kilometres)

Item	1924	1937	1947
Standard-gauge railways	16,652	18,102	20,949
Narrow-gauge railways	3,500	2,250	2,549
Navigable rivers and canals	3,070	5,120	4,979
Hard-surfaced roads	27,330	60,788	96,605

The principle of state ownership of the standard-gauge railways, main roads and other chief means of communication, including telecommunications and radio, was carried over from the pre-1939 system; in addition those narrow-gauge railways still in private use were nationalized after 1945.

Table XII shows the development of railways, roads and canals in Poland between 1924 and 1947.

The Polish state-owned air lines, Lot, form part of the interlocking system of services linking the main cities of the Soviet bloc countries. The flights from Warsaw to Moscow are restricted, however, to the Soviet air lines. In 1952 Lot maintained services to Paris, Brussels and Copenhagen and to Amsterdam via Warsaw, in western Europe. In 1949 Lot's passenger traffic was 13,510,500 passenger-miles, as compared with 5,864,700 passenger-miles in 1938 (in prewar territory).

TABLE XIII.—*Air Traffic, 1948*

Item	Lot	Foreign air lines
Flights	7,730	1,221
Miles flown	1,467,550	...
Passengers flown	77,522	6,960
Cargo carried (metric tons)	900.3	536.6

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POLAR BEAR: *see* BEAR; CARNIVORA.

POLAR BODY: *see* CYTOLOGY.

POLARITY or POLARIZATION. For electrolytic polarization *see* BATTERY; for optical *see* LIGHT.

POLAROGRAPHY (POLAROGRAPHIC ANALYSIS, VOLTAMMETRY), an electrochemical method of analyzing solutions of reducible or oxidizable substances, invented by Jaroslav Heyrovský at Charles university, Prague, Czech., in 1922.

The aqueous solution to be analyzed is placed in a glass cell containing two electrodes. One electrode consists of a glass capillary tube (internal diameter about 0.05 mm. or 0.002 in.) from which mercury slowly flows dropwise (dropping mercury electrode), and the other is a pool of mercury or other nonpolarizable electrode. The cell is connected in series with a galvanometer for measuring the flow of current, in an electrical circuit which contains a battery, or other source of direct current, and a rheostat by means of which the voltage applied to the electrodes can be varied from zero up to about two volts. Usually with the dropping mercury electrode connected to the negative side of the polarizing voltage, the voltage is increased by small increments and the corresponding current is observed on the galvanometer. The current is very small until the applied voltage is increased to a value large enough to cause the substance being determined to be reduced at the dropping mercury electrode. The current increases rapidly at first as the applied voltage is increased above this critical value, but gradually attains a limiting value and remains more or less constant as the voltage is increased further. The critical voltage required to cause the rapid increase in current is characteristic of, and serves to identify, the substance being reduced (qualitative analysis). Under proper conditions the constant limiting current is governed by the rate of diffusion of the reducible substance up to the surface of the mercury drops, and its magnitude is a measure of the concentration of the reducible substance (quantitative analysis).

Limiting currents also result from the oxidation of certain easily oxidized substances at the dropping electrode.

In 1925 J. Heyrovský and M. Shikata invented an instrument called the polarograph which automatically applies an increasing voltage to the dropping electrode cell and photographically records the resulting current-voltage curve. Curves thus recorded are called polarograms.

When the solution contains several substances that are reduced or oxidized at different voltages, the polarogram shows a separate current increase (polarographic wave) and limiting current for each. The method is thus capable of detecting and determining several substances simultaneously.

The method is applicable to relatively small concentrations of reducible or oxidizable substances (10^{-5} up to about 0.01 moles per litre, or approximately 1 to 1,000 parts per 1,000,000).

The majority of the chemical elements can be determined by polarographic analysis. The method is applicable to the analysis of alloys and other metallic products, and various inorganic compounds.

Polarography is also used to determine many types of organic compounds, and to study chemical equilibria and rates of reactions in solutions.

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POLAR REGIONS: *see* ANTARCTIC REGIONS; ARCTIC REGIONS.

POLDER, the Dutch name for a piece of artificially drained low-lying land reclaimed from the sea or other water and protected by high embankments (*see* HOLLAND).

POLE (FAMILY). The family of the Poles, earls and dukes of Suffolk, which, but for Richard III's defeat at Bosworth, might have given the next king to England, had its origin in a house of merchants at Kingston-upon-Hull. The Poles were among the first English peers whose fortunes had been founded upon riches gained in trade.

William atte Pole (d. *c.* 1329), a merchant of Ravensrode, settled in Hull. His sons, Sir Richard and Sir William atte Pole, were both famous for their wealth.

Sir Richard (d. 1345), the king's butler in 1327, moved to London, and is styled a London citizen in his will. The male line of this, the elder branch of the Poles, failed with a grandson, John Pole, whose daughter was Joan, lady of Cobham, the Kentish heiress, whose fourth husband was Sir John Oldcastle the Lollard.

Sir William atte Pole (d. 1366), the second son of William, joined his brother in advancing large sums to the government

while keeping safely apart from politics. The first mayor of Hull, he sat for Hull in five parliaments, and was advanced to be knight banneret and a baron of the exchequer. He was counted "second to no merchant in England," but after his time his descendants left the counting-house, his four sons all serving in the French wars. The eldest son, MICHAEL POLE, 1st earl of Suffolk, who had fought under the Black Prince and John of Gaunt, became (1383) chancellor of England. In 1385 he was created earl of Suffolk, a grant from the Crown giving him the castle and honour of Eye with other East Anglian lands formerly held by the Ufford earls. In 1386 the opposition, led by Gloucester, the king's uncle, pulled him down. He was dismissed from his chancellorship, impeached, and convicted. Richard was forced to send his minister into ward at Windsor until the parliament was dissolved, when Suffolk once more appeared as the leader of the king's party. But the opposition was insistent, and Suffolk fled over sea to Calais. He died an exile in Paris in 1389.

The exile's son Michael, 2nd earl, was restored in 1397, died of dysentery at Harfleur, and his son Michael was killed at Agincourt. Michael was succeeded as 4th earl by his brother William. (*See* SUFFOLK, WILLIAM DE LA POLE, DUKE OF.)

John Pole (1442–1491), the only son of the 4th earl, should have succeeded to the dukedom, his father having died unattainted. But the honours were apparently regarded as forfeited, and the dukedom was formally restored to the boy in 1455, the earldom of Pembroke being allowed to lapse. He married King Edward IV.'s sister Elizabeth. The marriage confirmed him a partisan of the White Rose. Before he was of age he was steward of England at his brother-in-law's crowning, and at Queen Elizabeth's crowning he bore her sceptre. Having held many offices under Edward IV. he was ready to bear a sceptre at Richard's coronation, and, after Bosworth, to swear fealty to the Tudor dynasty and to bear another sceptre for another Queen Elizabeth. He died in 1491, having safely kept his lands, his dukedom, and his head through perilous years. (*See* SUFFOLK, EARLS AND DUKES OF and POLE, RICHARD DE LA.)

Another family of the name of Pole, having no kinship with the house of Suffolk, owed their advancement and their fall to a match with a princess of the royal house. Sir Richard Pole, a Buckinghamshire knight, was the son of Geoffrey Pole, a squire whose wife, Edith St. John, was sister of the half-blood to the mother of Henry VII. About 1490 or 1491 he married the Lady Margaret, daughter of George, duke of Clarence. He died in 1505, and in 1513 King Henry VIII. created the widow countess of Salisbury, as some amends for the judicial murder of her brother, the Earl of Warwick. Four years later, the barony of Montague was revived for her eldest son Henry. Until the king's marriage with Anne Boleyn, the countess of Salisbury was governess of her godchild, the Lady Mary. When her son, the famous Cardinal Pole, published his *Pro ecclesiasticae unitatis defensione* the whole family fell under the displeasure of the king, who resolved to make an end of them. The Lord Montague was the first victim, beheaded in 1539 on a charge of treasonable conversations, on evidence of his brother, Sir Geoffrey Pole. In 1541 the aged countess, attainted with her son Montague, was also executed. Sir Geoffrey Pole fled the country, and joined the cardinal in exile. He returned with him at Mary's accession, both dying in 1558. His sons Arthur and Edmund, taken in 1562 as plotters against Queen Elizabeth, were committed to the Tower of London, where they died after eight years of imprisonment.

See T. Rymer's *Foedera;* C. Frost, *History of Hull* (1827); *Chronicon de Melsa* (Rolls Series); G. E. C., *Complete Peerage; Testamenta Eboracensia* (Surtees Soc.); Hon. and Rev. H. A. Napier, *Swincombe and Ewelme* (1858); *Dict. Nat. Biog. s.v.* "Pole."

POLE, REGINALD (1500–1558), English cardinal and archbishop of Canterbury, born at Stourton Castle, Staffordshire, was the third son of Sir Richard Pole and Margaret, countess of Salisbury, niece of Edward IV. Intended for the Church, he was sent for five years to the grammar school founded by Colet at Sheen. Here he had Linacre and William Latimer as teachers. In his thirteenth year he went to Magdalen College, Oxford, and two years after took his degree in arts. In 1517 Henry VIII. appointed his young kinsman to a prebend in Salisbury, and soon afterwards to the deaneries of Wimborne and Exeter. He was a friend of Sir Thomas More, who says that Pole was as learned as he was noble and as virtuous as he was learned. In 1519, at the king's expense, he went to Padua, the Athens of Europe, according to Erasmus; and there, where Colet and Cuthbert Tunstall had also been educated, he came into contact with the choicest minds of the later Italian Renaissance, so forming his friendships.

In 1525 he went to Rome for the Jubilee, and two years after returned to England and was initiated by Thomas Cromwell into the mysteries of statesmanship, that master telling him that the main point consisted in discovering and following the will of princes, who are not bound by the ordinary code of honour. When the divorce question arose, Pole seems at first to have been in its favour. He probably took the same view that Wolsey had, viz., that the dispensation of Julius II. was insufficient, as of two existing impediments only one had been dispensed. When, however, the king raised the theological argument which ended in disaster, Pole could not accept it; and, after the failure of Campeggio's mission, when the king asked him for his opinion, he excused himself on the score of inexperience, but went by Henry's order to Paris (1530) to obtain the judgment of the Sorbonne, insisting on the presence of a colleague to do the necessary business. On his return to England he spoke strongly against the project to the king, who sought to propitiate him by the offer of the sees of York or Winchester, which were kept vacant for ten months for his acceptance. There was a stormy interview at York Place; but eventually Henry told him to put into writing his reasons against the divorce. This was done, and, recognizing the difficulties of the situation, the king gave him leave to travel abroad, and allowed him still to retain his revenues as dean of Exeter. In 1535, which saw by the deaths of Bishop Fisher and Sir Thomas More a change in Henry's policy, Pole received orders to send a formal opinion on the royal supremacy, and the king promised to find him suitable employment in England, even if the opinion were an adverse one. The parting of the ways had been reached. Pole's reply, which took a year to write, and was afterwards published with additions under the title *Pro ecclesiasticae unitatis defensione,* was sent to England (May 25, 1536), meant for the king's eye alone. It contained a severe attack upon the royal policy, and a warning of temporal punishment at the hands of the emperor and the king of France if Henry did not repent of his cruelties and return to the Church. Pole was again summoned to return to England to explain himself, but declined until he could do so with honour and safety; but he was on the point of going at all risks, when he heard from his mother and brother that the whole family would suffer if he remained obstinate.

Paul III., who had prepared a bull of excommunication and deposition against Henry, summoned Pole to Rome in October, and two months after created him cardinal. In January 1537 he received a sharp letter of rebuke from the king's council, together with the suggestion that the differences might be discussed with royal deputies either in France or Flanders, provided that Pole would attend without being commissioned by any one. He replied that he was willing and had the pope's leave to meet any deputies anywhere. Paul III. in the early spring of that year named him legate *a latere* to Charles V. and Francis I., to secure their assistance in enforcing the bull by helping a projected rising in England against Henry's tyranny. The mission failed, owing to the mutual jealousy of the sovereigns. Francis feared to allow his presence in France, and Pole passed over to Flanders, and awaited in vain royal deputies. In August 1537 the cardinal returned to Rome. There he was appointed to the commission established by Paul III. for considering the reforms necessary for the church and Roman curia. The report *Consilium delectorium cardinalium* is, in its plain-spoken directness, one of the most noteworthy documents of the history of the period. Towards the end of 1539, after Henry had destroyed the shrine of St. Thomas Becket, another attempt was made to launch the bull of deposition, and Pole again was sent to urge Charles V. to assist. Once more his efforts were in vain, and he retired to his friend Sadoleto at Carpentras. As Pole had escaped Henry's power the royal ven-

geance fell on his mother, who was executed on May 27, 1541.

On Aug. 21, 1541, the cardinal was appointed legate at Viterbo, and for a few years passed a happy and congenial life amid the friends that gathered round him. Here he came into close relations with Vittoria Colonna, Contarini, Sadoleto, Bembo, Morone, Marco Antonio, Flaminio, and other scholars and leaders of thought; and many of the questions raised by the Reformation in Germany were eagerly discussed in the circle of Viterbo. The burning question of the day, justification by faith, was a special subject of discussion. Pole's own attitude to the question of justification by faith is given by Vittoria Colonna, to whom he said that she ought to set herself to believe as though she must be saved by faith alone and to act as though she must be saved by works alone. In the excited temper of the times any defender of justification by faith was looked upon by the old school as heretical; and Pole, with the circle at Viterbo, was denounced to the Inquisition. Though the process went on from the pontificate of Paul III. to that of Paul IV., nothing was done against the cardinal until the time of the latter pope.[1]

While at Viterbo his rule was firm but mild; and he regained many heretics, such as his friend Flaminio, by patience and kindliness, to a reconsideration of their opinions. During this time also he was still engaged in furthering a proposed armed expedition to Scotland to aid the papal party, and in 1545 he was again asking help from Charles V. But the Council of Trent (*q.v.*) required all his attention. In 1542 he had been appointed one of the presiding legates and had written in preparation his work *De concilio;* and now in 1545, after a brief visit to Rome, he went secretly, on account of fear of assassination by Henry's agents, to Trent, where he arrived on May 4, 1545. At the council he advocated that dogmatic decrees should go together with those on reform as affording the only stable foundation. His views on the subject of original sin, akin as it is to that of justification, were accepted and embodied in the decree. He was present when the latter subject was introduced, and he entreated the fathers to study the subject well before committing themselves to a decision. On June 28, 1546, he left Trent on account of ill-health and went to Padua. While he was there frequent communications passed between him and the council and the draft of the decree on justification was sent to him. His suggestions and amendments were accepted, and the decree embodies the doctrines that Pole had always held of justification by a living faith which showed itself in good works. This effectually disproves the story that he left the council so as to avoid taking part in an adverse decree.

On the death of Henry (Jan. 28, 1547), Pole was excepted from the general pardon. At the conclave of 1549 Pole received two-thirds of the votes, but by a delay, he lost the election and Julius III. succeeded. He then retired to Magazzano on the Lake of Garda and occupied himself in editing his book *Pro unitate ecclesiae,* with an intended dedication to Edward VI.

On the accession of Mary he was appointed legate to the new queen, and began his negotiations. But he was still under attainder; and the temper of England was not yet ripe for the presence of a cardinal. The project of the queen's marriage was also an obstacle. A marriage between her and Pole, who was then only a deacon, was proposed by some, but this was opposed by the emperor. The marriage with Philip, of which Pole did not approve, having taken place (July 25, 1554), and Rome yielding on the practical difficulties of the lay holders of Church lands, Pole was allowed to return to England as cardinal. On his landing he was informed that the attainder had been reversed; and he was received with joy by Mary and Philip. He proceeded to parliament and there absolved the kingdom and accepted in the pope's name the demands respecting ecclesiastical property. He rectified the canonical position of those who had been ordained or consecrated since the breach with Rome. Those ordained in schism, indeed, but according to the old Catholic rite, were absolved from their irregularity, and, receiving penance, were reinstated; those ordained under the new rite were simply regarded as laymen and dismissed without penance or absolution. Pole was not responsible for the cruel persecution by which the reign was disfigured. On Nov. 4, 1555, Pole opened, in the chapel royal at Westminster, a legatine synod, consisting of the united convocations of the two provinces, for the purpose of laying the foundations of wise and solid reforms. In the *Reformatio Angliae* which he brought out in 1556, based on his Legatine Constitutions of 1555, he ordered that every cathedral church should have its seminary. He also ordered that the Catechism of Caranza, who, like him, was to suffer from the Inquisition for this very book, should be translated into English for the use of the laity. On Cranmer's deprivation, Pole became archbishop of Canterbury; and, having been ordained priest two days before, he was consecrated on March 22, 1556, the day after Cranmer suffered at Oxford. But the clouds began to gather round him. His personal enemy Caraffa had become pope under the name of Paul IV. and was biding his time. When Rome quarrelled with Spain, and France, on behalf of the pope, took up arms, England could no longer observe neutrality. Paul IV. deprived Pole of his power both as legate *a latere* and *legatus natus* as archbishop of Canterbury (June 14, 1557); he also reconstituted the process of the Inquisition against the cardinal, and summoned him to Rome to answer to the crime of heresies imputed to him. Mary, who had been warned by her ambassador to the pope that prison awaited Pole, prevented the breve ordering the cardinal to proceed to Rome from being delivered, and so Pole remained in England. Broken down as much by the blow as by ill-health the cardinal died at Lambeth on Nov. 17, 1558, twelve hours after Mary's death and under the unmerited disgrace of the papacy in defence of which he had spent his life. He was buried at Canterbury near the site of the shrine of St. Thomas Becket.

The chief sources for Pole's biography are his life written in Italian by his secretary Beccatelli, which was translated into Latin by Andrew Dudith as *Vita Poli cardinalis* (Venice, 1563), and his letters (*Epistolae Reginaldi Poli*) edited by Girolamo Quirini and published in 5 volumes (Brescia, 1744–57), a new edition of which is in preparation at Rome with additions from the Vatican Archives. *See* also the State Papers (foreign and domestic) of Henry VIII., Edward VI. and Mary; the Spanish and Venetian State Papers; vol. i. of A. Theiner's *Acta genuina S.S. Oecumenici Caecilii tridentini* (1874); the *Compendio dei processi del santo uffizio di Roma da Paolo III. a Paolo IV.* (Società romana di storia patria, *Archivio,* iii. 261 *seq.*); T. Phillipp's *History of the Life of R. Pole* (Oxford, 1764–67); Athanasius Zimmermann, S.J., *Kardinal Pole sein Leben und seine Schriften* (Regensburg, 1893); Martin Hailie, *Life of Reginald Pole* (1910); and F. G. Lee, *Reginald Pole.*

POLE, RICHARD DE LA (d. 1525), pretender to the English crown, was the fifth son of John de la Pole (1442–1491), 2nd duke of Suffolk, and Elizabeth, second daughter of Richard, duke of York and sister of Edward IV. His eldest brother John de la Pole, earl of Lincoln (*c.* 1464–1487), is said to have been named heir to the throne by his uncle Richard III., who gave him a pension and the reversion of the estates of Lady Margaret Beaufort. On the accession of Henry VII., however, Lincoln took the oath of allegiance, but in 1487 he joined the rebellion of Lambert Simnel, and was killed at the battle of Stoke. The second brother Edmund (*c.* 1472–1513) succeeded his father while still in his minority. His estates suffered under the attainder of his brother, and he was compelled to pay large sums to Henry VII. for the recovery of part of the forfeited lands, and also to exchange his title of duke for that of earl. For his negotiations with the German King Maximilian in Tirol, Henry seized his brother William de la Pole, with four other Yorkist noblemen. Two of them, Sir James Tyrell and Sir John Wyndham, were executed, William de la Pole was imprisoned and Suffolk outlawed. Then in July 1502 Henry concluded a treaty with Maximilian by which the king bound himself not to countenance English rebels. Presently Suffolk fell into the hands of Philip, king of Castile, who imprisoned him at Namur, and in 1506 surrendered him to Henry VII. on condition that his life was spared. He remained a prisoner until 1513, when he was beheaded at the time his brother Richard took up arms with the French king.

Richard de la Pole joined Edmund abroad in 1504, and remained at Aix as surety for his elder brother's debts. The creditors

[1] Within the institution of the Inquisition his name continued to be regarded as that of a heretic and misleader of others, as is proved by the mass of evidence accumulated against him in the *Compendium inquisitorum* (*v archivio della società di storia patria,* Rome, 1880).

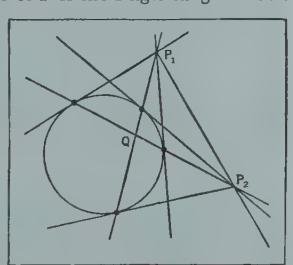
threatened to surrender him to Henry VII., but, more fortunate than his brother, he found a refuge with King Ladislas VI. of Hungary. He was excepted from the general pardon proclaimed at the accession of Henry VIII., and when Louis XII., went to war with England in 1512 he recognized Pole's pretensions to the English crown, and gave him a command in the French army. In 1513, after the execution of Edmund, he assumed the title of earl of Suffolk. In 1514 he was given 12,000 German mercenaries ostensibly for the defence of Brittany, but really for an invasion of England. These he led to St. Malo, but the conclusion of peace with England prevented their embarkation. Pole was required to leave France, and he established himself at Metz, in Lorraine, and built a palace at La Haute Pierre, near St. Simphorien. He had numerous interviews with Francis I., and in 1523 he was permitted, in concert with John Stewart, duke of Albany, the Scottish regent, to arrange an invasion of England, which was never carried out. He was with Francis I. at Pavia and was killed on the field on Feb. 24, 1525, so ending the male line.

See *Letters and Papers Illustrative of the Reigns of Richard III. and Henry VII.*, edited by J. Gairdner (2 vols., "Rolls Series," 24, 1861); *Calendar of Letters and Papers, Foreign and Domestic, of the Reign of Henry VIII.*; and Sir William Dugdale, *The Baronage of England* (London, 1675).

POLE, WILLIAM (1814–1900), English engineer, was born at Birmingham on April 22, 1814. He spent some years as a professor of engineering in Bombay, returning to England in 1848, and in 1859 was appointed to the chair of civil engineering in University college, London. He was secretary to the Royal Commission on Railways (1865–67); the duke of Richmond's Commission on London Water (1867–69), also taking part in the proceedings for establishing a constant supply; the Royal Commission on the Disposal of London Sewage (1882–84); and the departmental committee on the science museums at South Kensington in 1885. In 1871 he was appointed consulting engineer in London to the Japanese Government. He was elected F.R.S. in 1861 for some investigations into colour-blindness. Music was also one of his chief interests, and in 1867 he took his doctor's degree, acting for many years as examiner for musical degrees at the University of London. In 1879 he published his *Philosophy of Music*. He died on Dec. 30, 1900.

POLE. For pole star *see* POLE STAR; for polar regions *see* ARCTIC REGIONS; ANTARCTIC REGIONS; for magnetic poles *see* MAGNETISM. *See* also BATTERY; CRYSTALLOGRAPHY; GEODESY; GEOMETRY; POLE VAULTING; SPHERE.

POLE AND POLAR, in mathematics. If from a point P outside a circle the two tangents to the circle be drawn, the line joining the points of contact is called the *polar* of the point P, and P is called the *pole* of the secant line. If P is on the circle, the two tangents coincide and the polar of P is the single tangent at P. For Q, a point inside the circle, draw two secants to the circle through it. The line joining their poles is called the polar of Q. If the polar of P passes through Q, the polar of Q passes through P. The same principle applies to any conic. In space there is a corresponding theory of points and polar planes as to a sphere or any fixed quadric surface. The idea is due to Brianchon, who first applied it in 1806, but it was developed by Poncelet, and presented in final form in 1829. More recently the concept has been extended to other curves and surfaces, and to other configurations.



POLECAT, the name given to any member of the Musteline subgenus *Putorius* (*see* CARNIVORA). Polecats are confined to the northern hemisphere. The European polecat, *Mustela putorius*, inhabits the whole central and northern parts of the continent, though now rare in Britain. It is well known in its domesticated, albino variety as the ferret (*q.v.*). The wild polecat is dark brown above and black below, the face being variegated with white. The fur is long, coarse, and of little commercial value. It is more powerful than the marten (*q.v.*) but less active, and rarely climbs trees. Its food consists of small mammals and any birds it can catch, especially poultry. It also eats snakes, lizards, frogs, fish and eggs. It is extremely blood-thirsty and hunts at night. From three to eight young are produced in April or May, after a two months' gestation. It is very tenacious of life and has a fetid smell.

It is replaced in north Asia by an allied species, *M. eversmanni*, and on the central plateau of the United States by a third form, *M. nigripes*, with creamy-yellow fur, brown legs and black feet and tail. A related genus, *Vormela*, whose fur is white marbled with reddish spots above, extends from east Poland to Afghanistan. All these animals resemble *M. putorius* in habits.

POLENTA, DA, the name of a castle in Romagna, from which came the noble and ancient Italian family of Da Polenta. The founder of the house is said to have been Guido, surnamed l'Antico or the Elder, who wielded great authority in Ravenna in the 13th century. His grandson Guido Novello upheld the power of the house and was also *capitano del popolo* at Bologna; he was overthrown in 1322 and died in 1323. In 1321 he gave hospitality to the poet Dante, who immortalized the tragic history of Guido's daughter Francesca, unhappily married to Malatesta, lord of Rimini, in an episode of the *Inferno*. Guido's kinsman Ostasio I. was lord of Cervia and Ravenna from 1322 to 1329, and, after being recognized as a vassal of the Holy See, again became independent and went over to the house of Este, whom he served faithfully in their struggles with the Church until his death in 1346. His son Bernardino, who succeeded him as lord of Ravenna in 1346, was deposed in 1347 by his brothers, Pandolfo and Lamberto II., but was reinstated a few months later and ruled until his death in 1359; he was famous for his profligacy and cruelty. His son Guido III. ruled more mildly and died in 1390. Then followed Ostasio II. (d. 1396), Obizzo (d. 1431), Pietro (d. 1404), Aldobrandino (d. 1406), all sons of Guido III. Ostasio III. (or V.), son of Obizzo, was at first allied with the Venetians; later he went over to the Milanese, and, although he again joined the Venetians, the latter never forgave his intrigue with their enemies, and in 1441 they deprived him of his dominions. He died in a monastery in 1447.

POLESIE (*i.e.*, "along the forest"), the largest and most sparsely populated province of Poland. Area, 14,219 sq.mi. Pop. (1931) 1,131,000. The bulk of the inhabitants are Ruthenians—the so-called Polesians or Pinchuks, forming a special branch of the Ukrainian nationality, and belonging to the Orthodox Eastern Church. Polesie was taken by the U.S.S.R. in 1939 and by Germany in 1941.

Polesie forms an eastward extension of the central Polish plain sloping up to the northern highlands and the plateau of Podolia. It forms the basin of the Prypet, a tributary of the Dnieper, into which flow numerous slow rivers from the Lithuanian forests of the north, and from the uplands of the south. The falls of the Lower Dnieper hinder the drainage of Polesie, and the deepening of the channel of the Dnieper tends to dry up the Pinsk marshes. In spring the whole country is flooded and has the appearance of a sea. In reality it consists partly of marshes and lakes, partly of damp meadows with islands of clay or sand, on which most of the villages are built. In such a dreary plain the main feature is the vegetation, which consists of wide pine forests on the sand or on the swamps, with invading firs from the north, of mixed forests and birch groves, and of damp meadows grown with grasses, reeds and stunted willows. It is the only remaining home of the beaver in Poland, and the elk is still found there. The inhabitants maintain a precarious existence mainly by fishing and hunting. With few horses, there is a special breed of cattle.

Polesie originally formed the early Russian principality of Turov or Pinsk. Conquered by the Lithuanians in 1320, it became, after the union with Poland in 1569, the province of Brest Litovsk. The north-west portion formed part of the estates of the great Polish magnates, the Radziwills and Sapiehas. Wolczyn was the seat of the Czartoryski family. The chief towns are Brest Litovsk, pop. (1931) 50,733, the capital; Pinsk, the seat of an ancient Orthodox bishopric; Kobryn, Kamenets Litovsk and Luninets, a junction of the two railways which traverse the marshes.

POLE STAR or **POLARIS,** the (naked-eye) star nearest the pole in the northern hemisphere. (*See* ASTRONOMY: *Spherical Astronomy.*) It is the brightest star in the constellation Ursa Minor (*q.v.*), hence its Bayer equivalent, α Ursae Minoris. Polaris is a yellow supergiant star located at a distance of the order of 500 light-years from the sun.

POLE VAULTING, the art of jumping over an obstacle with the aid of a pole. Originally a means of clearing objects, such as ditches, brooks and fences, pole vaulting for height, clearing a bar supported by two uprights set not less than 12 ft. apart, became a competitive athletic sport. Requirements of the athlete are technical knowledge and an understanding of the physics of the sport, a high degree of co-ordination, timing, speed and gymnastic strength. Up to the end of the '80s all the world's record holders came from the small town of Ulverston, in Lancashire, England. It was not really "pole vaulting" but rather "pole climbing." This method was barred. The pole used is generally bamboo, sometimes aluminum, and the spike which was formerly used in the end of the pole has been abandoned. A slideway is sunk in the ground, the back of which is placed directly below the crossbar. Into this slideway the pole is thrust. A soft pit, generally of sawdust, is provided for the vaulter for landing.

The modern pole vaulter approaches the take-off with great speed, carrying the pole with his hands about $2\frac{1}{2}$ ft. apart. As the stride, next before the spring, is completed, he performs the shift, which consists of advancing the pole toward the slideway (which is known as the advance) and at the same time allowing the lower hand to slip up the pole until it reaches the upper hand, and raising both hands as high above his head as possible before leaving the ground. He is thus enabled to exert the full pulling power of both arms to raise his body and help the swing-up of his legs. There are two factors the pole vaulter bears in mind—one is height and the other is carry. Height gives him the elevation, and carry takes him across the bar. It is noteworthy that this trick, perfected by Raymond G. Clapp of Yale university (U.S.A.), raised the world's record in 1898 to 11 ft. $10\frac{1}{2}$ in.; whereas, not employing the manual shift, H. H. Baxter of the New York Athletic club (U.S.A.) in 1883 vaulted 11 ft. $\frac{1}{4}$ in.

The modern pole vaulter should have these qualifications: height (the taller man has a distinct advantage), speed, gymnastic strength and years of practice to master the modern technique. The modern pole vaulter generally uses the following technique:

A long run of approximately 150 ft., great speed down the runway and exact timing when the shift takes place, so that his hands are extended high above his head at the minute of the take-off. He then runs off the ground (he does not jump) leaving his body hanging by the hands as long as possible, not pulling too soon. He then lets his legs swing upward and to the side of the pole. The athlete's feet should reach a point well above the crossbar, in an attempt to actually make a handstand. At this stage the vaulter shoots his legs high above the crossbar by means of a strong arm pull on the pole. He next turns his body face downward and converts his pulling force into a pushing force. The bar lies in the concavity of the stomach, so that his feet are on one side and his head and shoulders are on the other side. The athlete finally carries his body across the crossbar, by what is known as the carry, which is the speed he has acquired from his run. Adoption of the bamboo pole, used with the modern technique, added approximately a foot to the records. In 1908, four Yale men (Campbell, Nelson, Dray and Gilbert) won all the places in the intercollegiate games at Philadelphia, using a bamboo pole. Astounding improvements in performance are indicated as follows: (1) H. H. Baxter (New York Athletic club), in 1883, 11 ft. $\frac{1}{2}$ in. (using old style), the first man to vault over 11 ft.; (2) Norman E. Dole, 1904 world's record, 12 ft. $1\frac{32}{100}$ in., the first man to vault over 12 ft.; (3) Robert A. Gardner (Yale university), at the I.C.A.A.A.A. games in 1912, 13 ft. 1 in., the first man to vault over 13 ft.; (4) Sabin W. Carr (Yale university), at the I.C.A.A.A.A. games in 1927, 14 ft., the first man to vault 14 ft.; (5) Cornelius Warmerdam (Olympic club), at Berkeley, Calif., in 1940, 15 ft., the first man to vault 15 ft.; (6) Cornelius Warmerdam, world's indoor record, at Chicago, 1943, 15 ft. $8\frac{1}{2}$ in., and world's outdoor record, at Modesto, Calif., in 1942, 15 ft. $7\frac{3}{4}$ in. (A. C. G.)

POLIANTHES, one of the florists' flowers, commonly called tuberose, probably derived from *P. tuberosa,* which is unknown as a wild plant. (*See* TUBEROSE.)

POLICE. As now generally employed, the term police means the maintenance of public order and the protection of persons and property from the hazards of public accidents and the commission of unlawful acts. Earlier meanings included such limited activities as street paving and lighting, or scavenging and sanitation, as well as applications broad enough to comprehend the entire range of the domestic policies of government.

Authoritarian states set up secret political police organizations that operate independently of the regular civil police establishments. Political police are always highly centralized agencies. The nazi gestapo and schutzstaffel, the tsarist ochrana, the soviet cheka, ogpu and N.K.V.D. and Mussolini's ovra all had common characteristics sharply distinguishing them from other civil police. Their governments, among others, came to be known as "police states." Democratic governments are also impelled to establish their security from subversive elements, but they do not hesitate to entrust it primarily to police forces charged with law enforcement in general. Popular governments permit much local autonomy in police administration while authoritarian states tend to centralize police control, but the intrusion of other factors also may produce centralized police control even under democratic patterns. England, Wales and Scotland have scores of local police forces, whereas the Republic of Ireland and the government of Northern Ireland each maintain but a single police establishment. Belgium has dual police systems for the national and local levels with municipal forces resting upon almost complete local autonomy, whereas in Denmark all police activities are administered by functionaries of the crown. Similar contrasts characterize the police arrangements of France and the Netherlands and of Sweden and Norway. In the United States and Canada, national and state (or provincial) police lie parallel to local police systems.

Modern police administration has five major aspects: uniformed patrol, criminal investigation (detection of criminals), traffic regulation, special measures for controlling commercialized vice (liquor, narcotics, prostitution and gambling) and procedures and facilities for dealing with women offenders and juvenile delinquents. The latter are often staffed by police women.

United States.—Strictly speaking, the United States has no police system. It has about 40,000 police jurisdictions represented by the federal government, the 48 states, the sheriffs and deputy sheriffs of 3,000 counties, a handful of county police forces independent of the sheriffs' offices, the police of 1,000 cities and occasional constables in more than 20,000 townships, magisterial districts or county districts, together with other minor forces in 15,000 villages, boroughs and incorporated towns. In addition, there are a number of special districts concerned with the patrol of parks, parkways, tunnels, bridges and aqueducts. In short, police administration follows the jurisdiction of the civil governments, whether federal, state or local. This produces serious internal strains since in a given area there may be as many as five or six levels of police administration. It also unduly complicates the task of co-ordinating investigations and other police activities. Central clearinghouses for crime records, criminal identification and police training and the vast interstate networks of police teletype and radio serve in part to overcome some of the more flagrant defects, however.

The total numerical strength of all full-time and part-time police in the service of these many jurisdictions was about 175,000 at mid-20th century. The well-defined trend is away from part-time police, particularly the township constables and deputy sheriffs; but when such as these are found to be inadequate, state and local governments still are prone to create new and additional police bodies without troubling to dispose of the outworn protective agencies. Multiple overlapping of police jurisdiction is thereby produced with occasional conflicts of interest among separate and distinct police forces operating independently within a given area.

Local police agencies range in size from only one or two part-time employees to the highly developed force of 20,000 men in New York city. The ratios of police to population generally are highest in the largest cities and decline by graduated steps. Thus, in cities of more than 250,000 population the number of police per thousand of population was 2.41 in 1949; while in places of less than 10,000 population, the ratio was only 1.35.

Similar variations appear when geographic location is considered. For cities and other urban places the Pacific coast has the highest police ratios. Cities with the lowest ratios of police to population are most commonly found in the central states.

The general effect of such relationships to size and location is that police strength is not only disproportionately greater in those parts of the country having the larger urban centres, but it is in large degree actually concentrated in the big cities. Thus, in 3,275 urban places where 139,000 policemen were employed in 1949, more than half (72,000) were in 37 cities of more than 250,000 population.

The inherent weakness of the smallest police establishments and the abdication of police authority by many rural functionaries combined to produce inadequate police defenses throughout most of the U.S. countryside. For many years this condition was ignored, but the advent of the motor age brought with it so many problems of crime control and traffic regulation that the ancient sheriff-constable system was quickly overwhelmed. A new type of police agency thereupon emerged—one destined to have a far-reaching influence upon the future development of police in the United States and upon the ultimate distribution of functions among local and state governments. The 19th century witnessed several limited and tentative experiments in state police administration—in Texas, Massachusetts and Connecticut—but it was not until 1905 that Pennsylvania established its state police force; and when New York and other large commonwealths followed at about the time of World War I, and shortly thereafter, success of the state police idea was assured. Because these agencies were in fact wholly new, they did not inherit the old U.S. police tradition, parts of which were thoroughly bad. Furthermore they were able to experiment with new devices for selection, training, promotion and discipline.

By the time of World War II every state had acquired a police agency of its own. Some of these were rudimentary in conception and limited in both authority and numbers. Some were charged merely with the patrol of state highways for the single purpose of traffic law enforcement. Others sprang into existence with broad enforcement powers exercised throughout great and populous states but especially in the rural areas where local policing was least adequate. Without exception, state police forces represented a break with the past and with the tradition of local autonomy in police management. But their numbers were nowhere great—Pennsylvania with 1,600 state troopers at mid-20th century maintained the largest single force—and all told they did not total more than 10,000 in the service of the 48 states. Moreover, the establishment of state police was not accompanied by any large-scale abandonment of the outworn and outdated local police units.

The federal government also was drawn more and more into the police field, because it could not be expected indefinitely to entrust the enforcement of many federal statutes to local and state police bodies. The stresses of the Civil War brought several rudimentary investigative agencies into existence while an expanding field of federal regulation encouraged the development of others. Forty federal agencies were performing some part of the police function by 1950. In all but a mere handful of these, law enforcement was either auxiliary to other administrative activities or was performed within a narrowly restricted area or involved in the conduct of military or naval operations.

General police jurisdiction at the national level is exercised only by the Federal Bureau of Investigation, popularly known as the FBI. This select corps of criminal investigators has performed its various law-enforcement functions in such fashion as to encourage repeated additions to the scope of its responsibilities. Extensive crime laboratories and a uniform system of crime reporting for all jurisdictions in the United States and its possessions serve to round out the central services performed by the FBI for state and local law-enforcement agencies.

In a special category are the police patrols maintained by such federal agencies as the Tennessee Valley authority, while the police department of Washington, D.C., is wholly unique in the U.S. scene. Commissioners appointed by the president administer the governmental affairs of this federal district and accordingly are responsible for law enforcement within its boundaries.

A prominent feature in a typical police force in the United States is the wealth of equipment, particularly for transportation and communication. Whatever the shortcomings of the various federal, state and local police systems, there can be no doubt that in the use of mechanical aids they lead the world by a wide margin. Also notable is the steady rise in police salary scales after 1910 and the increasing adoption of retirement systems, some of which are established on a sound actuarial basis.

Great Britain.—Modern police administration in Great Britain stems from the establishment in 1829 of the metropolitan police in the sprawling urban and suburban area surrounding the City of London. This extends in a wide circle of 700 sq.mi., most of it lying within a radius of 15 mi. from Charing Cross as a centre. The ancient City, however, is only 1 sq.mi. in area, is of limited resident population but of great wealth and importance and has never been a part of the metropolitan police district. With this exception, the metropolitan police district embraces all of London and Middlesex counties and parts of Surrey, Essex, Kent and Hertford, the whole including several score municipal and county boroughs.

Headquarters of the metropolitan force are at New Scotland Yard in the borough of Westminster on the Thames embankment—close by the offices of the national government and the seat of empire in Whitehall. The police commissioner of the metropolis is appointed by the crown, with the home office occupying the position of responsible police authority in all metropolitan police matters. The home secretary exercises direct control over this critically important agency for law enforcement in the nation's capital.

The commissioner of the City of London police is chosen by the mayor and aldermen, while in other cities and boroughs having their own police establishments, the watch committee of the city or borough council appoints the chief constable in each instance. Each county constabulary is under the control of a standing joint committee consisting of specially designated members of the county council and justices of the peace (quarter sessions). This committee selects the chief constable; but in counties, cities and boroughs alike, the choice of a chief constable must be ratified by the home office.

The early county constabularies were created around 1840, primarily for the protection of rural areas, but many now are also charged with responsibility for policing cities and boroughs, some of them of considerable size. This process of consolidation had been going on for many years and was speeded up greatly by the exigencies of World War II. Further absorption of 45 of the 47 noncounty borough forces followed application of the terms of the Police Act of 1946. Another trend toward integration is marked by the device of placing a single chief constable in command of two or more neighbouring forces. Examples are offered by the liberty of Peterborough and the city of Peterborough, by the county forces of Cumberland and Westmorland and by the borough of Hereford and Herefordshire. In some instances resort is had to such common commands where the forces concerned are rather small, and in any case they represent a kind of tentative or intermediate stage before outright consolidation.

Authorized strength of the metropolitan police in 1948 was 19,740, with the separately protected City of London adding 976 to the area's quota. In addition there were 55 county constabularies and 73 city or borough forces in England and Wales. These were responsible for policing almost 500 cities, boroughs and counties. The authorized strength of the county forces totalled 27,762 and that of the city and borough forces 20,950. Thus, the grand total for England and Wales was 69,428 officers and men.

The Scottish establishment consisted of 27 county constabularies with a total authorized strength of 2,750 and 18 borough forces aggregating 4,573 men.

Ratios of police to population are highest in England, where in 1947 there were 1.57 police per thousand of population as against Scotland's 1.42 and 1.08 in Wales. Some of this disparity is caused by the varying ratios of urban and rural population, some of it by special influences affecting the gravity of the local police problem.

Although the British police system is deeply imbedded in local political institutions, the national government nevertheless maintains a certain degree of surveillance over the administration of even the smallest borough forces and county constabularies and extends financial and technical aid in various important ways. This represents an effort to introduce some degree of unity and coherence into a system that in most respects is wholly decentralized. Hence, the home secretary (for England and Wales) and the secretary of state for Scotland may enforce standards of efficiency in all police establishments. They also control the conditions of police employment (appointment, promotion, discipline, compensation, etc.) through widely ranging regulations. Such controls are made effective by the grant-in-aid annually made to each police establishment, totalling one-half of the net cost of each force, including pensions. With the various forces thereby made dependent in large degree upon the national exchequer, it is provided that the grants shall be made only to those meeting the required standards. Annual visitations by his majesty's inspectors of constabulary (four for the home office, one for the Scottish office) operate to enforce compliance.

The national government provides various central facilities. It operates seven forensic science laboratories, district recruiting offices, regional networks for wireless communication and ten training centres serving a number of neighbouring forces. It also bears a special relationship to the metropolitan police that springs from the unique position and character of that force. For example, the metropolitan police force is charged with certain imperial and national duties not readily performed by any other existing body. It is responsible for the protection of the royal family and the ministers of government, the regulation of traffic and maintenance of order in the vicinity of the houses of parliament, the guarding of government buildings and special precautions taken at state functions. All such would impose an inequitable burden upon the ratepayer of the metropolitan police district were it not for the special contribution of £100,000 a year that is made from the exchequer for the general support and furtherance of these purposes. The chief agency engaged in these duties is the special branch of the metropolitan police.

The metropolitan police force performs a widely heralded and generally misunderstood function in investigating certain crimes committed outside the metropolitan area. For the most part these excursions are confined to cases of murder; and since they are authorized only upon the request of the local authorities directly concerned, their number in any one year is small. The metropolitan police force also operates the Criminal Record office, a national registry of crimes and criminals, and publishes the daily *Police Gazette* which is distributed without charge to the police of Great Britain and Ireland as well as to certain parts of the empire and a few foreign forces. This publication carries details of persons wanted for crime, or who are already in custody and may be wanted by other jurisdictions, plus descriptions of property stolen and recovered.

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(BR. S.)

POLICE COURTS, courts of summary jurisdiction held in London and certain large towns in England and Wales by specially appointed and salaried magistrates.

Police magistrates are appointed by the Crown. They must have been practising barristers for seven years or stipendiary magistrates for some place in England or Wales. One police magistrate has the same powers as two justices.

The precedent of appointing salaried magistrates was adopted in certain provincial towns under particular acts, and in 1863 the Stipendiary Magistrates Act enabled towns and boroughs of 25,000 inhabitants and upwards to obtain a stipendiary magistrate. There are at the present time (excluding metropolitan magistrates' courts) 18 stipendiary magistrates' courts throughout England and Wales.

In the United States there are no so-called police courts in the Federal system of courts except in the District of Columbia, where the President appoints, subject to confirmation by the Senate, two judges of the police court. In the various States, police courts, the presiding official of which is either a judge or a magistrate, have been created for many cities. They are elected by the voters, and try the violators of municipal ordinances.

POLICE POWER, in American constitutional law, the reserved or inherent powers of the States to legislate for the health, safety and morals of the community. The requirements of the 14th amendment of the U.S. Constitution that no State shall deprive any person of life, liberty or property without due process of law and the interpretation of that amendment by the Supreme Court to give it a supervisory jurisdiction over all State legislation restricting the exercise of individual rights, brought to the forefront the concept of police power as a basis for sustaining the exercise of novel State legislation. The ultimate test of constitutionality under the due-process clause being the arbitrariness to the judicial mind of the State legislation, the relationship between the legislation and the admitted power of State governments to act for the protection of the community in ways reasonably adapted to secure those ends becomes of acute and decisive importance.

Resolving this relationship in terms of traditional concepts of constitutional law, legislation provided that it falls within the police power of the States even though it interferes with property or personal rights does not then run afoul of the due-process clause of the 14th amendment. The ultimate question, of course, remains, namely the extent of the police power viewed in the light of the object sought to be effected by the legislation and the means devised to secure that object. The extent of the police power remains as the least defined of State powers. With a political collectivistic philosophy gradually supplanting the individualistic philosophy of an earlier age, illustrated by the increasing regulatory activities of government, the content of police power becomes an ever-broadening one. Supreme Court decisions reflect this change in later cases that overruled earlier decisions declaring unconstitutional State legislation seeking to protect interests not then deemed within the legitimate scope of governmental regulation.

The extent of the police power is generally said to embrace the protection of the health, safety and morals of the community. Regulation of the practice of trades directly related to the health of the community, restrictions upon the use of property for sanitation purposes, prohibition of immoral amusements, requiring the installation of equipment designed to protect the safety of employees or the public, the regulation of traffic, the regulation of hours of labour, are all types of governmental activity within the recognized domain of State legislation. The police power, however, extends to purposes not so clearly related to the health, safety or morals of the community. The conservation of natural resources, zoning legislation, the protection of the public against fraud and waste, the enforced destruction of property adapted for illegal uses but capable of permitted uses, are examples of the uncharted scope of the police power. It is commonly said that the police power may not be exercised purely for aesthetic purposes, but as a better understanding of the organization of society may illustrate an intimate relationship between the promotion of aesthetical ends and general social welfare, the concept of police power may well be enlarged to include purely aesthetic considerations. The Federal Government is said to possess no general police power. Inasmuch as the Federal Government is one of limited

powers and no general power for the protection of the health, safety and morals of the nation is granted to it under the Constitution, such a statement is accurate. But the Federal Government in the exercise of its granted powers may and does act for the promotion of ends within the concept of police power, and in this sense it has full freedom to protect the health, safety and morals of the community.

There are certain important differences between the exercise of the police power and other inherent State powers. The power of eminent domain, constitutionally restricted to employment for a "public use," can only take property by the payment of just compensation. The exercise of the police power may involve an equal "taking" of property but carries no obligation to compensate for such a taking. Again under the U.S. Constitution no State may pass legislation impairing the obligation of contracts already entered into. State action under the police power may, however, impair the obligation of contracts without conflicting with the constitutional prohibition, thus "taking" contract as well as property rights without compensation. (*See* CONSTITUTION AND CONSTITUTIONAL LAW.)

See Freund, *Police Power* (1904); Burdick, *Law of the American Constitution* (1922); Mott, *Due Process of Law* (1926).

(J. M. LA.)

POLIGNAC, an ancient French family, which had its seat in the Cevennes near Puy-en-Velay (Haute Loire). It can be traced to the 9th century, but in 1421 the male line became extinct. The heiress married Guillaume, sire de Chalançon (not to be confused with the barons of Chalançon in Vivarais), who assumed the name and arms of Polignac.

The first historically important member was Cardinal MELCHIOR DE POLIGNAC (1661–1742), a younger son of Armand XVI., marquis de Polignac, who became a distinguished diplomatist. In 1695 he was sent as ambassador to Poland, where he brought about the election of the prince of Conti as successor to John Sobieski (1697). In 1712 he was sent as the plenipotentiary of Louis XIV. to the Congress of Utrecht. During the regency he became involved in the Cellamare plot, and was sent to Flanders for three years. From 1725 to 1732 he acted for France at the Vatican. In 1726 he received the archbishopric of Auch, and he died at Paris in 1742.

Prince JULES DE POLIGNAC (1780–1847), son of Count Jules (d. 1817), played a conspicuous part in the clerical and ultra-royalist reaction after the Revolution. Under the empire he was implicated in the conspiracy of Cadoudal and Pichegru (1804), and was imprisoned till 1813. After the restoration of the Bourbons he held various offices, received from the pope his title of "prince" in 1820, and in 1823 was made ambassador to the English court. On Aug. 8, 1829, he was called by Charles X. to the ministry of foreign affairs, and in November became president of the council. His appointment was taken as symbolical of the king's intention to overthrow the constitution, and, with the other ministers, he was held responsible for the policy which culminated in the issue of the Four Ordinances which were the immediate cause of the revolution of July 1830. On the outbreak of this he fled for his life, but was arrested at Granville and condemned to perpetual imprisonment. The sentence was commuted to one of exile by the amnesty of 1836. During his captivity he wrote *Considérations politiques* (1832). He spent some years in England, but was permitted to re-enter France on condition that he did not live in Paris. He died at St. Germain on March 29, 1847.

POLIGNY, a town of eastern France, in the department of Jura, 18 m. N.N.E. of Lons-le-Saunier on the P.L.M. railway. Pop. (1936) 3,417. Under the name of *Polemniacum* the town seems to have existed at the time of the Roman occupation. It lies in the valley of the Glantine at the base of a hill crowned by the ruins of the old castle of Grimont, once the repository of the archives of the county of Burgundy. The church of Montivillard dates from the 12th century and has a fine Romanesque tower. The church of St. Hippolyte, early 15th century, and a convent-church serving as corn market are of some interest. Poligny has a national school of dairy instruction.

POLISH LANGUAGE. Together with Polabian—a now extinct language spoken by the Slavs of the Elbe before they became Germanized—Sorb or Wendish, and Czechoslovak, Polish belongs to the western branch of the Slavonic languages. The nearest relative of Polish is Polabian, with which it forms the Lech group, but in view of the fragmentary character of the remains of that language (a few words and sentences inexactly recorded), it is difficult to state with any detail more than the purely phonological agreements. Those which are shared by the Lech languages and Sorb are: extreme palatalization of consonants before front vowels, the absence of the vowels *r* and *l*, a particular development of *or* and *ol* between consonants, and the tendency to lose the old distinctions of quantity. In all these points there is a contrast with Czechoslovak which to some extent bridges the gap between the western and the southern branches; but the characteristic features of West Slavonic are naturally common to Polish and Czechoslovak. The features which are generally considered as belonging to common West Slavonic are: the development of *tj* and *dj* to *c* and *dz* (Polish and Slovak still have *dz*, but in Czech the sound has become *z*); the palatalization of consonants before *i*, *e*, *ę* and *ĭ* (only partially carried out in Czech, but Slovak agrees more completely with Polish); passage of *l* before back vowels and consonants to a sound like that in English "wall" (preserved also in Slovak dialects and in Old Czech, but the German *l* prevails in the modern language); loss of *ĭ* between vowels, with compensatory development of a long vowel; shortening of long vowels which originally had a falling intonation; and the tendency to throw the stress away from the final syllable.

Polish is softer than Czech to the ear, owing to the predilection for palatal and sibilant sounds. The sentence melody, in spite of a regular accent on the penultimate, is in no way disagreeable, and the consonantal groups, which at first seem frightening, are easily pronounced after some practice. The survival of the old nasal vowels imparts to Polish an acoustic effect not unlike that of French.

The Slavonic inflexional type has been well preserved: there are seven cases in both singular and plural (the dual has almost disappeared). The verb is of the normal type, except that it has lost the imperfect and aorist. A peculiar feature in the syntax of Polish is the impersonal passive construction, where the logical subject is put in the accusative after the neuter of the participle. The vocabulary of Polish has been considerably influenced by earlier Czech and also by German and Latin, but in the main the Slavonic character has not been seriously affected, and the number of words from other languages is negligible.

Polish dialects are usually divided into two broad divisions. The group to which the literary language belongs has preserved the old pronunciation of *sz* and *ż* (as in English "ship" and "azure" respectively), while the other has altered them to *s* and *z*. Scholars are disagreed on the question of Kašube, which is spoken by fewer than a quarter of a million people in the neighbourhood of Danzig. In its modern form, it is very close to Polish, especially from the point of view of vocabulary, but it has several features which make it possible that at an earlier stage it was more closely connected with Polabian.

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(N. B. J.)

POLISH LITERATURE. The Polish language belongs to the western branch of the Slavonic tongues, and exhibits the closest affinities with Czech, Slovak and Lusatian Wendish.

The earliest connected specimens of Polish prose are: the fragmentary *Holy Cross Sermons,* and the complete *Psalter of St. Florian,* both preserved in 14th century mss. which are probably copies of earlier originals. The beginnings of poetry are represented by the *Bogurodzica* song, a hymn in honour of the Virgin, often sung by the Poles of the middle ages when going into battle. Legend ascribed the origin of the song to St. Adalbert (Wojciech), in the 10th century. The oldest ms. of the song is dated 1408.

The 15th century brings a fuller development of religious poetry. A number of devotional songs are preserved, being mostly translations of Latin or Czech hymns. Many of these songs are the work of Ladislas of Gielniów, a Bernardine preacher, and of other friars of the same order.

The secular lyrics of the 15th century which have come down to us are not numerous but varied in contents, some being didactic in vein, such as the verses on table manners, some amatory and some in the nature of historical ballads on important public events; the victory over the German Knights in 1410, the defeat of Poles and Hungarians at the hand of the Turks in the battle of Varna (1444), Tartar invasions and other disasters, a riot of the Cracow citizens who kill an unpopular nobleman (1461)—such are the facts commemorated. The coming controversies of the Reformation period cast their shadows before them in a vivid poem by Andrew Galka, on the doctrines of Wycliffe, which had become known through the Hussite movement in Bohemia.

Prose works in the 15th century are scarce: Polish 15th century prose is largely devotional: its longest specimen is a translation of the *Bible* made for Sophia, queen of Poland, about 1455; several books of the Old Testament only are preserved.

Latin Literature in Mediaeval Poland.—If literature in Polish is scanty, Latin literature in Poland throughout the middle ages is fairly abundant, especially in the field of history. The first chronicle of Poland written in Latin is an early 12th century work by an anonymous foreign monk, whom tradition called "Gallus." It tells the story of Poland from the beginnings of the Polish State in the middle of the 10th century till 1113. A hundred years later, a continuation of this chronicle was undertaken by Vincent Kadłubek, bishop of Cracow.

In the 13th and 14th centuries, the number of chronicles increases: we may single out that of Jan of Czarnków (d. 1389), which gives a vivid account of conditions in later 14th century Poland. A great centre of intellectual and literary activities was created by the foundation of the University of Cracow. The university was originally erected as a legal college in 1364; in 1400 it was reorganised on a broader basis, mainly through the efforts of Queen Jadwiga, who, by her marriage with Duke Jagiełło, united Poland and Lithuania in a powerful monarchy. It is in the shadow of Cracow university that Poland's most distinguished mediaeval historian, Johannes Długosz or Longinus (1415–1480) undertakes his great Latin work on the history of the country. Through diligent study of the royal and ecclesiastical archives, which were open to him, and of the works of native and foreign historians, Długosz produced in his *Historia Poloniae* the first monumental work of Polish historiography which unites critical scholarship with literary excellence. History is supplemented by the lives of saints, ever popular in the middle ages.

Latin poetry in mediaeval Poland, as in other European countries, is represented by church hymns as well as by the Latin carollings of the *clerici vagantes.* As the Renaissance approaches, the ground for the elegant Latin versification of the humanist scholars is prepared.

Early Polish Printed Books.—A printing-press was in existence at Cracow about 1474. But it was only about 1500 that a permanent printing office was established at Cracow by Jan Haller, followed by a number of others. Among the books they printed, Latin are still in the majority; but Polish books begin to appear in increasing numbers. A large part of them is devotional. Fiction, as elsewhere, is represented by "chap-books" on such subjects of international popularity as the fabulous histories of Alexander the Great and the stories collected in cycles like the *Gesta Romanorum* or the *Seven Sages.* Among the translators who provided this sort of literary food, Bernard (Biernat) of Lublin (*c.* 1515), takes a prominent place, chiefly by his rhymed paraphrase of *Aesop's Fables* and the romantic *Life of Aesop.* Next to him stands Jan of Koszyczki, who paraphrased the ancient jests associated with the names of King Solomon and his legendary opponent, the shrewd peasant Marculf: these humours of *Marchołt,* as he is called in Polish, are a fine specimen of racy popular speech. So are some religious songs, especially Christmas carols, interlarded, in the fashion of the time, with jocular details from contemporary life. With such literature, still essentially mediaeval in character, we may rank even the elaborate and widely-read *Chronicle of the World* (1551), written in Polish by Martin Bielski, as well as his *Satires* and his allegorical play *Justinus and Constantia,* the first morality in Polish.

Humanism and the Reformation.—A period justly called "the golden age" of Polish literature was prepared by the spread of Renaissance humanist culture, and of the doctrines of the Reformation. Poland, like other countries, began to produce Latin prose and poetry during the 16th century. The witty and licentious, satirical and erotic epigrams of Bishop Andrew Krzycki (d. 1537), the serious political and moral epistles of the diplomat Joannes Dantiscus (a burgher of Danzig, d. 1548), the tender elegies of Clement Janicki (Janicius), dead in his prime in 1543, rank with the best Latin poetry of modern Europe. The mediaeval historical work of Długosz is surpassed in grace by the humanist Latin of Martin Kromer's *History of Poland* (1555). Poland's greatest political thinker of the period, Andrew Frycz-Modrzewski, used Latin for his work *De republica emendanda* (1551), a systematic treatise on social philosophy; and as late as the 17th century a Polish jesuit, Mathew Sarbiewski (d. 1640), became known throughout Europe as "the Christian Horace" for the beauty of his Latin religious lyrics. On their travels abroad, Polish students not only perfected their Latin and Greek, but witnessed the new growth of vernacular literatures based on classical models, and this awakened the ambition to rival foreign achievements by Polish verse and prose. Such ambitions were stimulated by a Protestantism which favoured the vernacular. After the council of Trent and the coming of the Jesuits (1564–1565), Protestantism began to decay: but what it had done for national literature remained effective. The Catholic Polish bible of Bishop J. Wujek (1599) has greatly influenced language and style.

The Poets of the Golden Age.—The year 1543 is a landmark, being the date of the appearance of the first important work of Nicholas Rej of Nagłowice (1505–1569). After a somewhat idle youth he wrote a long series of poetical works. He turned Calvinist in middle age, and produced a translation of the Psalms. His principal and most mature works—the *Image of an Honest Man's Life,* in verse, and the more elaborate prose *Life of an Honest Man*—present his moral ideals, being those of a good-natured country gentleman. The latter work is also known as *The Mirror.*

Rej's popularity was outshone by the fame of Jan Kochanowski (1530–1584). He resided in Paris, where he met Ronsard. Returning to Poland, he became in 1564 secretary to the king. His less important early works, among which a paraphrase of Vida's poem on the *Game of Chess* may be singled out, were followed by epigrams called *Trifles* ("Fraszki") and by numerous *Songs* varied in tone, idea and form like the Odes of his master Horace, yet instinct with modern sentiment. In a longer poem, *The Satyr,* he deals with the serious political problems of Poland in his time, in *St. John's Eve* (Sobótka) he delights us with pictures of nature and country life. Kochanowski's only dramatic work, *The Dismissal of the Grecian Envoys* (Odprawa posłow greckich) (Eng. tr. Noyes and Merrill, Berkeley, Cal., 1918), is a verse tragedy in the Greek style, with choruses, on a subject from *Iliad* iii. Another work of Kochanowski's, his verse paraphrase of the *Psalms,* remains one of the masterpieces of religious lyrical poetry in Polish, only rivalled among his works by the *Treny* or *Laments* for his little daughter Ursula who died in childhood (Eng. tr. Prall, Berkeley, Cal., 1920). Another great lyrist of the period, Nicholas Sep Szarzyński (1550–1581) died

in his prime. He introduced the sonnet into Polish poetry. The long descriptive and satirical poems, in Polish and Latin, by the townsman Sebastian Klonowicz (1545–1602) are interesting as illustrations of the social life of Poland. Simon Szymonowicz (or Simonides, 1554–1642), a burgher of Lwów, and an elegant Latin poet and dramatist, acquired fame as a Polish writer by his Pastorals which imitate Theocritus and Virgil, but contain vivid scenes from Polish life.

Prose Classics of the 16th Century.—Simultaneously with poetry, Polish prose rises into excellence. The religious and political controversies of the hot-blooded prelate Stanisłas Orzechowski (1515–1566) were conducted in a style of admirable vigour. The version of Castiglione's *Il Cortegiano,* by Lucas Górnicki (1566) is a fine monument of Polish prose style. Ecclesiastical eloquence found its master in the Jesuit Peter Skarga (1536–1612), indefatigable as the protagonist of the Catholic cause in Poland. His *Lives of Saints* have remained a religious classic; but his *Parliamentary Sermons* published in 1597 are the crown of his life's work. It is here that Skarga, exposing the faults of the Polish national character and foretelling the downfall of the State, challenges comparison with the Hebrew prophets.

FROM BAROQUE TO CLASSICISM

The Age of Baroque.—The 17th century, although a period of wars and invasions, is rich in literary production. Italian models, with all the extravagance of the *seicento* manner, give to 17th century Polish literature, variety and colour, but at the expense of unity and moral elevation. Important works, censored by the clergy, have come to light only in recent times.

Poets of the 17th Century.—The military events of the period, together with the influence of Tasso's epic (translated into Polish, as was also Ariosto's, by Peter Kochanowski) inspired a number of epic poems dealing with contemporary history. The principal poet of the period, Wacław Potocki (1625–96) composed an enormous epic on the Chocim campaign of 1621 against the Turks and followed it up with *The New Mercury* and *The Turks' Defeat at Chocim* on the victories of John Sobieski. He also left behind in ms. two large collections of minor verse, *The Garden* and *Moralia,* and both illustrative of all aspects of the Polish life of his time. Potocki is also the author of a huge body of religious verse, and of several verse romances both original and translated. Potocki was preceded by Samuel Twardowski (1600–60) author of three interminable rhymed chronicles on the stormy events of the time. A fantastic verse story of his, *The Beauteous Pasqualina,* is noteworthy as a paraphrase from Montemayor. A bitter satirist appeared in Christopher Opaliński (1610–56). His brother Lucas (1612–62) is also a satirist, and a better poet, as well as a political writer of merit. He wrote also an *Art of Poetry.* Vespasian Kochowski (1633–1700), in importance next to Potocki, surpasses him in artistic refinement. Having fought in many Polish wars, he told the story of some of them in voluminous epics. But neither these nor his long religious poems are as important as his *Polish Psalmody,* modelled on Kochanowski's verse Psalter, but written in poetic prose and embodying much of the poet's own inner life. A poet of peculiar charm and grace meets us in the person of Andrew Morsztyn (1613–93), who translated Tasso's *Aminta,* Corneille's *Cid,* and Marini's *Psyche,* and represents, in his own lyrics, the first instance of the deep influences of Italian and French literature. Simon Zimorowicz (1608–29), a burgher of Lwów, who died young, shines like a meteor by the freshness and poetic sentiment of his love lyrics *Roxolanki.* His elder brother Joseph Bartholomew (1597–1677), gives us delightful glimpses both of town and country life, and interesting accounts of quiet as well as of stormy times, in his *Idylls.*

18th Century Prose.—Among prose writers, we may single out: the Dominican preacher Fabian Birkowski (1566–1636), a baroque successor to Skarga; the learned and voluminous Latin and Polish writer Simon Starowolski (1585–1656), whose Latin works include the first history of Polish literature; Count Andrew Maximilian Fredro (1620–1697), whose *Proverbs* are a collection of maxims and observations comparable with the works of the French moralists of the time; Stanislas Heraclius Lubomirski (*c.* 1640–1702) who wrote several comedies based on Italian and Spanish originals, and finally, John Chrysostom Pasek (1630–1701), the king of Polish diarists, whose adventures in war and peace are embellished beyond the truth, yet simply and spontaneously narrated.

The Saxon Period.—The era of baroque is prolonged into the sad period of political decay and intellectual stagnation covered by the reigns of Augustus II. and III. (1697–1763). Specimens of literature worth recording, like the unpretending verse of Poland's first poetess Elizabeth Druzbacka (1695–1765), are isolated in this age. But even this darkest period of Polish civilisation is illuminated by such efforts as Stanislas Konarski's (1700–1773) reform of the secondary schools conducted by the Piarist fathers and his proposals for a thorough reform of Polish literary style (*De emendandis eloquentiae vitiis,* 1744).

The Era of Enlightenment: Poets.—The reign of the last king of Poland, Stanislas Augustus Poniatowski (1764–1795), is a period of literary development. Both the general atmosphere of the age of rationalism, and the peculiar conditions of Poland—the imminent danger of ruin to the commonwealth—gave the literature of the period a predominantly didactic character: satire, as elsewhere in Europe, is prominent. Thus, the representative writer of the age, Ignatius Krasicki (1735–1801) was, above all, a satirical poet. Krasicki is a typical eighteenth century prelate of the sort not uncommon in western Europe at the time. After his early heroic-comic poem, *Myszeis,* on the battle of the rats and mice against the cats, he soon rose to a higher level in his epic satire on monastic life, *Monochomachia.* This was followed by a biographical novel, *The Adventures of Doświadczyński,* which contains a good deal of satire on the Polish gentry. A second novel, *Pan Podstoli,* is more didactic in design: it draws Krasicki's picture of the ideal country gentleman. The high-water mark of Krasicki's work is reached in his *Satires,* the supreme achievement of 18th century classicism in Poland. They are followed by *Epistles,* but his most popular work is his *Fables,* which has made him the La Fontaine of Poland. His voluminous prose works include the first Polish survey of universal literature.

The poet next to him in the favour of his contemporaries, Stanislas Trembecki (1735–1812) is Krasicki's equal in clearness and expressiveness of language, but otherwise inferior to him. Trembecki excels in his *Fables* and *Epistles* by perfection of phrase and melody of verse. The fiery satirist Kajetan Wegierski (1755–84), who died in his prime after a youth of dissipation, was perhaps more deeply influenced than others by the French writers of the age, whom he loved to translate. The later poets of the period mark the transition from rationalism to romantic sentiment and include Francis Karpiński (1741–1825), and Francis Kniaznin (1750–1807).

Prose Writers of the 18th Century.—Bishop Adam Naruszewicz (1733–96), owes his chief title to fame to his ponderous history of mediaeval Poland, the first scholarly treatment of the subject. Stanisław Staszyc (1755–1826), a liberal-minded priest, began his career with powerful pamphlets advocating political and social reform, and continued it after the partitions of Poland as a scientist and an organiser of research and industry. His fellow-reformer, Father Hugo Kollontaj (1750–1812), surpassed him as a political journalist and in his later work, as a philosopher.

The Theatre.—It was for school theatres that Francis Bohomolec wrote his comedies (1755–60), based on French models, chiefly Molière. At the same time, Wacław Rzewuski (1706–1779), wrote tragedies from Polish history in the French classical style for the private theatre at his residence. But it was only with the foundation of the first public theatre in Warsaw in 1765 that Polish dramatic literature got a permanent footing; and the manager of that theatre, Wojciech Bogusławski, himself a popular playwright, is the real creator of Poland's theatrical tradition. It was for this theatre that Francis Zobłocki (1754–1821) wrote his satirical comedies, drawing for subject-matter on obscure French sources, but presenting Polish figures and Polish ways. *The Dandy's Courtship* (Fircyk w zalotach) is his masterpiece. The famous comedy *The Return of the Deputy* (Powrót Posła) by Julian Ursyn Niemcewicz (1757–1841), was written to help the

cause of political reform. Niemcewicz himself, aide-de-camp to Kościuszko, made his mark in many fields of literature. His *Songs of Polish History* (Spiewy historyczne) are still read and recited in schools. His *Fables* and *Satires,* comedies and tragedies belong to the 18th century, but by his translations of English ballads and romantic poems, as well as by his novels he heralds the coming of a new age. His *Memoirs* are a valuable chronicle of the transition period.

THE NINETEENTH CENTURY

The Romantic Era.—Soon after the disappearance of the old Polish State the vitality of the nation was manifested not only by military effort during the Napoleonic Wars, but also by intellectual and literary achievements. The University of Vilna (which had received its charter in 1579) entered on a flourishing period soon after 1800: the great poet Mickiewicz came from the ranks of its pupils. In the South-Eastern part of the borderlands, the Lyceum or public school of Krzemieniec in Volhynia displayed similar activities. In Warsaw itself a "Society of Friends of Learning" came into being in 1800, and a *Dictionary of the Polish Language* by Samuel Linde was among its many undertakings. Warsaw remained the capital of literary taste, and in the first decades of the century, the classicism of the former age still reigned there. It is represented by the poet and critic Kajetan Kozmian the author of Polish Georgics (*Ziemianstwo*), and bishop J. P. Woronicz (1757–1829) who, in his didactic poem *Sybilla,* drew comforting conclusions from a philosophical survey of Poland's history.

The strong didacticism of the classicist era also inspires the literary activities of Mme. Clementina Hofman (née Tanska), who produced the standard works of Polish educational fiction.

At the very end of its period classicism still gives Poland one great writer in Count Alexander Fredro (1793–1876) the author of the best Polish comedies. A soldier under Napoleon, he saw the masterpieces of French classical comedy in Paris and followed Molière. His first piece, *Pan Geldhab,* a satire on *nouveaux riches,* was produced in 1821. He wrote about twenty other comedies, and then abandoned production for fifteen years. At his death, however, he left behind a number of further plays in ms. His best-known works are: *Zemsta* (The revenge), which satirizes the mania for litigation among country gentlemen; *Śluby panieńskie* (Girlish Vows); *Damy i huzary* (Ladies and Hussars, Eng. trs. Noyes, 1925); *Mąz i zona* (Husband and Wife); *Dozywocie* (The Life Interest) and *Pan Jowialski* (The old Story Teller). The comedies, mostly in verse, portray the Polish country gentry to which Fredro belonged.

Midway between the classicists and the romantics stands the curious figure of Casimir Brodzinski (1791–1835). His verse idyl *Wiesław,* in which the manners of the peasants of the district of Cracow are portrayed, is classical in style and diction, but romantic in sentiment. His essay on *Classicism and Romanticism* and on *The Spirit of Polish Poetry* (1818) proclaimed the importance of national tradition and popular elements for literature, and in his lecture *On Polish Nationality* (1831) he partly anticipated the notion, fully developed by the great romantics, of Poland as a "chosen people." The boldness of new ideas was combined with supreme power of poetic achievement in Adam Mickiewicz (*q.v.*) (1798–1855), who soon became the acknowledged leader of the Romantic Movement.

Juljusz Słowacki (1809–49) is in many ways more representative of the essence of Romanticism than Mickiewicz. His genius develops under the influence of Byron. *Podróz na Wsckód* (A Voyage to the East), is a poem in the manner of *Childe Harold.* Słowacki's fantastic verse play *Kordjan* combines reminiscences of a Warsaw conspiracy against the tsar in 1829 with the influence of *Manfred* and of *Hamlet.* Mickiewicz's *Ksiegi Pielgrzymstwa* (Books of Pilgrimage), written in biblical prose for the comfort of Polish exiles in France, are paralleled by Słowacki's *Anhelli,* in which the Polish emigrant community in western Europe is represented under the allegorical disguise of a body of exiles in Siberia. It is, however, under the direct influence of Shakespeare that Słowacki attained his supreme poetic triumphs in drama.

His verse tragedies, *Balladyna* and *Lilla-Weneda* are placed in a legendary, pre-historic Poland: *Mazepa* takes place at the court of a Polish noble of the 12th century. The Polish world of the 12th and 18th centuries is the scene of two further plays of Juljusz Słowacki, *Horsztyński* and *Złota Czaszka* (The Golden Skull), both unfortunately incomplete. The influence of Victor Hugo gives a sensational tinge to *Beatrix Cenci.* From Shakespeare and Victor Hugo, Słowacki passes under the influence of Calderon: he deals in Calderonian style with events from 18th century Polish history in his dramas *Ksiadz Marek* (Father Mark) and *Sen Srebrny Salomei* (The Silver Dream of Salomea). The last years of Słowacki's short life were spent among the Polish emigrants in Paris. The political and religious doctrines, the illusions, disillusionments and quarrels which agitated that little world, are mirrored in Słowacki's satirical epic *Beniowski,* which occupies, in his career, the place of *Don Juan* in Byron's. The mystical creed, which possessed the poet entirely in his latest years, inspired one of his most sublime works, the unfinished epic *Król Duch* (The Spirit King). The poet's complete spiritual philosophy of the mystical period is embodied in a prose treatise *Genesis z Ducha* (The Genesis from the Spirit), which curiously anticipates, in some of its ideas, the theory of evolution.

Zygmunt Krasinski (1812–1859)[1], long considered the equal of Mickiewicz and Słowacki, rose to an extraordinarily high level in his precocious early work. He became absorbed in meditations on the social revolution which after 1830 seemed to be threatening all Europe, and he put his vision of it, at the age of 21, into a drama *Nieboska Komedja* (The Un-Divine Comedy) (Eng. tr. Kennedy and Uminska, 1923). Krasinski's second work, the drama *Iridion* (Eng. tr. Noyes, 1927), placed in Rome in the second century of our era, has for its subject an attempted revolt of the Greeks against the Roman Empire. The attitude of the Christians, who refuse to fight, is the cause of failure. Krasinski links up his subject with philosophical speculations on the historical mystery of Poland's sufferings. His creed in this matter is embodied in a visionary poem called *Przedświt* (The Dawn), in which he extols the passive heroism of his oppressed country as the earnest of victory in the ideal sphere. These ideas are repeated in several didactic lyrics called *Psalmy Przyszłości* (Psalms of the Future). Krasiński's waning talent spent itself on political, religious and philosophical pamphlets and lyrics.

All the three great Romantic poets had come, for a time under the spell of an emigrant thinker named Andrzej Towianski (1799–1878) who had woven religious and patriotic mysticism together into the creed of a new sect, making of Poland a "messiah among nations." Krasiński's thought, in particular, also shows close relation to that of August Cieszkowski (1814–1894), the most distinguished and independent of a group of Polish philosophers who were disciples of Hegel. ("Our Father," selections in English by Dr. W. Rose, 1924.)

It is only in the 20th century that another Polish metaphysician of the Romantic period, Joseph Maria Hoene-Wronski (1778–1853), who wrote mainly in French, has won an increasing amount of international recognition.

Among the lesser romantic poets, the so called "Ukrainian school" forms a group apart. Its earliest representative, Antoni Malczewski (1793–1826), preceded even Mickiewicz as the author of a Byronic tale in verse. His romance *Marja* (Mary, 1825), breathes all the charm of chivalrous tradition and melancholy steppe landscape associated with Poland's south-eastern border.

Byronic colours are laid on more thickly by Seweryn Goszczynski (1803–1876) in his verse tale *Zamek Kaniowski* (Kaniow Castle), full of the horrors of age-old class war between the Ukrainian peasantry and the Polish borderland gentry. In his later work, he became a forerunner of realism.

The third most prolific singer of Ukrainian traditions and landscape in Polish poetry, Joseph Bohdan Zaleski (1802–1886), is a lyrical poet of great melody, but fatal facility. In his most ambitious effort, the philosophical poem *The Spirit of the Steppe* (Duch od stepu) he endeavours to reconcile the Romantic dreams

[1]*See* the study by Monica M. Gardner: *The Anonymous Poet of Poland* (Cambridge, 1919).

of the high dignity of Poland's sufferings with a moral and Christian view of her past errors and contemporary fate.

Another region of Poland's historical domains, the Masovian plains in the centre of the country with their purely Polish peasantry, are the subject of the lyric poetry of Teofil Lenartowicz (1822–1893): although he spent his later years as a sculptor in Florence, he never ceased to sing of Polish country life.

His counterpart is Wincenty Pol (1807–1872), who sings with equal persistence of the old-world life of the country gentry. A soldier in the insurrection of 1831, he commemorates this in a series of stirring and popular songs (*Pieśni Janusza*): a Professor of geography in his later days, he produces a picturesque descriptive account of Poland in verse (*Pieśn o Ziemi Naszej*) and several geographical works in very vivid prose.

What the Ukrainian group did for the South-East, and Lenartowicz and Pol for central Poland, was done for the North-Eastern domains of the historical Poland (Lithuania and White Ruthenia) by Ludwik Władysław Kondratowicz, known as Syrokomla (1823–1862). A son of the minor gentry of those lands, he is at his best when drawing on his memories of his own youthful surroundings (as in the two charming longer poems on the *Early Life and School-Days of Jan Deboróg*).

The romantic inspiration still produced a poet of action in Mieczysław Romanowski (1834–1863), who died a hero's death in the ranks of the insurgents of 1863. He had shown promise in a longer narrative poem of Polish town life in past ages (*Dziewczę z Sącza*), but this bears clear traces of the influence of Mickiewicz' epic masterpiece. It is echoes also of the song of the great Romantic masters that we catch everywhere in the poetry of Kornel Ujejski (1823–1897). He had made his mark, at the age of twenty with the verse tale *Marathon*. Not long afterwards, the national disaster of the Galician peasant riots of 1846 inspired him to write a series of elegies entitled *The Lamentations of Jeremiah* (Skargi Jeremiego), one of which, the *Choral Song* became the anthem of national woe. Before fading away utterly, the Romantic flame once more leaps up wildly in the enigmatic and convulsive, but intensely inspired poetry of Cyprian Norwid (d. 1885). The poet lived in disregard and neglect, and only came into his own long after his death through the efforts of a 20th century critic (Z. Przesmycki).

Of novelists of the romantic period, the very spirit of romance seems incarnate in Michael Czajkowski, who began active life as a Polish insurgent in 1831 and ended it as a Mussulman and a pasha in the Turkish Army. His novels, chiefly from the history of Poland's 18th century wars, are marred by wild improbabilities and artificial glitter. Higher literary value distinguishes the works of Count Henry Rzewuski (1791–1866), especially his stories from 18th century Polish life *The Memoirs of Severin Soplica* and *November* (*Listopad*).

We are on the road from romance to realism in the novel and plays of Joseph Korzeniowski (1797–1863). His drama *The Carpathian Mountaineers* (*Karpaccy Górale*) is aglow with the colours of folk-lore, his comedies, such as *The Jews* (*Zydzi*) or *Miss and Mrs.* (*Panna mężatka*) take us out of the region of old-fashioned comic types into the sphere of modern individualism in character-drawing, and his novels, e.g., *The Schemer* (*Spekulant*) or *The Neighbourhood* (*Kollokacja*) are satiric.

The transition from romance to realism is shown in Joseph Ignatius Kraszewski (1812–1887), whose untiring pen produced over 500 volumes of fiction, history, criticism and other literary matter. His historical novels have made him the Scott of Poland: but he deals with Polish contemporary life as well. The picture of the decay of the land-owning aristocracy in *Morituri* shows deep insight. Of his historical novels, those relating to the "Saxon period" of the early 18th century—such as *Brühl* or *Countess Kosel*—are the best. His influence on readers and other novelists has been enormous.

In the field of the historical novel, Kraszewski is almost equalled in popularity by Zygmunt Kaczkowski (1826–96), who excels in stories of the troublous partitions of Poland. Another popular novelist is Theodor Tomasz Jez (whose real name was Zygmunt Miłkowski, 1824–1915), an insurrectionary soldier and an exile, who has described the history and folk-lore of the Balkans.

Of historians and essayists, Joachim Lelewel (1786–1861), laid the foundation of modern Polish historical research. Among his followers Karol Szajnocha (1818–68), is conspicuous for the literary qualities of his work, as shown chiefly in his monographs of *Jadwiga and Jagiełło* and of *Two Years of Polish History* (viz., 1647–48). History and literary criticism are combined in the brilliant writings of Maurycy Mochnacki, who became the historian of the insurrection of 1830. In Juljan Klaczko, Poland produced a distinguished student of Dante and of renaissance art: but his writings were mainly in French.

The Period of Realism.—The disaster of the second Polish insurrection, in 1863, produced violent reaction against all Romantic dreams both in politics and in literature. The mood of realism was fostered from abroad by the progress of natural science, of economic development, and of political liberalism in Western Europe. The few eminent poets of this age of prose make themselves the heralds of its ideals. The representative lyrist of the positivist generation, Adam Asnyk (1830–97) passed in his own career from the romantic exaltation of national martyrdom to the advocacy of positive social work for popular education: he even became the founder of the "People's School Society" (1891). His mature lyrics are lyrics of thought rather than feeling, and even in his nature poetry reflection predominates over enthusiasm. Feeling abounds in the verses of his most distinguished contemporary in Polish poetry, the poetess Marie Konopnicka (1840–1916): both in her lyrics and her short stories, the dominant note is one of profound pity for the poor. In her long epic, *Mr. Balcer in Brazil* (*Pan Balcer w Brazylji*), she tells the story of the sufferings of Polish peasant emigrants in the Brazilian forest.

The outstanding modern journalist, Aleksander Świętochowski (1849–1938) waged fearless war, both in his articles and his dramas, for the liberal ideals. His younger contemporary, Andrew Niemojewski (1864–1921) was chiefly preoccupied, in his journalism and his poetry, with the new industrial problem.

In the sphere of the novel, Madame Eliza Orzeszko (1842–1910), represents peasants, Jews, great industrialists, but she always returns to the life of the Polish country gentry in her native Lithuania. Bolesław Prus (real name: Aleksander Głowacki, 1847–1912) is, like Dickens, whom he resembles by his humour, a child of the city: the scene of his best social novels, like *The Puppet* (Lalka) and *The Emancipated Woman* (Emancypantki), is laid in his beloved Warsaw. But he also gave a touching account of the peasant's attachment to the soil in *The Outpost* (Placówka). In his largest work, *The Pharaoh*, he performed a *tour de force* by expressing modern ideas in a story of ancient Egypt. Poland's greatest modern writer is Henryk Sienkiewicz (*q.v.*) (1846–1916), whose Quo Vadis became known to all the civilised world, while his epic novels from Polish history—*The Trilogy* and *The Knights of the Cross*—together with the great historical paintings of Jan Matejko revived the romantic sense.

Younger novelists have imitated the extremes of the *roman naturaliste* in the fashion of Zola. Adolf Dygasiński (d. 1903) tells depressing stories of peasant poverty in Russian Poland: but he achieved his highest successes in his accounts of animal life in the Polish country-side, chiefly in *The Feast of Life* (*Gody Zycia*). The high-water mark of *naturalisme* in Poland is reached in the numerous plays and novels of Mme. Gabrielle Zapolska (d. 1923), an actress.

The historical verse play was cultivated with some effect by the illustrious Cracow scholar J. Szujski (1835–83), who, however, is notable chiefly as the author of a monumental *History of Poland*. He became one of the founders of the so-called "Cracow School" of moralising historians, represented beside him with distinction by Walerjan Kalinka (1826–86). Among later members of this group, the historian and jurist Michael Bobrzynski (1849–1935) must be mentioned. While the Cracow school chiefly stressed the faults which contributed to Poland's ruin, Warsaw historians like Tadeusz Korzon (d. 1917) and Władysław Smoleński (d. 1925) consciously emphasized the positive achievements of the nation. The stormy history of Poland

in the 18th century found an able exponent in Ludwik Kubala (d. 1918), whose vivid pages inspired Sienkiewicz. More recently, the history of Poland's struggles for independence during the 19th century has been treated with brilliant talent in the writings of Professor Simon Askenazy. In recent decades, Count Stanislas Tarnowski, president of the Polish Academy (d. 1917), Professor Peter Chmielowski in Warsaw (d. 1905) and Professor Aleksander Brückner in Berlin (1856–1939) won distinction.

POLISH WRITERS OF RECENT TIMES

The "Young Poland" Group.—During the last decade of the 19th century a whole group of young exuberant talents appeared together in the forefront of Poland's literary life. Dissatisfied with the utilitarian character of the art and poetry of the preceding period, they organised themselves into an independent body, soon known as "The Young Poland," with the view of working out a new theory of art, based on absolute individual freedom in form and matter. True to this principle, practically every one of them tried his best to find his own way of expression. The first among these young poets to gain fame was Kazimierz Tetmajer (1865–1940), whose love lyrics are comparable to the best work of the French Parnassians. The modern poetry of France and Belgium found a gifted and congenial interpreter in the person of Zenon Przesmycki, who wrote under the name of "Miriam" (b. 1861). The most forceful individuality of this group was Stanisław Przybyszewski (1868–1927), who, having spent several years among the young Scandinavian and German writers, came back to Poland in 1898 to become at once the leader of the group and the editor of their organ, a weekly called *Zycie* (Life). His dramas full of fatalistic terror, and his prose poems, dealing with the mysteries of love and death, became the fashion of the day.

The art editor of the new weekly was Stanisław Wyspianski (1869–1907), a painter of great originality, who became also the foremost Polish dramatic poet of his age His leading idea was to unite in the theatre the arts of painting, of architecture, and of poetic drama. Gradually his attention turned to national subjects, and especially to the problem of national strength and weakness, which is the root of the three dramas, *Warszawianka* (The Song of Warsaw), *Lelewel,* and *Noc Listopadowa* (The November Night). *The Legion,* a play of which the tragedy of Mickiewicz as the leader of Polish romanticism is the subject-matter—links the past with the present. In three powerful dramas—*Wesele* (The Wedding, 1901), *Wyzwolenie* (Deliverance), and *Akropolis,* he deals with Poland's deliverance

Jas Kasprowicz (1860–1926) was no doubt the greatest Polish lyrical poet of his day. With him, as with Thomas Hardy, the problem of evil and human suffering is the predominant subject. This problem finds expression in *Chrystus* (Christ), *Na Wzgórzu Śmierci* (On the Hill of Death), and finally in the cycle of hymns *Ginącemu Światu* (To the Perishing World). In his later years, the poet attains the wisdom of a resigned sage, which speaks from every line of his last volumes called *Księga Ubogich* (The Book of the Poor) and *Mój Swiat* (My World).

The mood of spiritual calm is also the dominant note of Leopold Staff (b. 1878), who started his poetical career with *Sny o Potędze* (Dreams of Might): but struggles with the eternal mysteries are not absent even from his later volumes, e.g. *Ucho Igielne* (The Eye of the Needle, 1927).

Novelists.—Brought up under Russian oppression, Stefan Zeromski (1867–1925) indulges in pessimism. The most typical of his novels are *"Ludzie Bezdomni"* (The Homeless), *Popioły* (Ashes), dealing with the Napoleonic period, and the story-cycle *Wiatr Od Morza* (The Wind from the Sea)—with his final work, *Przedwiośnie* (Before Springtime) in which he gives a threatening picture of the new Poland.

The winner of the Nobel Prize for literature in 1924, Władysław Stanisław Reymont (1868–1925) was a born realist. His early ambition was to draw a picture of life in a big industrial city. After a stay at Łódz, he produced a novel called *Ziemia Obiecana* (The Promised Land, Eng. tr. M. H. Dziewicki, 1927) which caused him to be hailed by critics as "The Polish Zola." Like Zola, but on a larger scale, he afterwards wrote a novel of peasant life: as the result of five years of incessant work there appeared his tetralogy *"Chłopi"* (The Peasants, Eng. tr. by M. H. Dziewicki, 1924). This great epic novel gives a rich and vivid picture of Polish peasant life especially in the Tatra mountains.

The most talented representative of exoticism in Polish literature is Wacław Sieroszewski (1858–1945) whose stay in political exile among the native tribes of northeastern Siberia resulted in a series of fascinating short stories. An artist of rare subtlety and literary skill was Wacław Berent (1873–1940). His novels *Próchno* (Rot) and *Ozimina* (The Winter Crop) contain a penetrating analysis of the late 19th century mood: his later work, *Żywe Kamienie* (Living Stones) is a rich and interesting picture of mediaeval life. Among disciples of Sienkiewicz, the most talented is Józef Weyssenhoff (1860–1932), whose hunting stories *Sóból i Panna* (The Sable and the Girl, Eng. tr. Mme. K. Zuk-Skarszewska, 1928) describe Poland's Eastern borderland.

Literature in Poland After the World War.—With the reunion of Poland, her literature must lose influence as a national force. But even during the War, there came into being two notable groups of young poets, one in Poznan (the capital of the western provinces of Poland), another in Warsaw. The latter soon surpassed the former, and became the centre of a boldly aggressive and joyous view of life. Among these young poets the most promising are J. Tuwim, K. Wierzyński, J. Lechoń, A. Słonimski, and J. Iwaszkiewicz.

Another group, headed by E. Zegadłowicz and calling itself *Czartak,* looks for inspiration to the quietness and retirement of country life, and to the simple piety and legendary traditions of the folk. In Miss I. K. Iłłakowicz the new Poland possesses a poetess of great lyrical charm. The terrible experiences of the war, and of Bolshevism on the Eastern border, found expression in some notable works by such writers as Mme. Z. Kossak-Szczucka (*Pozoga*—The Blaze—Eng. tr. 1926). The wanderings of Polish exiles in war-time over the vast territories of European and Asiatic Russia have born literary fruit in the vigorous and racy stories of F. Goetel, as well as in the spirited yarns of wild adventures in Mongolia by F. Ossendowski. Otherwise, the novels written since the War, like the *comedies* and *dramas*—the works of W. Perzyński and others—deal with daily reality. The tradition of *poetic drama,* in the fashion of Słowacki and Wyspianski, is kept up by the verse plays of K. H. Rostworowski, E. Zegadłowicz and L. H. Morstin. The reflective post war mood is shown most ably in the novelist Julius Kaden Bandrowski.

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POLISH SUCCESSION WAR (1733–1735), the name given to a war which arose out of the competition for the throne of Poland between the elector August of Saxony, son of August II. (the Strong), and Stanislaus Leszcynski, the king of Poland installed 30 years before by Charles XII. of Sweden and displaced by August the Strong when Charles's projects collapsed. The claims of Stanislaus were supported by France, Spain and Sardinia, those of the Saxon prince by Russia and the empire, the local quarrel being made the pretext for the settlement of minor outstanding claims of the Great Powers amongst themselves. The war was therefore a typical 18th century "war with a limited object," in which no one but the cabinets and the professional armies were concerned. It was fought on two theatres, the Rhine and Italy. The Rhine campaigns were entirely unimportant, and are remembered only for the last appearance in the field of Prince Eugène and Marshal Berwick—the latter was killed at the siege of Philippsburg—and the baptism of fire of the young crown prince of Prussia, afterwards Frederick the Great. In Italy, how-

ever, there were three hard-fought—though indecisive—battles, Parma (June 29, 1734), Luzzara (Sept. 19, 1734) and Bitonto (May 25, 1735), the first and last won by the Austrians, the second by the French and their allies. In Poland itself, Stanislaus, elected king in Sept. 1733, was soon expelled by a Russian army and was afterwards besieged in Danzig by the Russians and Saxons (Oct. 1734–June 1735).

POLITIAN (1454–1494). Angelo Ambrogini, known in literary annals as Angelo Poliziano or Politianus from his birthplace, was born at Montepulciano in Tuscany on July 14, 1454. His father, Benedetto, a jurist of good family and distinguished ability, was murdered by political antagonists for adopting the cause of Piero de' Medici in Montepulciano; this circumstance gave his eldest son, Angelo, a claim on the family of Medici. At the age of ten the boy came to study at Florence, where he learned Latin under Cristoforo Landino, and Greek under Argyropulos and Andronicos Kallistos. From Marsilio Ficino he imbibed the rudiments of philosophy. His genius for scholarship and poetry was early manifested. At 13 years of age he began to circulate Latin letters; at 17 he sent forth essays in Greek versification; at 18 he published an edition of Catullus. In 1470 he won for himself the title of *Homericus juvenis* by translating four books of the *Iliad* into Latin hexameters. Lorenzo de' Medici, who was then the autocrat of Florence and the chief patron of learning in Italy, took Poliziano into his household, made him the tutor of his children, and secured him a distinguished post in the University of Florence. Before he reached the age of 30, Poliziano expounded the humanities with almost unexampled lustre even for that epoch of brilliant professors. Among his pupils could be numbered the chief students of Europe, the men who were destined to carry to their homes the *spolia opima* of Italian culture. Not to mention Italians, it will suffice to record the names of the German Reuchlin, the English Grocyn and Linacre, and the Portuguese Tessiras.

Poliziano published the notes of his courses on Ovid, Statius, the younger Pliny, Quintilian, and the writers of Augustan histories. He also undertook a recension of the text of the *Pandects* of Justinian, which formed the subject of one of his courses; and this recension, though it does not rank high in the scale of juristic erudition, gave an impulse to the scholarly criticism of the Roman code. His versions of Epictetus, Herodian, Hippocrates, Galen, Plutarch's *Eroticus* and Plato's *Charmides* delighted contemporaries by a certain limpid fluency of Latin style and grace of manner which distinguished him also as an original writer. Of these learned labours the most universally acceptable to the public of that time were a series of discursive essays on philology and criticism, first published in 1489 under the title of *Miscellanea*. They had an immediate, a lasting and a wide renown, encouraging the scholars of the next century and a half to throw their occasional discoveries in the field of scholarship into a form at once so attractive and so instructive. Poliziano was not, however, contented with these simply professorial and scholastic compositions. Nature had endowed him with literary and poetic gifts of the highest order. These he devoted to the composition of Latin and Greek verses, which count among the best of those produced by men of modern times in rivalry with ancient authors. The *Manto*, in which he pronounced a panegyric of Virgil; the *Ambra*, which contains a beautiful idyllic sketch of Tuscan landscape, and a studied eulogy of Homer; the *Rusticus*, which celebrated the pleasures of country life in no frigid or scholastic spirit; and the *Nutricia*, which was intended to serve as a general introduction to the study of ancient and modern poetry—these are the masterpieces of Poliziano in Latin verse, displaying an authenticity of inspiration, a sincerity of feeling, and a command of metrical resources which mark them out as original productions of poetic genius rather than as merely professorial lucubrations. Exception may be taken to their style, when compared with the best work of the Augustan or even of the Silver age. But what renders them noteworthy to the student of modern humanistic literature is that they are in no sense imitative or conventional, but that they convey the genuine thoughts and emotions of a born poet in Latin diction and in metre moulded to suit the characteristics of the singer's temperament.

Poliziano's principal Italian works are the stanzas called *La Giostra*, written upon Giuliano de' Medici's victory in a tournament; the *Orfeo*, a lyrical drama performed at Mantua with musical accompaniment; and a collection of fugitive pieces, reproducing various forms of Tuscan popular poetry. *La Giostra* had no plan, and remained imperfect; but it demonstrated the capacities of the octave stanza for rich, harmonious and sonorous metrical effect. The *Orfeo* is a slight piece of work, thrown off at a heat, yet abounding in unpremeditated lyrical beauties, and containing in itself the germ both of the pastoral play and of the opera. The Tuscan songs are distinguished by a "roseate fluency," an exquisite charm of half romantic, half humorous abandonment to fancy, which mark them out as improvisations of genius. It may be added that in all these departments of Italian composition Poliziano showed how the taste and learning of a classical scholar could be engrafted on the stock of the vernacular, and how the highest perfection of artistic form might be attained in Italian without a sacrifice of native spontaneity and natural flow of language.

Beyond the sphere of pure scholarship and pure literature Poliziano did not venture. He was present, indeed, at the attack made by the Pazzi conspirators on the persons of Lorenzo and Giuliano de' Medici, and wrote an interesting account of its partial success. He also contributed a curious document on the death of Lorenzo de' Medici. Otherwise, his uneventful life was passed as a house-friend of the Medici, as the idol of the learned world, and as a simple man of letters to whom (with truly Tuscan devotion to the Saturnian country) rural pleasures were always acceptable. He was never married; and his morals incurred suspicion, to which his own Greek verses lend a plausible colouring. He died, half broken-hearted by the loss of his friend and patron Lorenzo de' Medici, on Sept. 24, 1494.

See F. O. Mencken (Leipzig, 1736); Jac. Mähly, *Angelus Politianus* (Leipzig, 1864); Carducci's ed. of the Italian poems (Florence, Barbera, 1863); Del Lungo's ed. of the Italian prose works and Latin and Greek poems (Florence, Barbera, 1867); the *Opera omnia* (Basle, 1554); Greswell, *Life of Politian* (1805); Roscoe, *Lorenzo de' Medici* (10th ed., 1851); J. Addington Symonds, *Renaissance in Italy* (1875–86), and translations from Poliziano's poems in Symonds's *Sketches and Studies in Italy* (1879). (J. A. S.; X.)

POLITICAL ECONOMY: *see* ECONOMICS.

POLITICAL PENSIONS: *see* PENSIONS, POLITICAL.

POLITICAL SCIENCE, ARTICLES ON: *see* CONSTITUTION AND CONSTITUTIONAL LAW; LEGISLATURE; PARLIAMENT; CONSERVATIVE PARTY; WHIG AND TORY; REPUBLICAN PARTY, THE; DEMOCRATIC PARTY; etc.

POLK, JAMES KNOX (1795–1849), 11th president of the United States, was born in Mecklenburg county, N.C., on Nov. 2, 1795. In 1806 he crossed the mountains with his parents and settled in what is now Maury county, Tennessee. He graduated from the University of North Carolina in 1818, studied law in the office of Felix Grundy (1777–1840) at Nashville, Tenn., in 1819–20, was admitted to the bar in 1820, and began to practise in Columbia, the county seat of Maury county. After two years of service (1823–25) in the State house of representatives, he represented his district in the National house of representatives from 1825–39. In the party conflicts which succeeded the presidential election of 1824 he sided with the Jackson-Van Buren faction, and soon became recognized as leader of the Democratic forces. He was speaker from 1835 until 1839, when he retired from Congress to become governor of Tennessee. His administration (1839–41) was successful, but he was unable to overcome the popular Whig movement of that period, and was defeated in 1841 and again in 1843. When the Democratic national convention met in Baltimore in 1844 he was mentioned as a possible candidate for the vice presidency, but was suddenly brought forward as a "dark horse" and selected to head the ticket. Finding it impossible under the two-thirds rule to nominate their candidate, the followers of Van Buren brought forward Polk, who was popular in the South, in order to defeat Lewis Cass and James Buchanan. George Bancroft, the historian, has asserted that this

suggestion came originally from him, and Gideon J. Pillow, Polk's intimate friend, did much to bring about the nomination.

The unequivocal stand of Polk and his party in favour of the immediate annexation of Texas and the adoption of a vigorous policy in Oregon contrasted favourably with the timid vacillations of Henry Clay and the Whigs. Polk was elected, receiving 170 electoral votes to 105 for his opponent Clay. In forming his cabinet he secured the services of James Buchanan of Pennsylvania as secretary of State, Robert J. Walker of Mississippi as secretary of the treasury, William L. Marcy of New York as secretary of war, and George Bancroft, then of Massachusetts, as secretary of the navy. There is no doubt that each of these men, and Bancroft in particular, influenced the policy of the administration, yet the historian, James Schouler, who has made a careful study of the Polk papers, is doubtless correct in saying that the president himself was "the framer of the public policy which he carried into so successful execution, and that instead of being led (as many might have imagined) by the more famous statesmen of his administration and party who surrounded him, he in reality led and shaped his own executive course." Bancroft's opinion is that Polk was "prudent, far-sighted, bold, exceeding any Democrat of his day in his undeviatingly correct exposition of Democratic principles."

The four chief events of President Polk's administration were the final establishment of the independent treasury system, the reduction of the tariff by the Walker bill of 1846, the adjustment of the Oregon boundary dispute with Great Britain by the treaty concluded on June 15, 1846, and the war with Mexico and the consequent acquisition of territory in the south-west and west. The first three of these were recommended in his first annual message, and he privately announced to Bancroft his determination to seize California. The independent treasury plan originated during Van Buren's administration as a Democratic measure; it had been repealed by the Whigs in 1841, and was now re-enacted. Protectionists contend that the tariff legislation of 1846 was in direct violation of a pledge given to the Democrats of Pennsylvania in a letter written by Polk during the campaign to John K. Kane of Philadelphia. Briefly summarized, this letter approves of a tariff for revenue with incidental protection, whereas the annual message of Dec. 2, 1845, criticizes the whole theory of protection and urges the adoption of a revenue tariff just sufficient to meet the needs of the Government, conducted on an economical basis. It is difficult to determine whether this was always his idea of incidental protection, or whether his views were changed after 1844 through the influence of Walker and the example set by Sir Robert Peel in Great Britain, or whether he was simply "playing politics" to secure the protectionist vote in Pennsylvania.

The one overshadowing issue of the time, however, was territorial expansion. Polk was an ardent expansionist, but the old idea that his policy was determined entirely by a desire to advance the interests of slavery is no longer accepted. As a matter of fact, he was personally in favour of insisting upon 54° 40′ as the boundary in Oregon, and threw upon Congress the responsibility for accepting 49° as the boundary. He approved the acquisition of California, Utah and New Mexico, territory from which slavery was excluded by geographical and climatic conditions. Furthermore a study of his manuscript diary shows that he opposed the efforts of Walker and Buchanan in the cabinet, and of Daniel S. Dickinson (1800–66) of New York and Edward A. Hannegan (d. 1859) of Indiana, in the Senate, to retain the whole of Mexico, territory in which slavery might have thrived. At the close of his term (March 4, 1849) Polk retired to his home in Nashville, Tenn., where he died on June 15, 1849.

He was married in 1824 to Sarah Childress (1803–91).

See John S. Jenkins, *James Knox Polk* (1850), and L. B. Chase, *History of the Polk Administration* (1850), both of which contain documentary material, but are not discriminating in their method of treatment. George Bancroft contributed a good short sketch to J. G. Wilson's *Presidents of the United States* (1894). He made copies of the Polk manuscripts and was working upon a detailed biography at the time of his death in 1891. These copies, now deposited in the Public library, New York city, contain a diary in 24 typewritten vols. They were used by James Schouler in his *Historical Briefs* (1896), and by E. G. Bourne in an article entitled "The Proposed Absorption of Mexico in 1847–1848," published in the *Annual Report of the American Historical Association for 1899*, i. 157–169 (1900). Bourne discusses the part which Polk took in preventing the complete absorption of Mexico. *See* also the *Diary of James K. Polk . . . 1845 to 1849* (1910), edit. by M. M. Quaife; R. L. Schuyler, "Polk and the Oregon Compromise of 1846," *Pol. Sci. Quart.*, vol. xxvi. p. 443–461 (Lancaster, Pa., 1911); E. I. McCormac, *James K. Polk* (1922); J. S. Bassett, *The Southern Plantation Overseer as Revealed in His Letters* (1925); A. Nevins, ed., *Polk: The Diary of a President, 1845–49* (1929). (W. R. Sm.)

POLK, LEONIDAS (1806–1864), American general, was born at Raleigh, N.C., on April 10, 1806. He was educated at West Point, but resigned his army commission six months after graduation to enter the Virginia Theological seminary. In 1831 he took orders in the Protestant Episcopal Church. In 1838 he became missionary bishop of the southwest, including Arkansas, Indian territory, Louisiana, Alabama and Mississippi; in 1841 he was consecrated bishop of Louisiana. His work in the church was largely of an educational kind, and he played a prominent part in the founding of the University of the South. At the outbreak of the Civil War in 1861, he accepted a commission in the Confederate army and no longer exercised his episcopal authority. His rank in the hierarchy and the universal respect in which he was held in the south, rather than his early military education, caused him to be appointed to the important rank of major general. He fortified the post of Columbus, Ky., the foremost line of defense on the Mississippi, against which Brigadier General U. S. Grant directed the offensive reconnaissance of Belmont in the autumn. In the following spring, Polk commanded a corps at Shiloh in the field army commanded by Albert Sidney Johnston and Beauregard. In Oct. 1862 he was promoted lieutenant general, and thenceforward he commanded one of the three corps of the army of Tennessee under Bragg and afterwards was in charge of the department of Alabama, Mississippi and East Louisiana. He was killed at Marietta, while reconnoitring near Pine Mountain, Ga., on June 14, 1864.

See W. M. Polk, *Leonidas Polk, Bishop and General* (new ed., 1915).

POLKA, a lively dance of Bohemian origin, which at one period (about the middle of the 19th century) enjoyed extraordinary popularity throughout Europe. It is danced to music written in $\frac{2}{4}$ time. (*See* Dance.)

POLLACK (*Pollachius virens*), a fish that is distinguished from others of the cod genus by the long pointed snout, and the prominent lower jaw, without a barbel; the colour is greenish, with yellow markings. It ranges from Norway to the Mediterranean, but is most abundant southwards; it prefers rocky ground, and is piscivorous. It attains a weight of over 20 pounds.

POLLAIUOLO, the name of the brothers Antonio and Piero, sons of the goldsmith, Jacopo Pollaiuolo, Florentines who contributed much to Italian art in the 15th century, and of Simone, architect, the nephew of Antonio.

Antonio (1429–1498) distinguished himself as a sculptor, jeweller, painter and engraver, and did valuable service in perfecting the art of enamelling. He was apprenticed to Bartoluccio Ghiberti, a goldsmith (step-father of the great Ghiberti). It was not until later that Antonio took to painting. His chief achievement in that art is the "Martyrdom of St. Sebastian" (1475) in the National Gallery, London, in the execution of which he was helped by his brother. Here, too, is the fine small panel of "Apollo and Daphne." In the Uffizi, Florence, is his "Labours of Hercules." He aimed, above all, at the representation of the human figure in action, and he ranked as the foremost draughtsman of his time. He is said to have been one of the first artists who had recourse to dissection in his anatomical studies. But it was as a sculptor and metal-worker that he achieved his greatest successes. The museum of Florence contains the bronze group, "Hercules strangling Cacus," and the terra-cotta bust, "The Young Warrior." In 1489 Antonio took up his residence in Rome, where he executed the tomb of Sixtus IV. (1493). He died on Feb. 4, 1498, having just finished his mausoleum of Innocent VIII.

Piero (1443–1496) was a painter, probably the pupil of Alesso Baldovinetti. His principal works were his "Coronation of the Virgin," an altarpiece painted in 1483, in the choir of the cathe-

dral at San Gimignano; his "Three Saints," an altarpiece, and "Prudence" are both at the Uffizi gallery.

SIMONE (1457–1508), nephew of Antonio Pollaiuolo, a celebrated architect, was born in Florence and went to Rome in 1484; there he entered his uncle's studio and studied architecture. On his return to Florence he was entrusted with the completion of the Strozzi palace, begun by Benedetto de Maiano, and the cornice on the façade has earned him lasting fame. His highly coloured accounts of Rome earned for him the nickname of *il Cronaca* (chronicler). About 1498 he built the church of San Francesco at Monte and the vestibule of the sacristy of Santo Spirito. In collaboration with Guiliano da Sangallo he designed the great hall in the Palazzo Vecchio. He was a close friend of Savonarola.

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POLLAN (*Coregonus pollan*), the only Irish fish of the genus *Coregonus*, with three forms inhabiting respectively Lough Neagh, Lough Erne and the Shannon. The jaws are equal in front. (*See* SALMONIDAE.)

POLLARD, ALBERT FREDERICK (1869–1948), English professor of history, was born at Ryde on Dec. 16, 1869, and educated at Jesus college, Oxford. He was elected a fellow of All Souls college, Oxford, in 1898. From 1893 to 1901 he was assistant editor of the *Dictionary of National Biography*. From 1903 to 1931 he held professorial chairs of English history and constitutional history in the University of London. He was founder and first chairman of the Institute of Historical Research. He died Aug. 3, 1948, at Milford-on-Sea, Hampshire, Eng.

His publications include *Thomas Cranmer and the English Reformation* (1898; new ed., 1926); *Henry VIII* (1902); *Factors in Modern History* (1907; new ed., 1926); *Evolution of Parliament* (1920); *Factors in American History* (Cambridge, 1925).

POLLARD, ALFRED WILLIAM (1859–1944), English scholar, was born in London on Aug. 14, 1859, and educated at King's college school, London, and St. John's college, Oxford. In 1883 he entered the British museum as assistant in the department of printed books, of which he became assistant keeper in 1909, and keeper from 1919–24. In 1916 he was appointed Sandars reader in bibliography in Cambridge university, and in 1919 professor of English bibliography at King's college, London, and held that chair until 1932.

His publications include *Bibliographica* (1894–96); *Early Illustrated Books* (1893); *An Essay on Colophons* (1905); Shakespeare's *Folios and Quartos* (1909); *A New Shakespeare Quarto* (*Richard II, 1598*) (1916); *A Short Title Catalogue of English Books* (*1475–1640*), with G. R. Redgrave and others (1926).

POLLENTIA, an ancient town of Liguria, Italy, 10 mi. to the north of Augusta Bagiennorum, on the left bank of the Tanarus. Its position on the road from Augusta Taurinorum to the coast at Vada Sabatia, at the point of divergence of a road to Hasta (Asti) gave it military importance. Decimus Brutus managed to occupy it an hour before Mark Antony in 43 B.C.; and it was there that Stilicho on March 29, 403, fought the battle with Alaric which, though undecided, led the Goths to evacuate Italy. Considerable remains of ancient buildings still exist.

POLLINATION, a term used in botany for the transference of pollen (*see* FLOWER) to the stigma (the receptive surface) of the ovary of the flower. Such pollination brings about the fertilization of the ovules in the ovary and their subsequent development into seeds; there are, however, a few cases in which parthenogenesis occurs, *i.e.*, the ovules develop without fertilization. As the pollen-bearing parts of the stamens are rarely in contact with the stigma at the time when both of these are ripe, some mechanism is clearly necessary to bring the pollen to the stigma. The means in question is usually wind or insects, though sometimes other agencies such as water or birds may be responsible. The great variety in the form, colour and scent of flowers has been developed in relation to the particular agency of insects. Apart from the mechanism of pollination we can distinguish two types—self-pollination (autogamy) in which pollen is transferred from the stamens of one flower to the stigma of the same flower; and cross-pollination (allogamy) in which pollen is transferred to the stigma of another flower on the same plant (geitonogamy) or to the flower of another plant of the same species (xenogamy). Occasionally hybridization is possible, the pollen of one plant bringing about fertilization of the ovary of the flower of another species or, more rarely, of the flower of a plant belonging to another genus; cases of hybridization between genera are known for example in cycads (*see* GYMNOSPERMS) and in orchids.

Cross-Pollination and Dichogamy.—Cross-pollination is the only possible method in the case of unisexual flowers whether the plant is *monoecious* (*i.e.*, with staminate and pistillate flowers on the same plant), as in birch, beech, elder, oak, or *dioecious* (*i.e.*, with staminate and pistillate flowers on different plants) as in the case of willows and poplars. In hermaphrodite flowers, bearing both stamens and carpels, either self-pollination or cross-pollination can occur. It is interesting to note, however, that many flowers have special arrangements to ensure that the pollinating mechanism, whatever it may be, causes cross-pollination and not self-pollination. One of the commonest methods to achieve this is a separation *in time* of the sexes—the stamens dehisce and shed their pollen either before or after the stigma is receptive. This separation in time—and it may apply to the separate male and female flowers on the same plant—is known as *dichogamy*. When the stamens ripen first it is known as *protandry*, the more common case, while when the stigma is ready first, it is known as *proterogyny*. Protandry is very common in insect-pollinated (*entomophilous*) flowers, as in nearly all members of the Compositae (*q.v.*) and Umbelliferae, many Labiatae (such as dead-nettle [Lamium] and *Salvia*), the Caryophyllaceae, the large willow-herb (*Epilobium angustifolium*), etc. Proterogyny is found in the horsechestnut (*Aesculus*), the autumn crocus (*Colchicum*), many Araceae, and in wind-pollinated anemophilous flowers such as plantain (*Plantago*), meadow rue (*Thalictrum*) and many grasses, though here separation in time is very short and many are self-pollinated, such as wheat, barley and oats. It is often accepted that cross-pollination is of greater value to the plant than self-pollination in respect of weight and number of seeds; the question is, however, one of some difficulty. The numerous provisions in flowers for aiding cross-pollination and hindering self-pollination suggest the superiority of the former process, but there are numerous plants which normally and for generations are self-pollinated.

WIND POLLINATION (ANEMOPHILY)

The method of pollination of the earlier and more primitive flowers was probably by the wind, the insect-pollinated flowers being derived from them in later stages of evolution. Some flowers such as plantain and meadow rue mentioned above, are almost certainly anemophilous by reduction, all their congeners being entomophilous; other cases are *Poterium* among the Rosaceae and Kerguelen's Land cabbage (*q.v.*) among the Cruciferae.

Characters of Anemophilous Flowers.—These are such as might be expected. The flowers are usually inconspicuous (the corolla being commonly absent) for there is no advantage in their being easily seen, and they are without the scent or nectar so common in flowers visited by insects. Furthermore there is usually no tubular formation of the flower and no irregularities. On the other hand these wind-pollinated flowers form large quantities of pollen, since the greater proportion when consigned to the air must necessarily be lost. The large quantity of pollen produced by pines and other conifers is well known; in these plants the numerous stamens are massed in male cones often of considerable size, though smaller than the female cones. In other families, such as the grasses, Cyperaceae, Urticaceae, the number of stamens in each flower is small but the anthers are large. Again, in these flowers the pollen is dry and powdery and does not stick together in small masses as in entomophilous flowers; this enables the pollen to blow about easily. The pollen in this type of flower must be easily removed by the wind; the absence of floral envelopes facilitates this and so do the pendulous catkins (hazel, plane, etc.) which can sway in the wind. In addition the filament of the stamen is usually long so that the anthers hang out of the

flower, and are also versatile (*see* FLOWER) so that the pollen is easily shaken from them.

Another common characteristic of the flowers in question is that the stigma is much larger and rougher than that of entomophilous flowers and it is freely exposed to the air so as to increase the chance of reception of the pollen; in maize, for example, the stigma is of very great length. In many catkin-bearing plants the flowering stage occurs before the leaves appear, so that accidental interception of pollen by the leaves is avoided. As already stated dichogamy is quite common in anemophilous flowers but proterogyny is much more common than protandry.

INSECT POLLINATION (ENTOMOPHILY)

The special characteristics of entomophilous flowers are the attractive colour of the floral envelope, the presence of scent and of nectar, and of pollen which is not powdery but sticky and is present in comparatively small quantities. The entomophilous is the most common type of pollination in flowering plants and special floral conformations and irregularities adapted to insect visitors are characteristic of the higher families of flowering plants, as will be seen below. The evolution of flowers and of insects must have gone hand in hand; such groups as *Lepidoptera* (butterflies and moths) and *Hymenoptera* (bees, wasps, etc.) could not have existed without the more elaborate and honey-bearing flowers and *vice versa*. Hermann Müller (see *Bibliography*) has divided flowers into various classes according to their degree of specialisation for different insects, so that a brief survey of the types of insects concerned must be given.

Types of Insects.—There are five important classes of insects which visit flowers. The *Hemiptera* (bugs, etc.) have a few flower-visiting species but they show no special adaptation to flowers; the *Coleoptera* (beetles) have many species which visit flowers but they have only short tongues (only a few species with a length of 3 to 6 mm.) and so are able to reach only honey which is fully exposed. The *Diptera* (flies) include many species which visit flowers. The *short-tongued* ones (with tongues under 4 mm.) show no special adaptation to a diet of floral origin and are not usually clever enough to find any nectar which is not fully exposed in the flower; many of these flies have also other sources of feeding. The long-tongued flies (such as hover flies or drone flies) have tongues from 4–12 mm. and confine themselves to a diet of nectar, and are clever in discovering it when concealed. The *Hymenoptera* (bees, wasps, sawflies, ants, etc.) include a very large number of flower-visiting forms. Bees are the only long-tongued members of the group, and it is bees which have played the most important part in the evolution of the more complex flowers. The hive bee (*Apis*) and the humble-bee (*Bombus*) have long tongues (over 6 mm.) while most of the other bees have shorter tongues, *i.e.*, less than 6 mm. The "cleverness" of bees, combined with the length of their proboscis, enables them to find and reach nectar which is deeply concealed in the flower. Bees do not confine themselves to sucking nectar from the flower; they also collect pollen (some flowers provide only pollen and no nectar), which is carried in small masses attached to the hairs of the hind legs. The *Lepidoptera* (butterflies and moths) are insects with tongues usually about as long as those of bees, but the hawk moths may have tongues, when unrolled, of enormous length. The British hawk moth, *Sphinx convolvuli*, has a tongue 80 mm. (3⅛ in.) long and some tropical moths a tongue of 300 mm. (12 in.).

Classes of Flowers.—The entomophilous flowers have been divided by H. Müller into nine classes based on the structure of the flower and its relation to particular insects.

(i.) Class A. *Flowers with Exposed Nectar.*—In this class come most Umbelliferae, many Saxifragaceae, the bedstraws (*Galium*), ivy (*Hedera*) and such trees as maple, elder and lime. The flowers are wide open and usually small and the visitors are mostly short-tongued; they are rarely visited by bees and butterflies. Such flowers run the risk of the nectar being washed away by rain.

(ii.) Class AB. *Flowers with Partially Concealed Nectar.*—In this class fall the buttercups (*Ranunculus*), the Cruciferae, the strawberry (*Fragaria*) and the willows (*Salix*). The nectar is protected and concealed by the position of the stamens, by the development of hairs or scales, or by the flower being partially tubular, as in wallflower where the sepals stand erect and give a tubular form to the lower part of the flower.

(iii.) Class B. *Flowers with Fully Concealed Honey.*—In this class are the flowers of many Carophyllaceae (such as *Gypsophila, Geranium*), *Polemonium*, blackberry (*Rubus*), eyebright (*Euphrasia*) mint (*Mentha*), heather (*Calluna*). In these the nectar may be concealed by the stamens, by the calyx, by the receptacle becoming hollowed, or by the petals being united to form a sympetalous corolla. The insect visitors are the smaller bees with a few of the longer tongued flies. This type of flower is clearly the most effective of the classes so far mentioned. The bees show a high degree of skill in reaching the concealed honey and mostly confine themselves during a given flight to one or a few species of flower, and thus avoid the great waste of pollen caused by shorter tongued insects, which are liable to carry it indiscriminately from the flower of one species to another.

(iv.) Class B′ is an extension of Class B and includes the flowers of the Compositae, most Dipsaceae and some Campanulaceae, in which the flowers have the same length of tube, etc., as Class B, but are aggregated into an inflorescence, which by the uninstructed might be mistaken for a flower, and which acts like a single flower as a unit of attraction.

(v.) Class F. *Lepidoptera Flowers.*—This includes those flowers in which the floral tube has been so deepened that short-tongued insects are excluded altogether and in many cases only *Lepidoptera* can reach the nectar. The alpine moss campion (*Silene acaulis*), for example, is adapted to butterflies, while the bladder campion (*S. inflata*) is adapted to moths and emits a scent at night. To the latter class belong also the honeysuckle (*Lonicera*), tobacco plant (*Nicotiana*), evening primrose (*Oenothera*), and night-scented stock and many others.

(vi.) Class H. *Bee Flowers,* are those which are visited mostly by long-tongued bees, the depth of the tube being 6 to 15 mm. The flowers are also often markedly zygomorphic (*i.e.*, having a special kind of irregularity; *see* FLOWER), providing a landing place for the bee; others are of such a shape that (as in the snapdragon and broom) it requires an insect like the humble-bee which is not only "clever" but of considerable size and weight in order to open the flower.

(vii. and viii.) The D and K classes of flowers include those adapted to small insects; they are pollinated by flies, beetles and small bees.

Lastly, there is (ix.) the Class Po, *Pollen Flowers.* These provide no nectar, but abundant pollen for which the flower is visited, mainly by bees; examples are *Clematis,* meadowsweet (*Spirea*), rock rose (*Helianthemum*) dog rose (*Rosa canina*), poppy. In some flowers, such as *Cassia,* some stamens provide "food-pollen" for insects, other stamens supply the fertile pollen for fertilization.

Nectar, Colour and Scent.—Nectar is a watery fluid secreted by certain parts of the flower and sometimes by other parts of the plant, as in the case of the extra-floral nectaries. It contains a sugar (glucose) sometimes to as much as 25%. It is from the nectar that the bee makes honey, which is a manufactured product with nectar as the raw material. As has already been indicated the position of the nectaries (the nectar-secreting glands) is very various; they may be fully exposed or hidden and deeply enclosed. In some cases the nectar is secreted by one organ and collected in another as in *Viola,* where it collects in the spur but is secreted by appendages of the stamens. In other cases there is no free nectar but the insect must pierce with its proboscis the juicy, sapid cells, which in the case of some orchids line the spur.

The importance of colour in attracting the attention of insects is obvious, but it does not follow that the flowers most striking or attractive to our eyes are those most conspicuous or alluring to the insect. The problem of the colour-sense of insects has been investigated by a number of workers and it seems clear that bees at least can distinguish some colours, such as blue and yellow, and do not merely depend on the different brightness between, say, a deep purple flower and a light yellow one. In the different flower classes (A to H) already defined, there is a tendency to a progres-

sion in colour; the simpler flowers in the A and AB classes tend to be white or yellow, while in the B class blues and purples are found. In class H, the bee flowers, blues and purples predominate, while in class F, the butterfly and moth flowers, pale tints of pink and purple are most common. The special colour markings on flowers, such as the yellow eye of forget-me-not (*Myosotis*), the darker lines on the petals of the violet and pansy, appear to assist the insect to find the nectar and are known as honey guides.

Scent is obviously of great importance and the olfactory sense of some insects such as moths is very much greater than ours. J. H. Fabre showed that moths when out of sight of honeysuckle would fly straight to it from a distance of several hundred yards. K. van Frisch has investigated elaborately the olfactory sense of the honey bee. Bees which had been drilled by association of oil of orange with sugar could pick out this scent from 43 other ethereal oils. As stated by M. Skene (*see* p. 172) the general conclusion is "that colour is the guide to the flower, and that scent is useful in enabling the bee, flying among the many flowers of similar colour, to pick out the species it has formed the temporary habit of visiting." In this it is helped by the sense of form.

SPECIAL MECHANISMS OF ENTOMOPHILOUS FLOWERS

Pollination of Sage.—Such a plant as the sage (*Salvia pratensis*) has a typical humble-bee flower. The bee alights on the platform formed by the lower lip of the sympetalous corolla and pushes its head down the tube to reach the nectar at the bottom. Each of the two stamens is of special shape; the connective is very large and two-armed, and is hinged to the short filament. The longer arm bears a half anther while the short arm is sterile, the whole stamen having a lever mechanism. The bee, in probing for the honey, comes in contact with the short arm of the lever and in pressing this down brings the half anther at the end of the longer arm down upon its back where the pollen becomes deposited. The flower is protandrous and in a later stage the style elongates and is brought into the same position as occupied by the back of the bee when in contact with the anther. Cross pollination is thus brought about when the bee passes from a younger to an older flower.

Papilionaceous Type.—The Leguminosae (Pea family) show a very interesting series of pollination mechanisms. In this familiar type of flower to which the pea and gorse belong, the essential parts of the flower are enclosed in the keel. The nectar is secreted by the inner sides of the lower part of the staminal tube; one of the ten stamens is usually free and at its base are two openings leading to the nectar. The nectar is thus not only carefully concealed but is also at a considerable depth. Cleverness and length of proboscis are thus required so that as might be expected these flowers are bee flowers. An insect visiting the flower alights on the wings, thus depresses them and, as they are joined to the keel, this is depressed also. The stigma and stamens are thus forced out, the stigma usually first so that it has the chance of brushing off pollen from the under-side of the bee and thus being cross pollinated.

There are four different types. (1) Flowers in which the stamens and stigma return within the keel so that repeated visits are possible; examples are the clovers, melilot (*Melilotius*) and laburnum. (2) Flowers that are explosive, since the style and stamens are confined under tension in the keel and when it is depressed they are released with suddenness, thus scattering pollen on the undersurface of the bee. Only one insect visit is thus effective. Examples are broom (*Genista*), gorse (*Ulex*), lucerne (*Medicago*). (3) Flowers which display a *piston mechanism*—the pollen is shed early and the heads of the five outer stamens act as a piston so that the weight of the bee on the keel squeezes a narrow ribbon of pollen through the pore at the apex of the keel. A further pressure causes a protrusion of the stigma which is thus brought in contact with the bee. Examples are lupin (*Lupinus*), rest harrow (*Ononis*) and bird's foot trefoil (*Lotus corniculatus*). (4) Flowers which show a *brush mechanism*, for the pollen is again shed early and the style, which is provided with a brush of hairs, sweeps the pollen in small portions out of the tip of the keel. Flowers of this type usually allow of repeated insect visits.

Pinch Trap Flowers.—This type of flower is found in the Asclepiadaceae. The pollen is massed together into pollinia and pairs of these are attached to a sort of clip in which the leg of the insect (bees, wasps, etc.) becomes caught. The pollinia are thus carried away to another flower and are likely to come in contact with its stigmatic surface. *Pitfall flowers* are shown by the cuckoo pint (*Arum maculatum*), a common British plant, and by *Aristolochia* and *Asarum*. In *A. maculatum* there is a spathe surrounding a spadix which bears a fringe of stiff downwardly projecting hairs at the top. These hairs allow the entry of insects but not their return; the insects are thus trapped for a time in the spathe and pollinate the pistillate flowers; later the hairs wither and exit becomes possible. Flies are the common visitors.

Piston Mechanism of Compositae.—The flowers of this family show a very efficient pollination mechanism which, with the economy of material resulting from the massing of the flowers into heads and the effective method of seed dispersal, probably explains the dominant position of the family.

Pollination of Fig.—The fig shows a very remarkable interrelationship between an animal and plant. The flowers in the fig are unisexual and are borne in numbers together on the inside of the hollow inflorescence, which opens to the outside by a pore. The swollen and fleshy infructescence (as the inflorescence becomes) is the edible fruit; each "seed" being the product of a single flower and in reality a fruit. The female of a small wasp (*Blastophaga*) enters the inflorescence and deposits eggs in special "gall flowers" incapable of setting seed. The larvae are hatched out and undergo metamorphosis. The male wasps fertilise the female and then die without leaving the inflorescence. The female wasps leave the gall flowers and crawling out through the pore become dusted with pollen from the male flowers in the neighbourhood of the pore. They then enter other figs and pollinate the female flowers, which set seed. The fig and wasp are thus mutually dependent. When Smyrna figs were introduced into California it was found necessary to introduce the caprifig (non-edible fig) containing the wasp *Blastophaga*.

Pollination of Yucca.—This is another case of the complete interdependence of a flower and a moth. The large white flowers of this plant emit their perfume especially at night and are visited by a moth (*Pronuba yuccasella*). The female moth (*see* YUCCA-MOTH) collects pollen from the anthers of the flower and kneads it into a pellet about three times the size of its head. It flies to another flower and, piercing the ovary wall with its long ovipositor, lays a few eggs between the ovules. After this it climbs down the style of the hanging flower and presses the ball of pollen into the stigma; by this means fertilisation is ensured. Only a certain proportion of the seeds are destroyed by the developing insects, which, when mature, eat through the fruit wall, drop to the ground and remain dormant in a cocoon until the next flowering season, when the moth emerges. This seems to be the only method of pollination, for in the absence of the moth the plant is said to be completely sterile.

Pollination of Orchids.—The orchids show many and complicated adaptations to pollination by insects. A great impetus to their study was given by the publication in 1862 of Darwin's monograph on the various pollination mechanisms exhibited by this group. As is well known, in this flower there is generally only one stamen, which is two-lobed, and the pollen is in the form of two stalked masses, the pollinia which the insect carries away stuck to its head. As the insect flies away, the pollinia, if not already properly oriented, execute such a movement as brings them into position to touch the stick stigma of the next flower that is visited. There are, however, a great many variations in the details of this process. Nectar is not usually secreted by the orchid flower, but to obtain a sweet juice the insect has to pierce a special tissue, usually that of the labellum (the posterior petal), which is often spur-like.

Heterostylism.—In some cases the plant bears more than one type of flower. The primrose (*Primula vulgaris*) and the cowslip (*P. veris*) are dimorphic, *i.e.*, some plants have flowers with a long style bearing a knob-like stigma at the mouth of the corolla tube and the five stamens stand half-way down the tube: in others

the flower has a short style with a stigma half-way down the tube while the stamens stand at the top. These two types of flower are known as "pin-eyed" or long-styled and "thrum-eyed" or short styled, respectively. From their correspondence in position, the insect tends to transfer pollen from the thrum-eyed to the stigma of the pin-eyed and *vice versa*. These two types of pollination are spoken of as "legitimate," and Darwin showed that this type produces more seed and more vigorous progeny than "illegitimate" pollination of thrum-eyed stigma by thrum-eyed pollen or pin-eyed stigma by pin-eyed pollen. In trimorphic plants such as the loosestrife (*Lythrum Salicaria*), there are three types of flower, short-styled, long-styled and those with styles of intermediate length. In each type the stamens are in two groups of different lengths; in the first type the stamens are long and intermediate, in the second type they are short and intermediate, and in the third they are short and long. Eighteen possible methods of pollination are possible, six being "legitimate" and 12 "illegitimate." Legitimate unions are found to yield a larger amount of seed than illegitimate.

POLLINATION BY AGENCIES OTHER THAN WIND AND INSECTS

In some water plants the pollen is brought to the stigma by the agency of water. In *Najas* the pollen grains sink in the water and are caught by the stigma. In the eel-grass (*Zostera*), the American water-weed (*Elodea canadensis*), and others, the pollen floats on the surface and so reaches the female flowers. In *Vallisneria*, the male and female flowers are on separate plants and the male becoming detached and floating free on the surface of the water, may reach and become entangled with the fixed larger female flowers, with the result that the anthers come in contact with the projecting stigmas.

In some cases animals other than insects are responsible for pollination. In some countries pollination by birds (humming birds, honeysuckers and sun birds) plays a considerable part. These *ornithophilous* flowers, as they are called, are not very different from insect flowers, many bird flowers being also visited by insects. A landing place is, however, not necessary, as the birds sip the nectar while hovering. The flowers are scentless, and the styles, stigma and filament often rigid. The colour red seems to be predominant in flowers of this type. Examples of ornithophilous flowers are *Strelitzea regina* in South Africa, species of *Salvia* and *Erythrina* in South America. In Java, species of *Freycinetia* and in Trinidad *Bauhinia megalandra*, are said to be pollinated by bats.

SELF POLLINATION (AUTOGAMY)

Self pollination is effected in various ways. In the simplest case the anthers are close to the stigmas, covering these with pollen when they open; this occurs in a number of small annual plants, also in *Narcissus, Crocus*, etc. In snowdrop and other pendulous flowers the anthers form a cone around the style and the pollen falls on to the underlying stigmas, or in erect flowers the pollen may fall on to the stigmas which lie directly beneath the opening anthers (e.g., *Narthecium*). In very many cases the pollen is carried to the stigma by elongation, curvature or some other movement of the filament, the style or stigma, or some other part of the flower, or by correlated movements of two or more parts. For instance, in many flowers the filaments are first directed outwards so that self pollination is not possible, but later incline towards the stigmas and pollinate them (*e.g.*, numerous Saxifragaceae, Cruciferae and others); or the style which first projects beyond the anthers, shortens later on, so that the anthers come into contact with the stigmas (*e.g.*, species of Cactaceae); or the style bends so that the stigma is brought within the range of the pollen (e.g., species of *Oenothera, Epilobium*, most Malvaceae, etc.). In *Mirabilis Jalapa* and others the filaments and styles finally become intertwined, so that pollen is brought in contact with the stigma. Self-pollination frequently becomes possible towards the end of the life of a flower which during its earlier stages has been capable only of cross-pollination. This is well seen in the case of the flowers of the Compositae, where the stigma lobes later bend round and come in contact with the pollen held by the brush of the style below.

Cleistogamy.—The extreme case of autogamy is that of cleistogamous flowers which must necessarily be self-pollinated. The sweet violet (*Viola odorata*), the wood sorrel (*Oxalis acetosella*), *Lamium amplexicauli* and other British plants bear, in addition to the ordinary flowers, small bud-like flowers (cleistogamous flowers) which never open. The pollen germinates in the anthers and the pollen tubes pierce the walls and so reach the stigmas and the ovules are fertilised. Some plants such as *Salvia cleistogama* produce only cleistogamous flowers.

BIBLIOGRAPHY.—The classical compendium on flower pollination in English is P. Knuth, *Handbook of Floral Pollination* (Oxford, 1906, original German edition, 1898–1905), where a great mass of data is brought together. Good brief reviews of the subject are given in M. Skene, *The Biology of Flowering Plants* (1924); Kerner and Oliver, *The Natural History of Plants* (1895); the earlier editions (*e.g.*, the 2nd of 1904) of J. C. Willis, *A Dictionary of Flowering Plants*. Most text books of botany give some review of the subject. The earliest work on the subject was C. K. Sprengel's book entitled *Das entdeckte Geheimnis der Natur in Bau und in der Befruchtung der Blumen* (Berlin, 1793); Sprengel's first observation in this field was that of the presence of hairs in the throat of the corolla of a species of *Geranium*, which, he concluded, were for the purpose of preventing the nectar being washed out by rain; from this he was led on to consider the function of corolla markings such as the yellow centre of forget-me-not which he interpreted as honey guides to the insects. For the distinction of flower classes *see* H. Müller, *The Fertilisation of Flowers* (London, 1883). For the colour sense and olfactory sense of bees *see* K. von Frisch, *Der Farbensinn und Formensinn der Biene* (Jena, 1914) and *Über den Geruchsinn der Biene* (Jena, 1919). For a review of ornithophilous flowers *see* F. Werth, "Kürzer Überblick über die Gesamtfrage der Ornithophilie," *Bot. Jahrb.* (1915).

(V. H. B.)

POLLIO GAIUS ASINIUS (76 B.C.–A.D. 5; according to some, 75 B.C.–A.D. 4), Roman orator, poet and historian. In 54 he impeached unsuccessfully C. Porcius Cato. In the civil war Pollio sided with Caesar, was present at the battle of Pharsalus (48), and commanded against Sextus Pompeius in Spain. He subsequently threw in his lot with M. Antonius, for whom he governed *Gallia Transpadana*. In superintending the distribution of territory amongst the veterans, he saved Virgil's property from confiscation. In 40 he helped to arrange the peace of Brundisium by which Octavian (Augustus) and Antonius were for a time reconciled. In the same year he was consul; it was now that Virgil addressed the famous fourth eclogue to him. Next year Pollio conducted a successful campaign against the Parthini, an Illyrian people who adhered to Brutus, and celebrated a triumph on Oct. 25. From the spoils of the war he constructed the first public library at Rome, in the Atrium Libertatis, also erected by him (Pliny, *Nat. hist.* xxxv. 10). Thenceforward he withdrew from active life and devoted himself to literature. He seems to have maintained an attitude of independence, if not of opposition, towards Augustus. He died in his villa at Tusculum, regretted and esteemed by all.

Pollio was a distinguished orator; his speeches showed ingenuity and care, but were marred by an affected archaism (Quintilian, *Inst.* x. 1, 113; Seneca, *Ep.* 100). He wrote tragedies also, which Virgil (*Ecl.* viii. 10) declared to be worthy of Sophocles, and a prose history of the civil wars of his time from the first triumvirate (60) down to the death of Cicero (43) or later. His writings are lost except a few fragments of his speeches (H. Meyer, *Orat. rom. frag.*, 1842), and three letters to Cicero (*Ad. Fam.* x. 31–33).

See Plutarch, *Caesar, Pompey;* Vell. Pat. ii. 36, 63, 73, 76; Florus iv. 12, 11; Dio Cassius xlv. 10, xlviii. 15; Appian, *Bell. civ.;* V. Gardthausen, *Augustus und seine Zeit* (1891), i.; P. Groebe, in Pauly-Wissowa's *Realencyclopädie* (1896), ii. pt. 2; Teuffel-Schwaben, *Hist. of Roman Literature* (Eng. trans.), § 221; M. Schanz, *Geschichte der römischen Literatur*, pt. 2, p. 20 (2nd ed., 1899); Cicero, *Letters*, ed. Tyrrell and Purser, vi. introd. p. 80; E. D. Pierce, *A Roman Man of Letters* (New York, 1922).

POLLOCK, the name of a great English legal family. The well-known members are: SIR JONATHAN FREDERICK POLLOCK (1783–1870), chief baron of the exchequer. Born on Sept. 23, 1783 in London, the son of David Pollock, saddler, of Charing Cross, he was educated at St. Paul's and Trinity college, Cambridge, and was called to the bar in 1809. He took silk in 1827, and in 1831 was member of parliament for Huntingdon He was

attorney-general in 1834, and again in 1841; in 1844 he succeeded Abinger as chief baron of the exchequer, and sat until 1866, when he retired. He died at Hatton, Middlesex, on Aug. 23, 1870. His greatest judicial triumph was in *Egerton* v. *Brownlow*.

See Sir F. Pollock (2nd Bart.) *Personal Remembrances* (1887).

SIR FREDERICK POLLOCK (1845–1937), born on Dec. 10, 1845, was educated at Eton and Trinity college, Cambridge. He was called to the bar in 1871, and was Corpus professor of Jurisprudence at Oxford, 1883–1903. He was made a Privy Councillor in 1911 and in 1914 became judge of the admiralty court of Cinque ports. In 1920 he was made a King's Counsel. His legal textbooks are standard; he wrote certain legal articles for the *Encyclopaedia Britannica*. He edited the *Law Quarterly Review* from 1885 to 1919 and was Editor of the *Law Reports*, 1895–1935.

His works include *Principles of Contract* (1876, 9th ed. 1921); *Digest of the Law of Partnership* (1877, 12th ed. 1930); *The Law of Torts* (1887, 13th ed. 1929); *Possession in the Common Law* (with Sir R. S. Wright, 1888); *History of English Law* (with Prof. F. W. Maitland, 1895, 2nd ed. 1898); Selden's Table Talk (for Selden Society, 1927); *Spinoza, his Life and Philosophy* (1880, 2nd ed. reissued with additions, 1912); etc.

POLLS, PUBLIC OPINION: *see* PUBLIC OPINION SURVEYS.

POLL TAX. A tax of a uniform amount levied on each individual; a tax of so much per head (middle English *polle*, a head). By mid-20th century this tax had long been abandoned by most countries and was not an important revenue raiser in any tax system in the world.

The most famous poll tax in English history is the one levied in 1380, which led to the revolt of the peasants under Wat Tyler in 1381, but the first instance was in 1377, when a tax of a groat a head was voted by both clergy and laity. In 1379 the tax was again levied, but on a graduated scale. John of Gaunt, duke of Lancaster, paid ten marks, and the scale descended from him to the peasants, who paid one groat each, every person over 16 years of age being liable. In 1380 the tax was also graduated, but less steeply. For years after the rising of 1381 money was raised in this way only from aliens, but in 1513 a general poll tax was imposed. This produced only about £50,000, instead of £160,000 as was expected, but a poll tax levied in 1641 resulted in a revenue of about £400,600. During the reign of Charles II, money was obtained in this way on several occasions. For years after 1688 poll taxes were a favourite means of raising money for the prosecution of the war with France.

Although a few U.S. states at mid-20th century still levied the tax for revenue purposes only, most discussion of the tax centred around its use as a voting prerequisite in the southern states. Ten southern states made the poll tax a voting prerequisite between 1889 and 1902; an 11th, Georgia, had enacted the requirement many years earlier. In its origins the tax is associated with the agrarian unrest of the 1880s and 1890s, which culminated in the rise of the Populist party in the west and the south. The Populists, a low-income farmers' party, gave the Democrats the only serious competition they had experienced since the end of Reconstruction. The intensity of competition led both parties to bring the Negro back into politics and to compete for his vote. Once the Populists were defeated the Democrats amended their state constitutions or drafted new ones to include various disfranchising devices. The poll tax was one of these. Its purpose was to disfranchise Negroes and possibly also to weaken politically the poor whites who had made up the backbone of the Populist party.

After 1920 the poll tax was abolished by state action in North Carolina, Louisiana, Florida, Georgia, South Carolina and Tennessee. Constitutional amendments to wipe out the tax were submitted to the voters in Arkansas, Virginia and Texas, but failed to pass. The tax still prevailed in these states as well as in Alabama and Mississippi at mid-century; the rate ranged from $1 to $2 per year. In Texas and Arkansas, failure to pay merely disfranchised a person for that year only and did not create an obligation which must be paid in subsequent years if he wished to vote. In Virginia and Mississippi the tax was in some degree cumulative, and in Alabama it was possible to run up a bill of as much as $36 in delinquent poll taxes which would have to be paid in order to vote. (D. S. S.; X.)

POLLUX, IULIUS, of Naucratis in Egypt, Greek grammarian and sophist of the 2nd century A.D. He taught at Athens, where, according to Philostratus (*Vit. Soph.*), he was appointed to the professorship of rhetoric by the emperor Commodus on account of his melodious voice. His only surviving work is the *Onomasticon*, a Greek dictionary in ten books, which supplies much rare and valuable information on classical antiquity.

The chief editions of the *Onomasticon* are those of W. Dindorf (1824), with notes of previous commentators, I. Bekker (1846), containing Greek text only, and Bethe (1900). There are monographs on special portions; by E. Rohde (on the theatrical terms, 1870), and F. von Stojentin (on constitutional antiquities, 1875).

POLLUX or **POLLUCITE,** a rare mineral, consisting of hydrous caesium and aluminum silicate, $H_2Cs_4Al_4(SiO_3)_9$, and, being the richest source of caesium, in demand for the construction of thermionic valves. Caesium oxide (Cs_2O) is present to the extent of 30%–36%, the amount varying somewhat owing to partial replacement by other alkalis, chiefly sodium. It crystallizes in the cubic system, it is colourless and transparent, and has a vitreous lustre. There is no distinct cleavage, and the fracture is conchoidal, so that the mineral closely resembles quartz in general appearance. The hardness is $6\frac{1}{2}$ and the specific gravity 2.90. It occurs sparingly, together with the mineral "castor" (*see* PETALITE), in cavities in the granite of Elba, and with beryl in pegmatite veins at Andover and Hebron in Maine. (L. J. S.)

POLO, MARCO (*c.* 1254–1324), Venetian traveller, was grandson of Andrea Polo of San Felice, and son of Nicolo Polo. The three Polos were presumably "noble," for Marco the traveller is officially so styled (*nobilis vir*). The three sons of Andrea Polo were engaged in commerce; the eldest suggests, by his will, a long business partnership with Nicolo and Maffeo.

About 1260, Nicolo with his wife and Maffeo were at Constantinople. The two brothers were led in their trading operations to the Crimea, and eventually to Bukhara, where they joined some envoys returning from a mission from Kublai Khan, with whom they journeyed to Cathay. (*See* CHINA.) It was the first time that the khan had met Europeans and he was delighted with the Venetian brothers, whom he sent back to the pope, with letters requesting the despatch of a body of educated men to instruct his people in Christianity and the liberal arts. On arriving at Acre in April 1269, they learned that no new pope had been appointed after Clement IV's death in 1268, and they returned to Venice. The brothers resolved after two years to start again for the east, taking with them Nicolo's son, Marco. They had letters authenticating their delay; but, hearing of the papal election soon after their start, they returned to execute Kublai's mission. The new pope, however, could supply but two Dominicans, who soon turned back.

Leaving Acre about Nov. 1271, Polo's book indicates that the party proceeded to Hormuz (Hurmuz) at the mouth of the Persian gulf, with the purpose of going on to China by sea; but that, abandoning their plans, they returned northward through Persia. Traversing Kerman and Khurasan, they went on to Balkh and Badakshan and ascended the upper Oxus through Wakhan to the plateau of Pamir (a name first heard in Marco's book). Crossing the Pamir, the travellers descended upon Kashgar, Yarkand and Khotan (Khutan). These are regions which remained almost absolutely closed to western knowledge till after 1860. From Khotan they passed on to the vicinity of Lop-Nor. Thence the desert of Gobi was crossed to Tangut, the region at the extreme northwest of China, within and without the Wall. In his account of the Gobi, or desert of Lop, as he calls it, Polo describes the waste, strikingly reproducing the description of the superstitious terrors of Suan T'sang, who crossed the desert 600 years earlier.

Early in 1275 the Venetians were cordially received by the Great Khan at Shangtu, and Marco made rapid progress. The "young bachelor" studied the languages of the Khan's subjects and soon entered the public service. On his public missions he travelled through Shansi, Shensi, and Szechuen provinces, and the wild country on the borders of Tibet, to the province of Yunnan, called by the Mongols *Karajang*, and northern Burma (Mien). Marco,

during his stay at court, had observed the khan's interest in strange countries, and his disgust at the stupidity of envoys and commissioners who could tell of nothing but their official business. He made notes on facts likely to interest Kublai, which, on his return, he related. He encountered many semi-civilized and barbarous tribes, many of which interested Kublai greatly.

Marco rose rapidly in favour and was often employed on distant missions as well as in domestic administration; he held for three years the government of Yangchow; on another occasion he visited Kangchow, the capital of Tangut, just within the Great Wall, and perhaps Karakorum on the north of the Gobi, the former residence of the Great Khans: also Ciampa, or southern Cochin-China; and perhaps, once more, on a separate mission to the southern states of India. We are not informed whether his father and uncle shared in such employments, though they rendered great service to the khan, in forwarding the capture of Siang-yang (on the Han river) during the war against southern China, by the construction of powerful artillery engines—a story, however, perplexed by chronological difficulties.

The Polos had become rich, and after their exile they began to dread what might follow Kublai's death. The khan, however, was deaf to suggestions of departure and the opportunity only came by chance. Arghun, khan of Persia, a grand-nephew of Kublai, lost in 1286 his favourite wife. Her dying injunction was that her place should be filled only by a lady of her own Mongol tribe. Ambassadors were despatched to the court of Peking to obtain one. The lady Cocacin (Kukachin), a maiden of seventeen, was chosen. The overland road from Peking to Tabriz was then imperilled by war, and Arghun's envoys proposed to return by sea. Having met the Venetians, and being eager to profit by their experience, they begged the khan to send the Franks in their company. He fitted out the party nobly for the voyage, sending friendly messages to the potentates of Christendom, including the pope, and the kings of France, Spain and England. They sailed from *Zaiton* or Amoy harbour in Fukien (probably the modern Changchow), then one of the chief Chinese havens for foreign trade, in 1292. The voyage involved long detention on the coast of Sumatra, and in south India, and two years or more passed before they arrived in Persia. Two of the three envoys and most of their suite died by the way; but the three Venetians survived all perils, and so did the young lady, who had come to look on them with filial regard. Arghun Khan had died before they left China; his brother reigned in his stead; and his son Ghazan married the lady. The Polos went on by Tabriz, Trebizond, Constantinople and Negropont to Venice, arriving about the end of 1295.

The first biographer of Marco Polo was John Baptist Ramusio, who wrote more than two centuries after the traveller's death. We need not hesitate to accept as a genuine tradition the substance of his story of the Polos' arrival at their family mansion in St. John Chrysostom parish in worn and outlandish garb, of the scornful denial of their identity, and the stratagem by which they secured acknowledgment from Venetian society.

We next hear of Marco Polo in a militant capacity. Jealousies had been growing between Venice and Genoa throughout the 13th century. In 1298 the Genoese prepared to strike at their rivals on their own ground, and a powerful fleet under Lamba Doria made for the Adriatic. Venice equipped a larger fleet under Andrea Dandolo. The crew of a Venetian galley at this time amounted to 250 men, under a *comito* or master. On one of the galleys of Dandolo's fleet Marco Polo served as *sopracomito* or gentleman commander. The hostile fleets met before Curzola Island on Sept. 6, and engaged next morning. The battle ended in victory for Genoa, and Marco Polo was taken there as a prisoner. The captivity lasted less than a year, and Marco returned to Venice in July or August 1299.

His captivity was the immediate cause of his *Book*. Up to this time he had related his experiences among his friends; and from these stories he had acquired the nickname of *Marco Millioni*. Yet he had written nothing. The narratives not only of Marco Polo but of other famous mediaeval travellers seem to have been extorted from them by pressure, and written down by other hands. In the prison of Genoa Marco Polo met Rusticiano or Rustichello of Pisa, also a captive of the Genoese, who was a respectable literary hack; he wrote down Marco's experiences at his dictation.

We learn little of Marco Polo's history after this captivity; at his death he left a wife, Donata, and three daughters, Fantina, Bellela and Moreta. One last glimpse of the traveller is gathered from his will. On Jan. 9, 1324, he sent for a priest and notary to make his testament, and died the same day. He was buried, according to his wish, in the Church of St. Lorenzo. The archives of Venice have yielded a few traces of our traveller. Besides his own will just alluded to, there are the wills of his uncles, Marco and Maffeo; a few legal documents connected with the house property in St. John Chrysostom, and two or three entries in the record of the Maggior Consiglio. We have mentioned the sobriquet of Marco Millioni. Ramusio tells us that he had himself noted the use of this name in the public books of the commonwealth, and this statement has been verified in an entry in the books of the great council (dated April 10, 1305), which records as one of the securities in a certain case the "Nobilis vir Marchus Paulo Milion." It is alleged that long after the traveller's death there was always in the Venetian masques one individual who assumed the character of Marco Millioni, and told Munchausen-like stories to divert the vulgar. There is also a record (March 9, 1311) of the judgment of the court of requests (*Curia Petitionum*) upon a suit brought by the "Nobilis vir Marcus Polo" against Paulo Girardo, who had been an agent of his. Another document is a catalogue of curiosities and valuables in the house of Marino Faliero, which mentions several objects that Marco Polo had given to one of the Faliero family. The most tangible record of Polo's memory in Venice is a portion of the Ca' Polo—the mansion where the three travellers, after their long absence, were denied entrance. The court in which it stands was known in Ramusio's time as the *Corte del millioni*, and now is called Corte Sabbionera. That which remains of the ancient edifice is a passage with a decorated 13th century archway.

No genuine portrait of Marco Polo exists. There is a medallion portrait dated 1761 on the wall of the Sala dello Scudo in the ducal palace. The oldest professed portrait is one in the gallery of Monsignor Badia at Rome, which is inscribed *Marcus Polus venetus totius orbis et Indie peregrator primus*. It is a good picture, but of the 16th century. The Europeans at Canton have absurdly attached the name of Marco Polo to a figure in a Buddhist temple there containing a gallery of "Arhans" or Buddhist saints, and popularly known as the "temple of the five hundred gods." The Venetian municipality obtained a copy of this on the occasion of the geographical congress at Venice in 1881.

Polo was the first traveller to trace a route across the whole longitude of Asia, describing kingdoms which he had seen; the first to speak of the court at Peking; the first to reveal China in its wealth and vastness, and to tell of the nations on its borders; the first to tell more of Tibet than its name, to speak of Burma, Laos, Siam, Cochin-China, Japan, Java, Sumatra; the Nicobar and Andaman Islands, Ceylon, India, but as a country seen and partially explored; the first in mediaeval times to give any distinct account of the empire of Abyssinia, and of the island of Sokotra, and to mention Zanzibar and Madagascar; while he carries us also to the remotely opposite region of Siberia and the Arctic shores, to speak of dog sledges, white bears and reindeer-riding Tunguses.

Within the traveller's own lifetime, we find the earliest examples of the practical and truly scientific coast charts (*Portolani*), based upon the experience of pilots, mariners, merchants, etc. In two of the most famous of the 14th century Portolani, we trace Marco Polo's influence—in the *Laurentian* or *Medicean Portolano* of 1351 (at Florence), and in the *Catalan Atlas* of 1375 (now at Paris). Both represent a very advanced stage of mediaeval knowledge, a careful attempt to represent the known world on the basis of collected fact, and a disregard for theological or pseudo-scientific theory; in the *Catalan Atlas*, as regards central and further Asia, and partially as regards India, Marco Polo's book is the basis of the map. His names are often much perverted, and it is not always easy to understand the view that

the compiler took of his itineraries. Still we have Cathay placed in the true position of China, as a great empire filling the south-east of Asia. The trans-Gangetic peninsula is absent, but India proper is for the first time represented with a fair approximation to correct form and position. The map of Fra Mauro (1459) gives a much less accurate idea of Asia than the *Carta catalana*. Columbus possessed a copy of the Latin version of Polo's book made by Pipino, and on many pages of this there are manuscript notes in the admiral's handwriting, testifying to the influence of the work of the Venetian merchant upon the discoverer of the new world.

When, in the 16th century, attempts were made to combine new and old knowledge, the results were unhappy. The earliest of such combinations tried to realize Columbus' ideas regarding the identity of his discoveries with the great khan's dominions; but even after America had vindicated its independent existence, and the new knowledge of the Portuguese had named China where the Catalan map had spoken of Cathay, the latter country, with the whole of Polo's nomenclature, was shunted to the north, forming a separate system. Henceforward the influence of Polo's work on maps was simply injurious; and when to his names was added a sprinkling of Ptolemy's, as was usual throughout the 16th century, the result was a hotchpotch conveying no approximation to facts.

As to the alleged introduction of important inventions into Europe by Polo—although the striking resemblance of early European block books to those of China seem clearly to indicate the derivation of the art from that country, there is no reason for connecting this introduction (any more than that of gunpowder or the mariner's compass) with the name of Marco. In the 14th century not only were missions of the Roman church established in eastern China, but a regular overland trade was carried on between Italy and China. Many a traveller other than Marco Polo might have brought home the block books, and some might have witnessed the process of making them. This is the less to be ascribed to Polo, because he so curiously omits to speak of the process of printing, when, in describing the block-printed paper money of China, his subject seems absolutely to challenge a description of the art.

The book indited by Rusticiano is in two parts. The first, or prologue, as it is termed, is unfortunately the only part which consists of actual personal narrative. It relates the circumstances which led the two elder Polos to the khan's court, together with those of their second journey (when accompanied by Marco), and of the return to the west by the Indian seas and Persia. The second part consists of a series of chapters of unequal length and unsystematic structure, descriptive of the different states and provinces of Asia (certain African islands and regions included), with occasional notices of their sights and products, of curious manners and remarkable events, and especially regarding the Emperor Kublai, his court, wars and administration. A series of chapters near the close treats of sundry wars that took place between various branches of the house of Jenghiz in the latter half of the 13th century. There is now no doubt that the original was written in French. A manuscript in rude and peculiar French, belonging to the National Library of Paris (Fonds, Fr., 1116), which was printed by the Société de géographie in 1824, is evidently either the original or a close transcript. It shows characteristics of the unrevised product of dictation which would necessarily have disappeared in a translation or revised copy. Eighty-five mss. of the book are known, and their texts exhibit considerable differences. For a discussion of these *see* the authorities quoted in the bibliography.

We know from Gilles Mallet's catalogue of the books collected in the Louvre by Charles V, dating *c.* 1370–75, that five copies of Marco Polo's work were then in the collection; but on the other hand, the 202 known mss. and the numerous early printed editions of "Mandeville," with his lying wonders, indicate a much greater popularity. Dante, who lived 23 years after the book was dictated, never alludes to Polo; nor can any trace of Polo be discovered in the book of his contemporary, Marino Sanudo the Elder, though he is well acquainted with the work of Hayton the Armenian. Mandeville himself, who plundered right and left, hardly ever plunders Polo. The only literary works we know of the 14th century which show acquaintance with Polo's book or achievements are Pipino's *Chronicle*, Villani's *Florentine History*, Pietro d'Abano's *Conciliator*, the *Chronicle* of John of Ypres, and the poetical romance of *Baudouin de Sebouro*.

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POLO, the most ancient of games with stick and ball. Its name is derived from the Tibetan *pulu*, a ball. Hockey, the Irish national game of hurling, and possibly golf and cricket, are derived from polo. The latter was called hockey or hurling on horseback in England and Ireland respectively, but historically hockey and hurling are polo on foot. The earliest records of polo are Persian. From Persia it spread to Constantinople, eastwards through Turkistan to Tibet, China and Japan. From Tibet polo travelled to Gilgit and Chitral, possibly also to Manipur. Polo also flourished in India in the 16th century. Then for 200 years its records in India cease, till in 1863 polo came into Bengal from Manipur by way of Cachar.

Chronology of Modern Polo.—Polo was first introduced to India in 1863 by Maj. Gen. Sherar. He brought two teams of Manipuri natives from Manipur to Calcutta, where they played an exhibition match. In 1869 polo was brought to England by the 10th Hussars. In 1871 the first recorded match took place on Hounslow Heath between the 9th Lancers and the 10th Hussars with eight players on each side. An account of this match appeared in the *Morning Post* in July 1871. In 1873 the numbers on each side were reduced to five. A match under these conditions took place at Lillie Bridge. The first code of rules was drawn up by the committee of the Hurlingham club in 1874. In 1876 the height of ponies was fixed by Hurlingham at 14.0 hands and the Champion cup was inaugurated at Hurlingham with five players on each side. In 1877 the first inter-regimental tournament was held in India, and in 1878 at Hurlingham. In the same year the first county cup tournament and the first Oxford *v.* Cambridge match were held at Hurlingham, and the first All-Ireland open cup at Phoenix park, Dublin. In 1882 the number of players on each side was reduced to four. In 1884 John Watson introduced the back-hand stroke to Hurlingham from India, and placed the players at No. 1, No. 2, No. 3 and No. 4 or back, thus laying the foundation of the modern combination game. In 1886 John Watson took the first team to the U.S. and won the Westchester cup.

Watson taught the U.S. players the back-hand stroke and the rudiments of the combination game. In 1888 the height of ponies in India was raised from 13.2 to 13.3. In 1895 the height of the ponies was raised by the Hurlingham committee to 14.2 and an official measurer appointed. In 1902 a U.S. team first visited England and was defeated by England by two matches to one. In India the height of ponies was raised to 14.1. In 1909 the U.S. won the cup at Hurlingham. In 1910 handicapping was introduced

into English polo, and offside was abolished. Both these innovations were copied from the U.S. India adopted these alterations. In 1911 and 1913 England was defeated in the U.S. In 1914 England beat the U.S. team in the U.S., and brought the cup back. In 1919 the height limit for ponies was abolished. In 1921 the U.S. regained the cup from England. In the same year a committee sat in London during the summer and evolved a code of universal rules. This code of rules has been adopted wherever polo is played, with local modifications as regards height of ponies and the duration of matches. In 1924, 1927, 1930, 1936 and 1939 England was defeated by the U.S.

The Game.—A full-sized ground should not exceed 300 yd. in length by 200 yd. in width, if unboarded; and 300 yd. in length by 160 yd. in width, if boarded. The goals are not less than 250 yd. apart, and each goal 8 yd. wide.

Polo is played with four players on each side, on exactly the same principles as hockey or association football. A match lasts about one hour, divided into periods of play; during the intervals ponies are changed. In England seven periods of eight minutes are played for a full match; in the U.S., eight or six periods of seven-and-a-half minutes. The players are placed at No. 1, No. 2, No. 3 and No. 4 or back, so there are two forwards and two backs. But during the course of the game as the players pass the ball to one another these places are being constantly changed. The modern game is a most elastic one, but there should always be one player in each place.

Two umpires are required in a first-class match to award the penalties for infringement of the rules, and in an important tournament a referee at the side of the ground decides disputes if the umpires disagree.

The Development of the Method of Play.—Previous to John Watson's teaching, the method of play was for one man on each side to be the goalkeeper, and for the others to play forward and to hit the ball when and how they could. He introduced the back-hand stroke, and placed his men at No. 1, No. 2, half-back or No. 3, and back. He also taught them to combine and hit to each other. But he taught the game on rather wooden and inelastic lines. Then the brothers Peat appeared on the scene, and soon found out and demonstrated how to play the game in a more scientific manner and with such success that they won the champion cup at Hurlingham on eight occasions. Then came the era of the Freebooters', Rugby, Old Cantab and Roehampton teams, and of the various good regimental teams, such as the 7th, 10th, 11th, 13th and 20th Hussars, the 9th and 17th Lancers and the Inniskilling Dragoons. The training both of men and ponies was rapidly improved. A very scientific game was developed, accurate combination being carefully taught; but too much importance was probably directed to defense, the principles of attack not being sufficiently developed.

While this was going on in England, polo was being rapidly improved in India, and many very fine players were produced there. The ponies were then much smaller, and consequently much more easy to train and ride. The grounds were harder and much easier to hit the ball on; also as the game was played in India all the year round, far more practice was possible. Everything seemed to be in a satisfactory state as regards the game till 1909, when English polo players got a rude awakening from the U.S. team at Hurlingham, who defeated the English representatives very easily.

The U.S. had never adopted the offside rule. They consequently developed a very much faster game. They also perfected strokes that had hardly been attempted elsewhere. They met the ball on all possible occasions and hit under their ponies' necks instead of hitting back-handers from the side of the ground. They played a most elastic game, hitting harder and passing more accurately. They had developed the science of the attack, galloped faster, and were much more accurate goal hitters.

In 1910 the Hurlingham club decided to profit by the lessons learned from the U.S. in 1909, and made two most important alterations in their rules. Offside was abolished and handicapping was introduced. The abolition of offside quickened up the game to a very great extent, and the institution of handicapping resulted in much harder and more even matches. The periods of play were shortened from ten to eight minutes, seven periods being played for a match instead of six. English polo probably reached its zenith in 1914 when the English team which visited the U.S. brought the cup back.

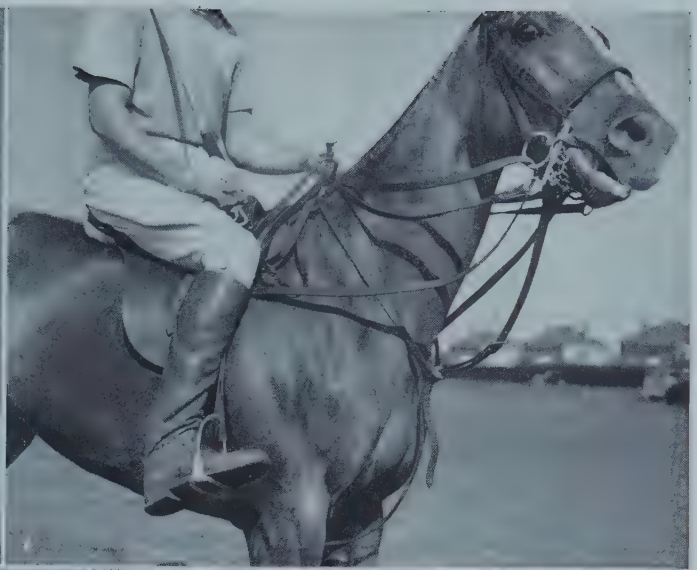
The Hurlingham club rules and the general and field rules of the U.S.A. Polo association are now practically identical, and except for minor differences, such as height of ponies and the duration of matches and periods of play, the Hurlingham rules are followed all over the world.

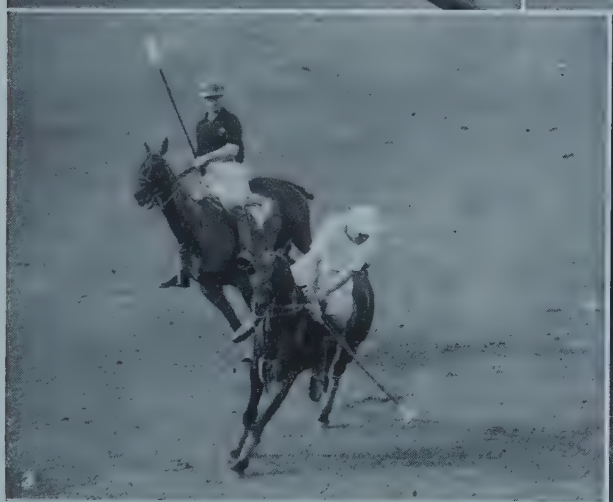
The Effects of the World Wars.—World War I gave a serious setback to English polo. The expenses of polo increased vastly over prewar years. In 1919, owing to the pony wastage of the war, the troubles in Ireland, formerly the chief source of supply of high-class ponies, and the fact that the breeding of ponies in both England and Ireland had almost ceased, it was impossible to supply the demand for 14.3 ponies of the right stamp. This necessitated the abolition of the height limit. The big thoroughbred pony thereafter used in first-class polo was more expensive to buy, dearer to keep and much more difficult to train and to ride. Also, undoubtedly, the abolition of offside and the institution of handicapping made the game more expensive. For the handy pony of moderate speed became quite useless for an ordinary good game, and the handicap entailed far more close matches, which meant that more ponies were required. In spite of this polo was in a very flourishing condition until the outbreak of World War II. In Great Britain it was played at Hurlingham, Ranelagh, Roehampton, and at about 30 county clubs affiliated with the County Polo association. It was played throughout the British empire, wherever sufficient players could collect together to make up a game. It was played all over India; many of the maharajahs and chiefs kept up teams in the native states. It was played on the continent, and was fast becoming a national game in the U.S.A. The game became practically dormant during World War II.

Polo Centres and Tournaments.—Prior to World War II, London attracted most of the best players of the world. During the season, May 1 to July 31, matches and tournaments for every class of player were held at Hurlingham, Ranelagh and Roehampton. These clubs maintained seven grounds, as well as three at Worcester park as an overflow. First-class teams from the U.S., India and the Argentine took part in the various tournaments, and as a rule there were two or three first-class English teams competing in all the principal events such as the Whitney Cup, the Champion Cup, the Ranelagh Open Cup and the Roehampton Open Cup. The second- and third-class players were catered for equally well in a variety of lesser competitions; the soldiers had their own tournaments, *i.e.*, the inter-regimental at Hurlingham, the Subalterns' Cup at Ranelagh and the handicap military tournament at Roehampton. The whole organization was well-nigh perfect, controlled by professional polo managers. India had good tournaments at far separated places such as Calcutta, Delhi, Meerut, Amballa, Rawalpindi, etc., but there was no place in India where good polo could be concentrated for a lengthy period as in England. In England a good player could play at Minehead, Somerset, in April; he could then go to London for May, June and July; then came the county tournaments beginning at Cowdray in Goodwood week, Rugby in the first week in August, Cirencester, Cheltenham, Tidworth, and he could finish up with a month of good games at Minehead. A keen player could, weather permitting, get nearly six months on end of match play.

Breeding of Polo Ponies.—The interest of the breeding of polo ponies is supervised by the National Pony society. This society edits a stud book for all kinds of riding ponies, and holds an annual show at the Agricultural hall, Islington. The society gives prizes and medals at many shows for polo pony classes. It has done, and is still doing, a great work for the encouragement of the breeding of the best class of riding pony.

Up to the year 1909 nearly all the best polo ponies used in the game were bred in Ireland, England and Australia. The latter were chiefly used in India. In India, until about 1888, country-breds were relied on chiefly, very good animals, not more than 13.2 in





PHOTOGRAPHS, (1-3, 5) ACME, (4) PUBLIX PICTORIAL SERVICE, (6) INTERNATIONAL

TECHNIQUE AND PLAYS IN POLO

1. A thong attached to the haft of the mallet is wound tightly around the player's wrist to insure against loss of the mallet during play. The ball is hit with the side, not the head, of the mallet
2. Proper arrangement of the bridle reins on a polo pony. A martingale passed between the pony's forelegs and fastened to the girth under the belly gives the rider added control over his mount
3. Player making a backhand save. The ball is at the far right
4. Strobo-flash photograph of beginning of the swing in a backhand save
5. The player at the left is racing forward to receive a pass from his teammate (right) who is being pressed from behind by an opponent
6. Making a goal

height. Then Arabs began to be bred in greater numbers, only to be superseded in their turn by walers from Australia, which were imported in large numbers by dealers to Calcutta and Bombay. When the height was raised to 14.1 in 1902, only the very best Arabs and a few country-breds produced on the government and regimental farms could compete with the Australian pony in high-class tournaments. Large numbers of easy, handy, rather common ponies were imported from 1892 to about 1909 from the Argentine to England. They were cheap and easy to play, but as a rule rather deficient in pace. Occasionally an absolutely first-class pony appeared, but they were few and far between. But since 1909 the class of pony bred in the Argentine has improved out of all recognition. Several generations of thoroughbred stallions have been used to such an extent that as good ponies as can be obtained anywhere are produced and exported. Many quite thoroughbred ponies are bred in the Argentine, and the remainder of the best animals have only a far back strain of the native pony in their pedigree on the dam's side. The best ponies are, whatever their nationality, thoroughbred or very nearly so. Probably the ideal breeding is for the sire to be thoroughbred and the dam nearly if not quite thoroughbred of the hardy old Irish stock. The National Pony society in England, and the polo breeding societies in the U.S. and the Argentine are doing a great work in proving that polo ponies can be bred to type.

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For the modern form of the game *see* J. Moray Brown, *Riding and Polo,* Badminton Library (revised by T. F. Dale, 1899), and *Polo* (1896); G. J. Younghusband, *Polo in India* (1897), *Tournament Polo* (1897), *Tournament Polo* (1904); T. F. Dale, *The Game of Polo* (1897); H. de B. de Lisle, *Hints to Polo Players in India* (1897); T. B. Drybrough, *Polo* (1898, revised 1906); E. D. Miller, *Modern Polo* (1903); H. L. Fitzpatrick, *Equestrian Polo,* in Spalding's Athletic Library (1904); W. Buckmaster, "Hints on Polo Combination," *Library of Sport* (1909); W. C. Forbes, *As to Polo* (1920); W. B. Devereux, *Position and Team Play in Polo* (1924); Hurlingham Club, *Rules of Polo; Register of Ponies; Polo and Riding Pony Society Stud Book* (12 volumes). Periodicals: *Bailey's Magazine; The Polo Monthly.* The American Polo Association and the Indian Polo Association issue annual publications. (E. D. M.; X.)

United States.—Attack was always stressed in play in the U.S. The system of fractional fouls also aided speed. Instead of stopping the game on a foul, and allowing a free hit from varying distances for the goal, a fraction was deducted from the offending side's score and play continued without a break. In 1888 what has since been regarded as perhaps the most important legislative contribution to the sport came with the first handicapping of players. The game, until that time, had been pretty well monopolized by the better players and H. L. Herbert conceived the idea of the handicap to make possible a wider spread of play. The handicap, low at the start of a player's career, increases with his ability. Thus the beginners are able to play with the more experienced players on a far more even footing. Only the international matches and the open tournaments are played without handicap. In a game the handicaps of all four players are totalled and the team handicaps compared.

One team (unless the totals are even) then receives the difference in total handicap. The handicapping system almost immediately resulted in new tournaments and new clubs, among them Myopia and the Dedham Polo and Country Club, two of the most famous of the Boston district.

Ten goals was the highest rating ever given to a player. This was held in the U.S. game at varying times by the following: Foxhall P. Keene, John E. Cowdin, Thomas Hitchcock, R. L. Agassiz, J. M. Waterbury, Jr., Lawrence Waterbury, Harry P. Whitney, Louis E. Stoddard, J. Watson Webb, M. Stevenson, D. Milburn, Thomas Hitchcock, Jr., Cecil Smith, Elmer Boeseke and Stewart Iglehart.

After the U.S., in 1909, won its first victory in the international series with England, the rules were assimilated. The U.S. took over the British rule permitting the hooking of mallets, and the English abandoned their offside rules and adopted the handicap system. At the close of World War I in 1918 all effort at limiting the size of ponies was abandoned.

At first the U.S. teams played with native horses, mainly found in the southwest and descended, in part, from the Spanish barb left by those who penetrated that part of the United States in its early history. Later, though Texas and Wyoming produced a great many polo horses, the thoroughbred was much in demand, with English and Irish blood prominent in a certain line of mounts. The ponies of Argentina became perhaps the most popular among the higher-rated players. (R. F. K.)

POLOCK, MOSES (1817–1903), U.S. publisher and bibliophile, was born in Philadelphia, Pa., on May 14, 1817, of Jewish-Dutch parentage. At 14 he was apprenticed to the firm of McCarty and Davis, then an old and established Philadelphia house of bookdealers and publishers. He became their chief businessman and succeeded to ownership of the firm in 1853. Polock is chiefly remembered as the first rare bookdealer to devote himself solely to Americana. At that period, many of the most distinguished U.S. libraries were being formed, including the collections of James Lenox (which became part of the N.Y. public library) and S. W. Pennypacker, and Polock's knowledge and experience as a bibliographer were highly valued. Notable among his own publications was the first collected edition of the works of Charles Brockden Brown (*q.v.*), earliest of U.S. novelists, which appeared in 1857. He was also responsible for the first U.S. collection of children's literature. William Brotherhood, a contemporary bookdealer in Philadelphia, has described him as a reticent and learned man who gradually lost interest in selling his books in his growing absorption as a collector (*Forty Years among the Old Booksellers of Philadelphia,* 1891). Polock died on Aug. 16, 1903.

POLONAISE, a stately ceremonious dance, usually written in three-fourths time. As a form of musical composition it has been employed by such composers as Bach, Handel, Beethoven and above all by Chopin. It is usual to date the origin of the dance from the election (1573) of Henry, duke of Anjou, afterward Henry III of France, to the throne of Poland. The ladies of the Polish nobility passed in ceremonial procession before him at Cracow to the sound of stately music. This procession to music became the regular opening ceremony at royal functions and developed into the dance.

The term is also given to a form of skirted bodice, which has been fashionable for ladies at different periods.

POLONIUM (*see* also RADIOACTIVITY, NATURAL). A radioactive element; symbol Po; atomic number 84.

Historical.—This element was discovered in 1898 by Pierre and Marie Curie. Having found that the radioactivity of uranium and thorium minerals was much greater than could be predicted by the content of uranium and thorium, they undertook to extract the substance responsible for this anomaly from a uranium mineral, Joachimsthal pitchblende. Since the only known property of this hypothetical substance was its radioactivity, Pierre and Marie Curie developed a new experimental method which has remained the basis of all radioactive chemistry. They carried out separations of the various substances in the mineral and measured the radioactivity of each portion. They quickly found that the activity became concentrated, partly with the alkaline earths and partly with the sulphides precipitated from acid solution. They were soon able to confirm the existence of two new radioelements: one a higher homologue of barium—radium; the other a homologue of tellurium, to which they gave the name polonium in honour of Marie Curie's birthplace, Poland. It was the first element to be discovered by the radiochemical method.

Since then the term polonium has been used in a more general sense and fills the 84th place in Dmitri Mendeléyev's table, allotted to the numerous isotopes listed below. Some of these iso-

topes are members of the natural radioactive families. (Their individual symbols are given in parenthesis). The others are artificial radioelements.

Isotope	*Period*	*Manner of Disintegration*
Po^{206}	9 days	K (90%), α (10%)
Po^{207}	5.7 hr.	K (about 100%), α (0.01%)
Po^{208}	about 3 yr.	α
Po^{209}	very long (?)	—
Po^{210} (RaF)	140 days	α
Po^{211} (AcC′)	5×10^{-3} sec.	α
Po^{212} (ThC′)	3×10^{-7} sec.	α
Po^{213}	4.4×10^{-6} sec.	α
Po^{214} (RaC′)	1.5×10^{-4} sec.	α
Po^{215} (AcA)	1.8×10^{-3} sec.	β (about 5.10^{-4}%), α (about 100%)
Po^{216} (ThA)	0.158 sec.	β (about 0.014%), α (about 100%)
Po^{217} (not discovered)		
Po^{218} (RaA)	3.05 min.	β (0.04%), α (about 100%)

The radioelement discovered by Pierre and Marie Curie is the principal isotope: Po^{210}.

Natural Occurrence and Preparation.—Polonium is found in much smaller amounts than radium in minerals containing uranium. About 2,900 kg. of uranium element are in radioactive equilibrium with 1 g. of radium and 0.224 mg. of polonium (1 curie). It can therefore be estimated that the polonium content of a Joachimsthal pitchblende containing 65% of uranium is about 0.05 mg. in 1,000 kg. of the mineral.

The half life of polonium is long enough to enable it to be extracted directly from uranium minerals. This process has been used but is of little practical value. It is usually extracted either from radio-lead, which is a by-product of the extraction of radium from uranium minerals, or from radium D, obtained by washing old radium tubes which contain the long-lived active deposit: radium D+E+F (I. Curie), or it can be extracted from old preparations of radium salts (E. Rona).

The extraction of polonium from solutions of radium D, as well as the preparation of strong sources (up to about one to two millicuries/cm.^{2}) of this radioelement is usually carried out by electrochemical deposition on Ag or Ni from a weak solution of acetic, nitric or hydrochloric acid. On Ag, Po is deposited free from RaE and RaD; on Ni, from hot solution, Po and RaE are deposited almost free from RaD (W. Marckwald, I. Curie, O. Erbacher and K. Philipp).

Strong sources can be obtained by volatilizing polonium at red heat in a quartz tube in a current of nitrogen or argon and collecting it on a cooled metallic surface (E. Rona and E. Schmidt, I. Curie and F. Joliot).

Finally, element number 84 can be produced artificially by transmutation of atoms of lead or bismuth (J. J. Livingood; D. G. Hurst, R. Latham and W. B. Lewis; D. H. Templeton, J. J. Howland and I. Perlman).

In certain nuclear reactions it is formed directly:

Pb^{204}	$(\alpha,2n)$	Po^{206}
Pb^{206}	$(\alpha,3n)$	Po^{207}
Pb^{207}	$(\alpha,3n)$	Po^{208}
Pb^{208}	$(\alpha,2n)$	Po^{210}
Bi^{209}	$(p,2n)$	Po^{208}
Bi^{209}	$(d,3n)$	Po^{208}
Bi^{209}	(d,n)	Po^{210}.

In others, Bi^{210}(RaE) is formed intermediately:

Bi^{209}	(n,γ)	Bi^{210}
Bi^{209}	(d,p)	Bi^{210}
Pb^{208}	(α,pn)	Bi^{210}

and $Bi^{210} \xrightarrow{\beta} Po^{210}$.

Properties and Radioactivity.—In 1910 Marie Curie and A. Debierne, using about 0.1 mg. of Po mixed with a few milligrams of other metals, studied the spark spectrum of this material and observed several lines attributable to polonium, the most intense of which was at 4,170.5 Å.U. In 1930 A. Czapek pointed out the existence of a line at 2,450.0 Å.U. B. Karlik and H. Petterson confirmed this and have drawn attention to a line at 2,558.12 Å.U.

The coefficient of diffusion of polonium at ordinary temperature in Al, Fe, Ni, Cu, Ag, Au and Pb is low, about 10^{-14} cm.^{2}/day according to E. Rona and E. Schmidt. In gold and platinum at 470° it is about 10^{-9} cm.^{2}/day (L. Wertenstein and H. Dobrowolska).

According to P. Bonet-Maury, the rate of volatilization *in vacuo* of Po deposited on Ni is measurable at 108° C. and, on heating for 5 min. at 350° C., 90% of the polonium atoms are liberated. From Pt, volatilization does not begin until about 350°. According to Rona it begins from Au at a slightly lower temperature and from Pd only at about 500°–560° C. The vaporization temperature of Po increases with the age of the product. It also varies with the method of preparation of the sources and the gaseous atmosphere into which volatilization is carried out.

Since polonium belongs to the radioactive family uranium-radium and is formed by the disintegration of radium E, an isotope of bismuth, it is sometimes called radium F (RaF).

It disintegrates in its turn with the emission of α-rays to give radium G, an inactive isotope of lead (Pb^{206}). The disintegration period (half life) of polonium is 140 days.

$$\underset{\text{Period}=}{\text{Ra}} \xrightarrow[1{,}590\text{ years}]{\alpha} \text{Rn} \xrightarrow[3.82\text{ days}]{\alpha} \text{RaA} \xrightarrow[3.05\text{ min.}]{\alpha} \text{RaB} \xrightarrow[26.8\text{ min.}]{\beta} \text{RaC} \begin{cases} \xrightarrow[19.7\text{ min.}]{\alpha} \text{RaC}'' \xrightarrow[1.5\times10^{-4}\text{ sec.}]{\beta} \text{RaD} \\ \xrightarrow[1.32\text{ min.}]{\beta} \text{RaC}' \xrightarrow[22\text{ years}]{\alpha} \text{RaD} \end{cases} \xrightarrow[5\text{ days}]{\beta} \text{RaE} \xrightarrow[140\text{ days}]{\alpha} \text{Po(RaF)} \xrightarrow{\alpha} \text{RaG (Pb)}\ \text{stable}$$

The range of the α-rays from polonium has been determined with great accuracy by Irène Joliot-Curie and is 3.87 cm. in air at 15° C. and 760 mm. of Hg. In the gelatin of usual photographic plates it is about 27μ and in aluminum, 22μ. During its passage through air each of the α-particles emitted gives rise to 152,000 pairs of ions. It is calculated that the amount of polonium corresponding to a saturation current of 1 E.S.U. in an ionization chamber utilizing all the ions produced in a solid angle of 2π is equal to 1.67×10^{-10} g. A current of 1,350 E.S.U. represents 1 millicurie of polonium. This α-radiation, which does not seem to be of uniform (kinetic) energy, is accompanied by γ-radiation of weak intensity (about one quantum of 0.773 Mev for 10^5 α-particles) and a secondary β-radiation. According to A. Sanielevici the hourly heat output of 1 E.S.U. of polonium, equivalent to the kinetic energy of the α-rays and the recoil RaG atoms is equal to 20.24×10^{-6} cal.

M. Curie and A. Debierne have been able to make a direct determination of the Avogadro number by measuring the volume of helium corresponding to a known number of α-particles emitted by a source of polonium.

The radiation from polonium can bring about the decomposition of water, the ozonization of air, the marking of photographic plates and the coloration of glass or quartz. It exerts a toxic effect on living organisms. A rabbit injected with 500 E.S.U. of Po wasted considerably and died a few days afterward (A. Lacassagne, J. Lattès and J. Lavedan).

Polonium is often used in radioactivity as a source of α-radiation free from penetrating rays. I. Curie and F. Joliot discovered artificial radioactivity in 1934 by bombarding aluminum, boron and magnesium with α-rays from polonium. A deposit of polonium on beryllium forms a natural source of neutrons which are produced by the nuclear reaction:

$$^{9}_{4}\text{Be} + ^{4}_{2}\alpha = ^{12}_{6}\text{C} + ^{1}_{0}\text{n}$$

and

$$^{9}_{4}\text{Be} + ^{4}_{2}\alpha = 3\,^{4}_{2}\alpha + ^{1}_{0}\text{n}.$$

The chemical and electrochemical properties of polonium were determined by radiochemical methods using very small amounts of the order of 10^{-11} to 10^{-6} g. of Po^{210}(RaF).

Polonium in 0.1–0.5 normal solutions of nitric, hydrochloric or acetic acid is deposited spontaneously on Ag, Te, Bi, Ni and on the less noble metals (Marckwald and others).

By the action of an electric current it can be collected from acid solution on the cathode, probably in the metallic state, and on the anode as the peroxide (F. Paneth and G. Hevesy). Similarly, deposits on the cathode and the anode can be obtained from sufficiently alkaline soda solution (M. Haissinsky).

The critical deposition potential of Po in acid solution, for concentrations in the region of 10^{-8} to 10^{-10} normal, has been determined by the decomposition potential method devised by Hevesy and Paneth and considerably improved by F. Joliot. Assuming that Nernst's electrochemical law is applicable when extrapolating to normal potential, as shown by the experiments carried out by Haissinsky with solutions of Bi and its isotopes RaE and ThC, it is found for the electrode Po/Po^{++++} with respect to the hydrogen electrode that:

$$E^{0}_{H}\ (Po/Po^{++++}) = +0.77 \text{ v. at } 18° \text{ C.}$$

Polonium is situated, then, between Ag and Te in the normal potential series.

F. Joliot has shown that the cathode deposition potential is lowered if electrolysis is carried out in acid solution in the presence of different reducing agents.

Chemical Properties.—Chemically, polonium being the higher homologue of tellurium and next to bismuth in the periodic table is allied to both these elements.

The following properties of polonium are in common with those of tellurium and bismuth: hydrolysis of its compounds in aqueous solution near the neutral point with the formation of an insoluble hydroxide; precipitation of a sulphide insoluble in dilute acid (P. and M. Curie), reduction to the metallic state by hypophosphorus and hydrosulphurous acid, $TiCl_3$ in hydrochloric acid solution and by hydrazine and formaldehyde in soda solution (M. Guillot and Haissinsky).

Polonium resembles tellurium in its amphoteric character. It can, in effect, act as a cation in acid solution but also gives a volatile hydride PoH_2 (Paneth) and a sodium polonide $PoNa_2$ (V. Khlopin and A. Samartseva). Polonium hydroxide ($O=Po=[OH]_2$) is equally amphoteric and dissolves in concentrated sodium hydroxide to give a polonite Na_2PoO_3, analogous to the tellurites (J. Escher-Desrivières). As with tellurium, polonium is precipitated in the metallic state from hydrochloric acid solution by $SnCl_2$ (Marckwald). Finally, according to M. Guillot, it forms polonium hexachlorides isomorphous with similar salts of Te, Pb, Sn, Pt ($[M^{IV}Cl_6][NH_4]_2$) and is then, in that case, quadrivalent and hexa-co-ordinated.

On the other hand, contrary to tellurium, polonium is not precipitated from acid solution by hydrazine and SO_2. It resembles bismuth in the insolubility of its sulphide in ammonium sulphide in alkaline solution (M. Curie) and the insolubility of its pyrogallate in weakly acid solution (Haissinsky). Furthermore, M. Guillot has obtained mixed crystals of dithiocarbamates of polonium and the trivalent metals Bi^{+++} and Co^{+++}. This worker explains the analogies between Po and Bi by supposing that certain reducing agents convert polonium to the trivalent state, which is in agreement with the existence of two cathode deposition potentials. The co-ordination index of the ion Po^{+++} in the complex should be the same as Po^{++++} and equal to 6. Under certain conditions it forms an oxychloride soluble in anhydrous ethyl alcohol, acetone and dioxane (G. Bouissières).

An acetylacetonate of polonium is known (M. Servigne), also a polonium methyl (V. Khlopin and A. Samartseva) and a polonium carbonyl (I. Curie and M. Lecoin).

Summarizing, chemical and electrochemical work has led to polonium's being attributed positive valencies 6, 4, 3 and negative valency 2.

Dosage.—A thin layer of polonium is prepared when measuring the ionization produced by its α-radiation. If it is mixed with other salts, it must be extracted by electrochemical deposition on silver or nickel foil (1 E.S.U. equals 1.67×10^{-10} g. of Po). The magnitude of the activity of a source can be readily judged by the luminosity produced in the dark on a screen of zinc sulphide placed in front of it.

Glossary of Technical Symbols Used in This Article

Ra	Radium	Te	Tellurium
Ac	Actinium	Bi	Bismuth
Th	Thorium	Pb	Lead
Ag	Silver	Sn	Tin
Ni	Nickel	Co	Cobalt
Pt	Platinum	$TiCl_3$	Titanous chloride
Al	Aluminum	$SnCl_2$	Stannous chloride
Fe	Iron	SO_2	Sulphur dioxide
Cu	Copper	μ	Micron ($=10^{-3}$ mm.)
Pd	Palladium	E.S.U.	Electrostatic unit
Hg	Mercury	Mev	Million electron volts

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(I. J.-CE.; G. Bs.)

POLONNARUWA, a ruined city and ancient capital of Ceylon. It first became a royal residence in A.D. 368, when the lake of Topawewa was formed, and succeeded Anuradhapura as the capital in the middle of the 8th century. The principal ruins date chiefly from the time of Prakrama Bahu (A.D. 1153–86). The most imposing pile remaining is the Jetawanarama temple, a building 170 ft. in length, with walls about 80 ft. high and 12 ft. thick. The city is now entirely deserted, and, as in the case of Anuradhapura, its ruins have only recently been rescued from the jungle.

POLOTSK, a town of the white Russian S.S.R., at the confluence of the Polota and Dvina, in 55° 29′ N., 28° 49′ E. Pop. (1933) 25,300. It is on a railway junction and has sawmilling and timber industries and a flour mill. Its position between central Russia and the west made it a storm centre, and little of the ancient town remains; both the upper castle, which had seven towers, and the lower one are in ruins and its 12th-century cathedral fell in ruins in the 18th century.

Polotesk or Poltesk is mentioned in 862 as one of the towns given by the Scandinavian Rurik to his men. In 980 it had a prince of its own, Ragvald (Rogvolod or Rognvald), whose daughter is the subject of many legends. It remained an independent principality until the 12th century, resisting the repeated attacks of the princes of Kiev; those of Pskov, Lithuania, and the Livonian knights, however, proved more effective; and Polotsk fell under Lithuanian rule in 1320. About 1385 its independence was destroyed by the Lithuanian prince Vitovt. It was five times besieged by Moscow in 1500–18 and was taken by Ivan the Terrible in 1563. Recaptured by Stephen Bathory, king of Poland, 16 years later, it became Polish by the treaty of 1582. It was then a large and populous city and carried on an active commerce. Pestilences and conflagrations were its ruin; the plague of 1566 wrought great havoc among its inhabitants, and that of 1600 destroyed 15,000. The castles, the town and its walls were burned in 1607 and 1642. The Russians continued their attacks, burning and plundering the town, and twice, in 1633 and 1705, taking possession of it for a few years. It was not definitely annexed to Russia until 1772, after the first dismemberment of Poland. In 1812 its inhabitants resisted the French invasion, and the town was partially destroyed.

POLTAVA, a town in the Ukrainian S.S.R., Union of Soviet Socialist Republics, on the right bank of the Vorskla river, in 49° 36′ N., 34° 35′ E. Pop. (1939) 130,305.

It is the centre of an agricultural district in which grains, sugar beets, tobacco, vines and orchard fruits are grown. Leather is the chief manufacture, and there is an annual fair for the sale of skins, leather and leather goods. Other industries include smelting, stocking manufacture, distilling and brewing. The town is on the railway and is a grain-collecting centre. The Russian annals mention Poltava in 1174 under the name of Ltava. In 1430 it was given, together with Glinsk, to the Tatar prince Leksada by Gedimin, prince of Lithuania. Under the Cossack chief, Bogdan Chmielnicki, it was the chief town of the Poltava "regiment."

Peter the Great defeated Charles XII of Sweden in the neighbourhood of Poltava in 1709.

POLTERGEIST: *see* PSYCHICAL RESEARCH.

POLTORATSK: *see* ASHKHABAD.

POLTROT, JEAN DE (*c.* 1537–1563), sieur de Méré or Mérey, a nobleman of Angoumois, who murdered Francis, duke of Guise. He had lived some time in Spain, and his knowledge of Spanish, together with his swarthy complexion, which earned him the nickname of the "Espagnolet," procured him employment as a spy in the wars against Spain. Becoming a fanatical Huguenot, he determined to kill the duke of Guise and gained admission as a deserter to the camp of the Catholics who were besieging Orléans. On Feb. 18, 1563, he hid by the side of a road along which he knew the duke would pass, fired a pistol at him and fled. He was captured the next day, tried, tortured and sentenced to be drawn and quartered. On March 18, 1563, he underwent a frightful punishment. The horses not being able to drag off his limbs, he was hacked to pieces with cutlasses. He had made several contradictory declarations regarding the complicity of Admiral Gaspard de Coligny, but his accusations seem to have had no foundation.

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POLYAENUS, a Macedonian, who lived at Rome as a rhetorician and pleader in the 2nd century A.D. When the Parthian War (162–165) broke out, Polyaenus dedicated to the emperors Marcus Aurelius and Lucius Verus a work, still extant, called *Strategica* or *Strategemata,* a historical collection of stratagems and maxims of strategy written in Greek and strung together in the form of anecdotes. It is not strictly confined to warlike stratagems but includes also examples of wisdom, courage and cunning drawn from civil and political life. The work is divided into eight books (parts of the sixth and seventh are lost) and originally contained 900 anecdotes, of which 833 are extant. His works on Macedonia, on Thebes and on tactics (perhaps identical with the *Strategica*) are lost.

His *Strategica* seems to have been highly esteemed by the

Roman emperors and to have been handed down by them as a sort of heirloom. From Rome it passed to Constantinople; at the end of the 9th century it was diligently studied by Leo VI, who himself wrote a work on tactics; and in the middle of the 10th century Constantine Porphyrogenitus mentioned it as one of the most valuable books in the imperial library. It was used by Stobaeus, Suidas and the anonymous author of the work Περὶ ἀπίστων (*see* PALAEPHATUS). It is arranged as follows: bks. i, ii, iii, stratagems occurring in Greek history; bk. iv, stratagems of the Macedonian kings and successors of Alexander the Great; bk. v, stratagems occurring in the history of Sicily and the Greek islands and colonies; bk. vi, stratagems of a whole people (Carthaginians, Lacadaemonians, Argives), together with some individuals (Philopoemen, Pyrrhus, Hannibal); bk. vii, stratagems of the barbarians (Medes, Persians, Egyptians, Thracians, Scythians, Celts); bk. viii, stratagems of Romans and women. This distribution is not, however, observed strictly. Of the negligence or haste with which the work was written there are many instances; *e.g.*, he confounds Dionysius the elder and Dionysius the younger, Mithradates, satrap of Artaxerxes, and Mithradates the Great, Scipio the elder and Scipio the younger, Perseus, king of Macedonia, and Perseus, the companion of Alexander; he mixes up the stratagems of Caesar and Pompey; he brings into immediate connection events which were totally distinct; he narrates some events twice over, with variations according to the different authors from whom he draws. Though he usually abridges, he occasionally amplifies arbitrarily the narratives of his authorities. He never mentions his authorities, but among authors still extant he used Herodotus, Thucydides, Xenophon, Polybius, Diodorus, Plutarch, Frontinus and Suetonius; among authors of whom only fragments now remain he drew upon Ctesias, Ephorus, Timaeus, Phylarchus and Nicolaus Damascenus. His style is clear but monotonous and inelegant. In the forms of his words he generally follows Attic usage.

The best edition of the text is Wölfflin and Melber (Teubner series, 1887, with bibliography and editio princeps of the *Strategemata* of the emperor Leo); annotated editions by Isaac Casaubon (1589) and A. Coraës (1809); I. Melber, *Ueber die Quellen und Werth der Strategemensammlung Polyäns* (1885); Knott, *De fide et fontibus Polyaeni* (1883), Eng. trans. by R. Shepherd (1793).

POLYANDRY, the system under which a woman is married to several men at the same time (Gr. πολύς, many, and ἀνήρ, man). Cases of it have been noticed among certain South American Indians, and in North America among some Eskimo, the Tlingit, the Aleut and the Kaniagmiut on the Alaskan coast. In an old description of the conquest of the Guanches in the Canary Islands in 1402 it is said that in the Island of Lancerote most of the women have three husbands, "who wait upon them alternately by months." Sporadic cases of polyandry have been found in Madagascar, among a few peoples on the African continent, in some places of the Malay archipelago and among certain South Sea islanders, while in the Marshall Islands and the Marquesas it has been practised on a much larger scale. In Tibet polyandry has prevailed from time immemorial, the husbands being as a rule brothers, who live together with their common wife as members of the same household. Fraternal polyandry is more or less frequent in vast districts of the Himalayan region from Assam to the dependencies of Kashmir, chiefly among people of Tibetan affinities, and in South India, where its prevalence among the Todas of the Nilgiri hills has attracted special attention; and it existed throughout the interior of Ceylon until it was prohibited by the British government about the year 1860. Among the Nayars or Nairs of Cochin, Malabar and Travancore we meet with polyandrous unions of a different, nonfraternal type, the prevalence of which has been testified by a large number of travellers from the beginning of the 15th century onward. According to Nayar usage every girl, before she attained puberty, was subjected to a certain marriage ceremony, after which the nominal husband went his way and she was allowed to cohabit with any Brahman or Nayar she chose; usually she had several lovers, who cohabited with her by agreement among themselves but did not live with her. Strabo asserts that polyandry prevailed in Arabia Felix, and some modern scholars think that they have found confirmation of this statement in Sabian and Minaean inscriptions.

Frequently, polyandry is modified in a monogamous direction, one, usually the first, husband being the chief husband; in various cases any other man with whom he shares his wife acts as husband and master of the house only during the absence of the true lord. Where fraternal polyandry prevails, the eldest brother is commonly regarded as the principal husband; he chooses the wife, and the contract he makes may implicitly confer matrimonial rights on all the other brothers. Among many polyandrous peoples the various husbands live or cohabit with their common wife in turn; and if they are brothers, the eldest one is sometimes expressly said to take the lead.

Among many polyandrous peoples there are said to be more men than women, and their polyandry has in several cases been directly attributed to this fact; and even if some of these statements, in the absence of statistical data, are more or less hypothetical, there are others the accuracy of which is past all doubt. But polyandry has also been traced to economic motives. In Tibet it has been said to obtain as a necessary institution, serving the end of checking the increase of population in regions from which emigration is difficult and also keeping the family property together; and similar reasons have been assigned for polyandry in Ladakh, Bhutan, South India and Ceylon. The polyandry of the Tibetans, the Himalayans and some peoples in the south of India seems also to be partly because of the dangers or difficulties which would surround a woman left alone in her home during the prolonged absence of her husband. The peculiar polyandry of the Nayars is most probably connected with their military organization, which prevented their living the ordinary life of a husband and father of a family.

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POLYANTHUS, the oxlip (*Primula elatior*); also any narcissus derived from *Narcissus tazetta.*

POLYBIUS (*c.* 201–*c.* 120 B.C.), Greek historian, was born at Megalopolis in Arcadia, being the son of Lycortas, the friend and successor of Philopoemen as leader of the Achaean league. The precise dates of his birth and death are not known, but they can be inferred approximately. We have his own statement (xxiv, 6) that in 181 B.C., when he was appointed along with Lycortas and Aratus as an ambassador to Egypt, he was still under the legal age, which appears to have been 30 (xxix, 9). According to Cicero, *Ad Fam.,* v, 12, Polybius wrote a special history of the Numantine War, which ended in 132 B.C. Lastly, in Lucian, *Macrob.* 22, we read that he died in consequence of a fall from his horse at the age of 82.

The more notable events of his life may be briefly stated. As the son of Lycortas he was naturally brought into close contact with the leading men of the Achaean league. With Philopoemen he seems to have been on intimate terms. After Philopoemen's tragic death in Messenia (184 B.C.), he was entrusted with the honourable duty of conveying home the urn in which his ashes had been deposited (Plutarch, *Philopoem.* 21). In 181, as noted above, he was appointed, in spite of his youth, a member of the embassy which was to visit Ptolemy Epiphanes, king of Egypt, a mission, however, which the sudden death of Ptolemy brought to a premature end (xxv, 7). The next 12 years of his life are a blank, but in 169 he reappears as a trusted adviser of the Achaeans at a difficult crisis in the history of the league. In 171 war had broken out between Rome and the Macedonian king Perseus, and the Achaean statesmen were divided as to the policy to be pursued; there were good reasons for fearing that the Roman senate would regard neutrality as indicating a secret leaning toward Macedon. Polybius therefore declared for an open alliance with Rome, and his views were adopted. It was decided to send an Achaean force to assist the Roman consul Q. Marcius, and Polybius was appointed to command the cavalry. He was also one of the envoys who were

sent to consult with the consul, and, although the proffered assistance was declined, he remained for a time in the Roman camp (xxviii. 13). The turning point in his life came when Perseus was finally defeated by the Romans at Pydna in 168. Polybius was one of 1,000 leading Achaeans who were carried to Rome, at the instigation of Callicrates, on the charge of having been lukewarm in their support of the Roman cause.

While the others were distributed among the Italian towns, Polybius was allowed, through the influence of L. Aemilius Paullus, and his sons Fabius (Q. Fabius Maximus Aemilianus) and Scipio (P. Cornelius Scipio Africanus minor) to remain in Rome (xxxii. 9., Pausan. vii. 10. 2). With Scipio he formed a close friendship and to his influence with Scipio it was due that in 151 B.C., the remnant of the Achaean exiles obtained permission to return to their homes (xxxv. 6). Polybius himself, after a short stay in Achaea, joined Scipio in Africa in 147 and was present at the siege and destruction of Carthage in 146. Meanwhile the mistaken attempt of the Achaean League to assert its independence of Rome had ended in disaster and the remaining public work of Polybius was devoted to alleviating so far as possible for his countrymen the consequences of their policy, and to facilitating the establishment of order under the new régime (xl. 8–10).

The manner in which he accomplished this was such as to earn the gratitude of his compatriots, as was attested by the statues erected in his honour at Mantineia (Pausan. viii. 9. 1.), Pallantium (Pausan. viii. 44. 5), Tegea (Pausan. viii. 48. 8), Megalopolis (Pausan. viii. 30. 8)—where the inscription recorded that he "had roamed over all the earth and sea, and had been the ally of the Romans and had made them cease from their anger against Greece"—Acacesium, the inscription declaring that "Hellas would never have come to grief, if she had obeyed Polybius in all things, and, having come to grief, she found succour through him alone" (Pausan. viii. 37. 2). The base of a statue erected to him by Elis was discovered at Olympia in 1877 with the inscription:

ἡ πόλις ἡ Ἠλείων Πολύβιον Λυκόρτα Μεγαλοπολίτην.

The *Histories* (Ἱστορίαι), on which his reputation as a historian now rests, were in 40 books. Of these the first five are extant. For the remaining books we have excerpts from a collection of passages from the Greek historians, which was made by the order of Constantine Porphyrogenitus in the 10th century; excerpts of vi.–xviii. contained in another compilation of uncertain date, first printed at Basle in 1549; and a fragment of xi., 13–16, in a Berlin papyrus (3rd century A.D.).

The original intention of Polybius was to narrate the history of the 53 years (220–168 B.C.)—from the beginning of the Hannibalic War to the defeat of Perseus at Pydna—in which Rome made herself mistress of the world. The first two books are prefatory—a "preparation" (προκατασκευή I. 3)—dealing with the earlier history of Rome, the first Punic War, and contemporary events in other parts of the world. But the opening chapter of Book III. indicates an intention to modify his original plan by adding an account of the manner in which the Romans exercised their supremacy down to the destruction of Carthage in 146 B.C. Thus the history of the period 168–146 B.C. appears to have occupied the last ten books.

Scientific Conception of History.—With regard to the function of the historian, Polybius is one of those who consider history to be—in the phrase of Dionysius—"philosophy teaching by examples." Thus he says in i. 35: "Whereas there are for all men two ways of improvement, to wit by one's own disasters or those of others, the former is the more vivid, the latter is the less harmful. Therefore, one should never willingly choose the former, since the improvement which it brings is fraught with great danger and pain, but one should always pursue the latter, since in it one can discern the better way without hurt. And it is therefore to be considered that the best education for real life is the knowledge of affairs which accrues from practical history (πραγματικὴ ἱστορία) which alone, without personal hurt, makes men on every occasion and in all circumstances, true judges of the better way."

From this conception of history, which differs little, if at all, from that of Thucydides or the modern historian of the scientific school, it follows that the chief interest lies, not in the question of origins, in the legendary or semi-legendary traditions, by which states or nations, like individuals, when they have achieved greatness, are fain to decorate their origins, but in the actual transactions of historical times, the plain matters of fact which appeal to the plain man. This seems to be undoubtedly what Polybius means by the term "pragmatic" by which he several times characterizes his *History*. Thus in criticizing Phylarchus he writes (ii. 56. 7. *seq.*): "Endeavouring to excite his readers to pity and to make them sympathetic with his narrative, he introduces embracing of wives, disordered hair, baring of breasts, tears and lamentations of men and women haled away with their children and aged parents. This he does throughout his whole history, seeking always to give a vivid picture of horrors. The ignoble femininity of this design may be left out of the question; but we must consider what is proper and profitable in history. It is the function of the historian not to astonish his readers by prodigies nor to hunt up all possible tales and recount all the concomitants of his subjects, as tragedians do, but to narrate in their verity the things actually done and said, how modest soever they may be. For the end of history is not identical with that of tragedy, but quite the contrary. In tragedy the end is by the most plausible language to astonish and move the audience temporarily. In history the end is by real facts and real speeches to instruct and persuade for all time the lovers of knowledge: since in the former the leading motive is the plausible, even if the plausible be false, for the deception of the spectators; in the latter the leading motive is truth for the benefit of the student."

What Polybius himself means by "Pragmatic history" (i. 2. πόσακαὶ πηλίκα συμβάλλεσθαι πεφυκε τοῖς φιλομαθοῦσιν ὁ τῆς πραγματικῆς ἱστορίας τρόπος) is illustrated by his remarks (iii. 47) on those who have written of Hannibal's crossing of the Alps: "Wishing to astonish their readers by their marvellous account of the localities, they fall into two faults which are most foreign to all history; for they are compelled to tell falsehoods (ψευδολογεῖν) and to contradict themselves. On the one hand they introduce Hannibal as a general of inimitable daring and prudence, while they show him admittedly the most imprudent; and on the other hand, unable to reach a dénouement or an issue from their own mendacity, they introduce into pragmatic history gods and the children of gods. . . . Ignorant of these things they say that a hero (*i.e.*, a demigod) appeared and showed the Carthaginians the roads. Hence, naturally, they find themselves in the same position as the writers of tragedies. For the dénouements of their dramas need a god and a machine, because their first premises are false and contrary to reason; and historians must be in like case and must represent gods and heroes appearing when their premises are improbable and false."

Polybius (iii. 6) insists on the distinction between the remoter causes (αἰτίαι) of events and their immediate origins (ἀρχαί) and in the same spirit he emphasizes the necessity of taking a comprehensive or synoptic view of history, regarding history as a unity in so far as the interests of different nations mutually interact: "In previous times the actions of the world were sporadic . . . now history is, as it were, an organic whole; the affairs of Italy and Africa are intertwined with those of Asia and Greece and all have reference to one end" (i. 3). It is this conception of history which leads Polybius to prefix to his more immediate subject the preparatory narrative of his first two books: "The peculiarity of our study and the marvel of our times is this. Just as Fortune (τύχη) has bent almost all the affairs of the world to one end and has inclined them to one and the same goal, so by means of history we must bring under one conspectus for our readers the agency which Fortune has employed to accomplish the whole. For this consideration it is chiefly which incited and stimulated me to undertake my history, coupled with the fact that no one in our time has attempted a general history: otherwise I had been much less eager in this direction. But when I see that many writers occupy themselves with particular wars and some of the actions connected with them, while no one, so far as I know, has even attempted to examine

the general and comprehensive economy of events—when and whence they originated and how they attained fulfillment—I considered it absolutely essential not to omit or allow to pass unnoticed the most beautiful and at the same time the most beneficial exhibition of the power of Fortune. For many as are her innovations and unceasingly as she engages in the affairs of men, absolutely never has she wrought such a work or engaged in such a struggle as in our time. This cannot be seen from sectional histories—unless it be that one who visits the most eminent individual cities or sees them represented in a picture, imagines straightway that he understands the form of the whole world, and its general position and arrangement" (i. 4).

Sources of Information.—Starting with the initial advantage of being himself conversant with public affairs, Polybius seems to have taken pains unusual for his time to equip himself with the knowledge requisite to ensure accuracy. In the first place he was a careful student of the practice of war, and indeed wrote a treatise on *Tactics* (ix. 20. 4. *cf.* Arrian, *Tact.* i. 1., Aelian, *Tact.* i. 2; iii. 4; xix. 10). He had an extensive first-hand acquaintance with geography (*cf.* the inscription on his statue at Megalopolis as quoted above); he accompanied Scipio in many campaigns (Arrian, *Tact.* l.c.) and, as he tells us himself, "it was mainly for this reason that I undertook the dangers and discomforts incident to travel in Africa and Spain and also Gaul and the Outer Sea (Atlantic) adjacent to those lands, in order that I might correct the ignorance of my predecessors in those matters and make known those parts of the world to the Greeks" (iii. 59). He also tells us (iii. 48) in discussing Hannibal's passage of the Alps, that he had himself seen the region and had travelled over the Alps for the sake of information and observation. His intimate study of constitutional matters is shown by his account of the Roman constitution in Book VI. Finally he made diligent use of the documentary and monumental evidence accessible to him. Thus in iii. 33, after giving the numbers of Hannibal's forces with a detail "suggesting the plausible mendacity of a historian" he explains that he took the numbers from a record in bronze left at Lacinium (in Bruttium) by Hannibal himself. In xvi. 15 he appeals to the evidence of a despatch preserved in the *prytaneum* of Rhodes; and the manner in which he quotes the terms of the treaty which ended the first Punic War (i. 62) and of that between Hannibal and Philip (vii. 9) implies that he is either translating or quoting a translation of an original document which he possibly obtained from official sources.

His enlightened conception of the function of history, his careful preparation for his task, entitle Polybius to an honourable place among historians. The completely impartial historian is an ideal, certainly unattainable and perhaps undesirable. No very serious charge on this ground is made against Polybius, nor can such charges in any case be either confuted or confirmed authoritatively. He has himself at all events forestalled criticism: "That historians may incline the balance in favour of their own country I would allow—not that they should make statements which contradict the facts. There are enough errors of ignorance to which historians are liable and which a man may hardly avoid. But if we write falsely from intention—be it for country or for friends or for favour—what better are we than those who make their living by such means? . . . On this tendency readers should keep a watchful eye, and historians themselves should guard against it" (xvi. 14).

The main criticism directed against Polybius from Dionysius of Halicarnassus (1st century, B.C.) to the present day is made on the ground of style. Dionysius, from the standpoint of a strict Atticist, writes of the later Greek historians who have so far neglected style that they "have left behind them compositions which no one endures to read to the end—Phylarchus, Duris, Polybius" (Dionys. *De comp. verb.* iv.). The modern reader, from a more general standpoint, would be inclined to think that his defects of style have been exaggerated. But his unfamiliar vocabulary, his intentional rejection of the picturesque concomitants of historical events, his anxiety to point a moral, combine to render him less popular than his merits deserve: one more proof that something more than knowledge, more than accuracy, more than serious purpose and moral earnestness, is required in the historian to whom the world will gladly listen.

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POLYCARP (*c.* 69–*c.* 155), bishop of Smyrna and one of the Apostolic Fathers, derives much of his importance from the fact that he links together the apostolic age and that of nascent Catholicism. The sources from which we derive our knowledge of the life and activity of Polycarp are: (1) a few notices in the writings of Irenaeus, (2) the Epistle of Polycarp to the Church at Philippi, (3) the Epistle of Ignatius to Polycarp, (4) the Epistle of the Church at Smyrna to the Church at Philomelium, giving an account of the martyrdom of Polycarp. Since these authorities have all been more or less called in question and some of them entirely rejected by recent criticism, it is necessary to say a few words about each.

Sources.—1. *The Statements of Irenaeus* are found (*a*) in his *Adversus haereses,* iii. 3, 4, (*b*) in the letter to Victor, where Irenaeus gives an account of Polycarp's visit to Rome, (*c*) in the letter to Florinus—a most important document which describes the intercourse between Irenaeus and Polycarp and Polycarp's relation with St. John. The genuineness of (*c*) is not uncontested, but it is generally accepted.

2. *The Epistle of Polycarp.*—Though Irenaeus states that Polycarp wrote many "letters to the neighbouring churches or to certain of the brethren" only one has been preserved, viz., the well-known letter to the Philippians. The epistle is largely involved in the Ignatian controversy (*see* IGNATIUS). The rehabilitation of the Ignatian letters in modern times has, however, practically destroyed the attack on the Epistles of Polycarp. The date of the epistle depends upon the date of the Ignatian letters and is now generally fixed between 112 and 118. The language in this letter is simple but powerful.

3. *The Epistle of Ignatius to Polycarp.*—This epistle has of course been subjected to the same criticism as has been directed against the other epistles of Ignatius (*see* IGNATIUS); the general criticism, may now be said to have been completely answered by the investigations of Zahn, Lightfoot and Harnack. Some modern scholars feel a difficulty about the peremptory tone which Ignatius adopts towards Polycarp. There was some force in this argument when the Ignatian Epistles were dated about 140, as in that case Polycarp would have been an old and venerable man at the time. But now that the date is put back to about 112 the difficulty vanishes, since Polycarp was not much over forty when he received the letter.

4. *The Letter of the Church at Smyrna* to the Philomelians is a most important document, because we derive from it all our information with regard to Polycarp's martyrdom. Eusebius has preserved the greater part of this epistle (iv. 15), but we possess it entire with various concluding observations in several Greek mss., and also in a Latin translation. The epistle gives a minute description of the persecution in Smyrna, of the last days of Polycarp and of his trial and martyrdom; and as it contains many instructive details and professes to have been written not long after the events to which it refers, it has always been regarded as one of the most precious remains of the 2nd century. Certain recent critics, however, have questioned the authenticity of the narrative. The more moderate school of modern critics—*e.g.*, Lightfoot (*Ignatius and Polycarp,* 1589 *seq.*), Harnack (*Gesch. d. altchrist. Lit.* II. i. 341), and Krüger (*Early Christian Lit.,* 1897)—is unanimous in regarding it as an authentic document, though it recognizes that here and there a few slight interpolations have been inserted. Besides these we have no other sources for the life of Polycarp.

Life.—Polycarp must have been born not later than the year 69, for on the day of his death (*c.* 155) he declared that he had served the Lord for eighty-six years (*Martyrium,* 9). Irenaeus tells us that in early life Polycarp "had been taught by apostles and lived in familiar intercourse with many that had seen Christ" (iii. 3, 4).

This testimony is expanded in the remarkable words which Irenaeus addressed to Florinus:

"I saw thee when I was still a boy (παῖς ἔτι) in Lower Asia in company with Polycarp . . . I can even now point out the place where the blessed Polycarp used to sit when he discoursed, and describe his goings out and his comings in, his manner of life and his personal appearance and the discourses which he delivered to the people, how he used to speak of his intercourse with John and with the rest of those who had seen the Lord, and how he would relate their words. And everything that he had heard from them about the Lord, about His miracles and

about His teaching, Polycarp used to tell us as one who had received it from those who had seen the Word of Life with their own eyes, and all this in perfect harmony with the Scriptures. To these things I used to listen at the time, through the mercy of God vouchsafed to me, noting them down, not on paper but in my heart, and constantly by the grace of God I brood over my accurate recollections."

These words establish a chain of tradition (John-Polycarp-Irenaeus) which is without a parallel in early church history. Polycarp thus becomes the living link between the Apostolic age and the great writers who flourished at the end of the 2nd century. Recent criticism, however, has endeavoured to destroy the force of the words of Irenaeus. Harnack (*Chronologie*, i., 325–329), for instance, attacks this link at both ends. (*a*) The connection of Irenaeus and Polycarp, he argues, is very weak, because Irenaeus was only a boy (παῖς) at the time, and his recollections therefore carry very little weight. The fact, too, that he never shows any signs of having been influenced by Polycarp and never once quotes his writings is a further proof that the relation between them was slight. (*b*) The connection which Irenaeus tries to establish between Polycarp and John the apostle is probably due to a blunder. Irenaeus has confused John the apostle and John the presbyter. Polycarp was the disciple of the latter, not the former. In this second argument Harnack has the support of a considerable number of modern scholars who deny the Ephesian residence of John the apostle. But in spite of much modern criticism there seems to be no solid reason for rejecting the statements of Irenaeus and regarding Polycarp as the link between the Apostolic age and the first of the Catholic fathers.

Though Polycarp must have been bishop of Smyrna for nearly half a century we know next to nothing about his career. We get only an occasional glimpse of his activity, and the period between 115 and 155 is practically a blank. The only points of sure information which we possess relate to (1) his relations with Ignatius, (2) his protests against heresy, (3) his visit to Rome in the time of Anicetus, (4) his martyrdom.

His Relations with Ignatius.—Ignatius, while on his way to Rome to suffer martyrdom, halted at Smyrna and received a warm welcome from the church and its bishop. Upon reaching Troas he despatched two letters, one to the church at Smyrna, another addressed personally to Polycarp. In these letters Ignatius charged Polycarp to write to all the churches between Smyrna and Syria (since his hurried departure from Troas made it impossible for him to do so in person) urging them to send letters and delegates to the church at Antioch to congratulate it upon the cessation of the persecution and to establish it in the faith. The letters of Ignatius illustrate the commanding position which Polycarp had already attained in Asia. It was in the discharge of the task which had been laid upon him by Ignatius that Polycarp was brought into correspondence with the Philippians. The Church at Philippi wrote to Polycarp asking him to forward their letters to Antioch. Polycarp replied, promising to carry out their request and enclosing a number of the letters of Ignatius which he had in his possession.

Polycarp's Attack on Heresy.—All through his life Polycarp appears to have been an uncompromising opponent of heresy. We find him in his epistle (ch. vii.) uttering a strong protest against certain false teachers (probably the followers of Cerinthus).

For every one who shall not confess that Jesus Christ is come in the flesh is antichrist; and whosoever shall not confess the testimony of the Cross is of the devil; and whosoever shall pervert the oracles of the Lord to his own lusts and say that there is neither resurrection nor judgment, that man is the first-born of Satan. Wherefore let us forsake their vain doing and their false teaching and turn unto the word which was delivered unto us from the beginning.

Polycarp lived to see the rise of the Marcionite and Valentinian sects and vigorously opposed them. Irenaeus tells us that on one occasion Marcion endeavoured to establish relations with him and accosted him with the words, "Recognize us." But Polycarp displayed the same uncompromising attitude which his master John had shown towards Cerinthus and answered, "I recognize you as the first-born of Satan." The steady progress of the heretical movement in spite of all opposition was a cause of deep sorrow to Polycarp, so that in the last years of his life the words were constantly on his lips, "Oh good God, to what times hast thou spared me, that I must suffer such things!"

Polycarp's Visit to Rome.—It is one of the most interesting and important events in the church history of the 2nd century that Polycarp, shortly before his death, when he was considerably over eighty years old, undertook a journey to Rome in order to visit the bishop Anicetus. Irenaeus, to whom we are indebted for this information (*Haer.* iii. 3, 4; *Epist. ad victorem, ap.* Euseb. v. 24), gives as the reason for the journey the fact that differences existed between Asia and Rome "with regard to certain things" and especially about the time of the Easter festival. Unfortunately all he says is that with regard to the certain things the two bishops speedily came to an understanding, while as to the time of Easter, each adhered to his own custom, without breaking off communion with the other. We learn further that Anicetus as a mark of special honour allowed Polycarp to celebrate the Eucharist in the church, and that many Marcionites and Valentinians were converted by him during his stay in Rome.

Polycarp's Martyrdom.—Not many months apparently after Polycarp's return from Rome a persecution broke out in Asia. A great festival was in progress at Smyrna. The proconsul Statius Quadratus was present on the occasion, and the asiarch Philip of Tralles was presiding over the games. Eleven Christians had been brought, mostly from Philadelphia, to be put to death. The appetite of the populace was inflamed by the spectacle of their martyrdom. A cry was raised, "Away with the atheists. Let search be made for Polycarp." Polycarp took refuge in a country farm. His hiding-place, however, was betrayed and he was arrested and brought back into the city. Attempts were made by the officials to induce him to recant, but without effect. When he came into the theatre, the proconsul urged him to "revile Christ," and promised, if he would consent to abjure his faith, that he would set him at liberty. To this appeal Polycarp made the memorable answer, "Eighty and six years have I served Him and He hath done me no wrong. How then can I speak evil of my King who saved me?" These words only intensified the fury of the mob. They clamoured for a lion to be let loose upon him there and then. The asiarch, however, refused, urging as an excuse that the games were over. When they next demanded that their victim should be burned, the proconsul did not interfere. Timber and faggots were hastily collected and Polycarp was placed upon the pyre. With calm dignity and unflinching courage he met his fate and crowned a noble life with an heroic death.

Eusebius in his *Chronicon* gives A.D. 166 as the date of Polycarp's death, and until the year 1867 this statement was never questioned. In that year appeared Waddington's *Mémoire sur la chronologie de la vie du rhéteur Aelius Aristide*, in which it was shown from a most acute combination of circumstances that the Quadratus whose name is mentioned in the *Martyrium* was proconsul of Asia in 155–156, and that consequently Polycarp was martyred on Feb. 23, 155. Waddington's conclusion has received overwhelming support amongst recent critics. His views have been accepted by (amongst many others) Renan (*Antéchrist*, 1873, p. 207), Hilgenfeld (*Zeitschr. f. wiss. Theol.*, 1874, p. 325), Gebhardt (*Zeitschr. f. hist. Theol.*, 1875, p. 356), Lipsius (*Jahrb. f. prot. Theol.*, 1883, p. 525), Harnack (*Chronologie*, i. 334–356), Zahn (*Zeitschr. f. wiss. Theol.*, 1882, p. 227), Lightfoot (*Ignatius and Polycarp*, i. 629–702) and Randell (*Studia biblica*, 1885, i. 175). Against this array of scholars only the following names of importance can be quoted in support of the traditional view—Keim (*Aus dem Urchristentum*, p. 90), Wieseler (*Die Christenverfolgungen der Caesaren*, 1878, p. 34) and Uhlhorn (*Studia Biblica*, 1890, ii., 105–156). The problem is too complex to admit of treatment here. There seems to be little doubt that the case for the earlier date has been proved.

The significance of Polycarp in the history of the Church is out of all proportion to our knowledge of the facts of his career. The violent attack of the Smyrnaean mob is an eloquent tribute to his influence in Asia. "This is the teacher of Asia," they shouted, "this is the father of the Christians: this is the destroyer of our gods: this is the man who has taught so many no longer to sacrifice and no longer to pray to the gods." And after the execu-

tion they refused to deliver up his bones to the Christians for burial on the ground that "the Christians would now forsake the Crucified and worship Polycarp." Polycarp was indeed, as Polycrates says, "one of the great luminaries" (*μεγάλα στοιχεῖα*) of the time. It was in no small degree due to his staunch and unwavering leadership that the Church was saved from the peril of being overwhelmed by the rising tide of the pagan revival which swept over Asia during the first half of the 2nd century, and it was his unfaltering allegiance to the Apostolic faith that secured the defeat of the many forms of heresy which threatened to destroy the Church from within.

Polycarp had no creative genius. He was a "transmitter, not a maker." As Irenaeus says (iii. 3, 4), "Polycarp does not appear to have possessed qualifications for successfully conducting a controversial discussion with erroneous teachers . . . but he could not help feeling how unlike their speculations were to the doctrines which he had learned from the Apostles, and so he met with indignant reprobation their attempt to supersede Christ's gospel with fictions of their own devising." It is this that constitutes Polycarp's service to the Church, and no greater service has been rendered by any of its leaders in any age.

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POLYCHAETA, a class of segmented, largely marine worms (Annelida, *q.v.*). They comprise 64 families and nearly 10,000 species. The name refers to the serially arranged tufts of bristles at the sides of the body. Examples are *Nereis* and *Serpula*.

POLYCLEITUS, the name of two Greek sculptors of the school of Argos; the first belonging to the fifth century, the second to the early part of the fourth.

1. The elder and best known Polycleitus was a contemporary of Pheidias, and in the opinion of the Greeks his equal. Whether he was actually a pupil of Ageladas is disputed; at any rate he carried on the tradition. He made a figure of an Amazon for Ephesus which was regarded as superior to the Amazon of Pheidias made at the same time; and his colossal Hera of gold and ivory which stood in the temple near Argos was considered as worthy to rank with the Zeus of Pheidias. It would be hard for a modern critic to rate Polycleitus so high: the reason is that balance, rhythm and the minute perfection of bodily form, which were the great merits of this sculptor, do not appeal to us as they did to the Greeks of the 5th century. He worked mainly in bronze.

As regards his chronology we have data in a papyrus published by Grenfell and Hunt containing lists of athletic victors. From this it appears that he made a statue of Cyniscus, a victorious athlete of 464 or 460 B.C., of Pythocles (452) and Aristion (452). He thus can scarcely have been born as late as 480 B.C. His statue of Hera is dated by Pliny to 420 B.C. His artistic activity must thus have been long and prolific. His two great statues, ideal athletic types rather than portraits, are the Diadumonos and the Doryphorus, copies of both of which are common. The Doryphorus was known as the Canon, because it embodied the correct proportions of the ideal male form. The completest copy is from Pompeii, and there is a copy of the Diadumonos from Vaison in the British Museum. Both are late Roman copies, unpleasantly heavy and square and in marble, thus giving little idea of the finish of Polycleitus' work in bronze. This has been enforced by the discovery at Delos, by the French excavators, of a diadumenus of far more pleasing type and greater finish, which also goes back to Polycleitus. The excavations at Olympia have widened our knowledge of his early work. Among the bases of statues found on that site were three signed by Polycleitus, still bearing on their surface the marks of attachment of the feet of the statues. This at once gives us their pose; and following up the clue, A. Furtwängler has identified several extant statues as copies of figures of boy athletes victorious at Olympia set up by Polycleitus. Among these the Westmacott athlete in the British Museum is conspicuous.

The Amazon of Polycleitus survives in several copies, among the best of which is one in the British Museum. The masterpiece of Polycleitus, his Hera of gold and ivory, has of course totally disappeared. The coins of Argos give us only the general type. Waldstein has identified the head of a girl in the British Museum as belonging to this type.

The want of variety in the works of Polycleitus was brought as a reproach against him by ancient critics. Varro says that his statues were square and almost of one pattern. Except for the statue of Hera, which was the work of his old age, he produced scarcely any notable statue of a deity. His field was narrowly limited; but in that field he was unsurpassed.

2. The younger Polycleitus was of the same family as the elder, and the works of the two are not easily to be distinguished. Some existing bases, however, bearing the name are inscribed in characters of the 4th century, at which time the elder sculptor cannot have been alive.

See A. Furtwängler, *Masterpieces of Greek Sculpture* (Eng. trans. 1895); P. Paris, Polyclète (Paris, 1895); Mahler, *Polyklit und seine Schule* (Athens, 1902).

POLYCRATES, tyrant of Samos (*c.* 535–515 B.C.). Having won popularity by donations to poorer citizens, he took advantage of a festival of Hera, which was being celebrated outside the walls, to make himself master of the city (about 535 B.C.). After getting rid of his brothers Pantagnotus and Syloson, who had at first shared his power, he established a despotism which is of great importance in the history of the island. He equipped a fleet of 100 ships and so became master of the Aegean basin. This ascendancy he abused by numerous acts of piracy which made him notorious throughout Greece; but his real aim was the control of the archipelago and the mainland towns of Ionia. He maintained an alliance with Lygdamis of Naxos, and dedicated to Delos the island of Rheneia. He also defeated a coalition of two great naval powers of the Asiatic coast, Miletus and Lesbos. He made an alliance, probably commercial in object, with Amasis of Egypt. But the squadron he sent to Amasis' support against Cambyses of Persia, being composed of political opponents of Polycrates, suspected treachery and returned and attacked Polycrates. After a defeat by sea, Polycrates repelled an assault upon the walls, and subsequently withstood a siege by a joint armament of Spartans and Corinthians assembled to aid the rebels. He maintained his ascendancy until about 515, when Oroetes, the Persian governor of Lydia, who had been reproached for his failure to reduce Samos by force, lured him to the mainland and put him to death by crucifixion.

Beside the political and commercial pre-eminence which he conferred upon Samos, Polycrates adorned the city with public works on a large scale. He was also a patron of letters; he collected a library, and Anacreon lived at his court.

POLYGALACEAE, a family of dicotyledonous herbs, shrubs and small trees, comprising ten genera and about 700 species, not represented in New Zealand, Polynesia and the Arctic zone, but otherwise cosmopolitan. *Polygala vulgaris* is the British milkwort (*q.v.*), and *P. Senega*, the Senega snake-root, a North American medicinal plant. In North America some 50 species are found, chiefly in the southern and western United States.

POLYGLOTT or **POLYGLOT,** a book which contains side by side versions of the same text in several languages (Gr. *πολύς*, many, and *γλῶττα*, tongue). The most important polyglotts are editions of the Bible, or its parts, in which the Hebrew and Greek originals are exhibited along with the great historical versions. The famous *Hexapla* of Origen, in which the Old Testament Scriptures were written in parallel columns, probably suggested the later polyglotts, but though it gives six texts it is itself only in two languages. In the 16th and 17th centuries polyglotts became a favourite means of advancing the knowledge of Eastern languages as well as the study of Scripture. The series began with the *Complutensian* printed by Arnaldus Guilielmus de Brocario at the expense of Cardinal Jimenez (*q.v.*) at the university at Alcalá de Henares (Complutum). This contained for the Old Testament the Hebrew text, Latin Vulgate and the Septuagint

and Chaldee versions with Latin renderings; for the New Testament, the Greek and Vulgate Latin. The six volumes bear dates ranging from Jan. 10, 1514, to July 10, 1517, but the work did not receive the papal sanction till March 1520, and was apparently not issued till 1522, probably because of the Imperial privilege obtained by Erasmus for his Greek Testament in 1516. The *Antwerp Polyglott*, printed by Christopher Plantin (1569–72, in 8 vols. folio), under the patronage of Philip II of Spain, added a new language to those of the *Complutensian* by including the Syriac New Testament. Next came Le Jay's *Paris Polyglott* (1645), which embraces the first printed texts of the Syriac Old Testament and of the Samaritan Pentateuch. It has also a series of various Arabic versions. The last great polyglott was that edited by Brian Walton, published in London in 1657. This is much less beautiful than Le Jay's, but includes the Syriac of Esther and of several apocryphal books, Persian versions of the Pentateuch and Gospels, and the Psalms and New Testament in Ethiopic. It was in connection with this polyglott that E. Castell produced his famous *Heptaglott Lexicon* (2 vols. folio, London, 1669). Of the numerous polyglott editions of parts of the Bible it may suffice to mention the Genoa psalter of 1516, edited by Giustiniani, bishop of Nebbio. This is in Hebrew, Latin, Greek, Chaldee and Arabic, and is interesting from the character of the Chaldee text, being the first specimen of western printing in the Arabic character. (A. W. P.)

POLYGNOTUS, famous Greek painter, *c.* 470–440 B.C., son of Aglaophon, was a native of Thasos, but was adopted by the Athenians, and admitted to their citizenship. He painted for them, in the time of Cimon, a picture of the taking of Ilium on the walls of the Stoa Poecile, and another of the marriage of the daughters of Leucippus in the Anaceum. In the hall at the entrance to the Acropolis other works of his were preserved; and he collaborated with Mikon in paintings of Greeks and Amazons in the Theseum. The most important, however, of his products were his frescoes in the Lesche erected at Delphi by the people of Cnidus. The subjects of these were the visit to Hades by Odysseus, and the taking of Ilium. Fortunately the traveller Pausanias has left us a careful description of these paintings, figure by figure (Paus. x, 25–31); and we may form some idea of their style from contemporary vase decorations. The foundations of the building have been recovered in the course of the French excavations at Delphi. From this evidence some modern archaeologists have tried to reconstruct the composition of the paintings. The figures were detached and seldom overlapping, ranged in two or three rows one above another; and the farther were not smaller nor dimmer than the nearer. We learn also that Polygnotus employed but few colours. His excellence lay in the beauty of his drawing of individual figures; but especially in the "ethical" and ideal character of his art. His work must have had the same grandeur as the contemporary sculptures of Olympia, combined apparently with a new delicacy; for he is praised for his transparent garments, his head-dresses of variegated colours, and his speaking expressions. He was the great representative of Greek painting of the 5th century B.C., as Pheidias was of sculpture.

POLYGONACEAE, in botany, a family of dicotyledons, containing 40 genera with about 750–800 species, chiefly in the north temperate zone, and represented in Great Britain by three genera, *Polygonum*, *Rumex* (dock, *q.v.*) and *Oxyria*. They are mostly herbs characterized by the union of the stipules into a sheath or *ocrea*, which protects the younger leaves in the bud stage. Some are climbers, as, for instance, the British *Polygonum convolvulus* (black bindweed). In *Muehlenbeckia platyclada*, a native of the Solomon Islands, the stem and branches are flattened, forming ribbon-like cladodes jointed at the nodes. The leaves are alternate, simple and generally entire; the edges are rolled back in the bud. They are generally smooth, but sometimes, especially in mountain species, woolly. The small, regular, generally hermaphrodite flowers are borne in large numbers in compound inflorescences, the branches of which are cymose. The parts of the flower are whorled (cyclic) or acyclic. The former arrangement may be derived from a regular trimerous flower with two whorls of perianth leaves, two staminal whorls and a three-sided ovary—this type of flower occurs in the Californian genus *Pterostegia*. The flower of rhubarb (*Rheum*) is derived from this by doubling in the outer staminal whorl and that of the dock (*Rumex*) by doubling in the outer staminal whorl and suppression of the inner whorl. Dimerous whorled flowers occur in *Oxyria* (mountain sorrel), another arctic and alpine genus, the flowers of which otherwise resemble those of *Rumex*. In the acyclic flowers a pentamerous perianth is followed by five to eight stamens as in *Polygonum*. The perianth leaves are generally uniform and green, white or red in colour. They are free or more or less united, and persist till the fruit is ripe, often playing a part in its distribution, and affording useful characters for distinguishing genera or species. Thus in the docks the three inner leaves enlarge and envelop the fruit as three membranous wings one or more of which bear on the back large fleshy warts. The number of the carpels is indicated by the three-sided (in dimerous flowers two-sided) ovary, and the number of the styles; the ovary is unilocular and contains a single erect ovule springing from the top of the floral axis. The fruit is a dry one-seeded nut, two-sided in bicarpellary flowers, as in *Oxyria*. The straight or curved embryo is embedded in a mealy endosperm. The flowers are wind-pollinated, as in the docks (*Rumex*), where they are pendulous on long slender stalks and have large hairy stigmas; or insect-pollinated, as in *Polygonum* or rhubarb (*Rheum*), where the stigmas are capitate and honey is secreted by glands near the base of the stamens. Insect-pollinated flowers are rendered conspicuous chiefly by their aggregation in large numbers, as for instance in bistort (*Polygonum bistorta*), where the perianth is red and the flowers are crowded in a spike. In buckwheat (*q.v.*, *P. fagopyrum*) the numerous flowers have a white or red perianth and are perfumed; they are dimorphic, *i.e.*, there are two forms of flowers, one with long styles and short stamens, the other with short styles and long stamens. In other cases self-pollination is the rule, as in knotgrass (*P. aviculare*), where the very small, solitary, odourless flowers are very rarely visited by insects and pollinate themselves by the incurving of the three inner stamens on to the styles.

Polygonaceae is mainly a north temperate order. A few genera are tropical, *e.g.*, *Coccoloba*, which has 125 species restricted to tropical and sub-tropical America. *Polygonum* has a very wide distribution, spreading from the limits of vegetation in the northern hemisphere to the mountains of tropical Africa and South Africa, through the highlands of tropical Asia to Australia, and in America as far south as Chile. Most of the genera have, however, a limited distribution. In the British Isles, *Polygonum* has 14 species; *Rumex* (12 species) includes the various species of dock (*q.v.*) and sorrel (*R. Acetosa*); and *Oxyria digyna*, an alpine plant (mountain sorrel), takes its generic name (Gr. ὀξύς, sharp) from the acidity of its leaves. *Rheum* (rhubarb, *q.v.*) is central Asiatic.

In the United States the largest genus is *Eriogonum*, containing about 200 species, all natives of America, and most of them in the western United States. The other prominent genera occurring in America are *Rumex* (docks), and *Polygonum* (knotweeds). *Fagopyrum* (buckwheat) and *Rheum* (rhubarb or pie-plant) also are abundant, but they are natives of the old world. The Mexican genus *Antigonon* is cultivated in the south as an ornamental.

POLYGONAL AND POLYHEDRAL NUMBERS: *see* FIGURATE NUMBERS.

POLYGONS. A *polygonal line*, also called a *broken line*, joining the point A_1 to the point A_n is any finite set of points A_1, A_2, . . . , A_n and the segments A_1A_2, A_2A_3, . . . , $A_{n-1}A_n$. In this and the following definition of a polygon the phrase "a point A_i" means a point associated with the symbol A_i and the phrase "a segment A_iA_j" means the segment whose ends are the points which are the associates of the symbols A_i and A_j respectively, associated with the symbol A_iA_j. A *segment* is the set of all points of any (straight) line which are between any two points of that line. Each of the latter points is called an *end* of the segment. A *polygon* is any finite set of points A_1A_2, . . . , A_n and the segments A_1A_2, A_2A_3 . . . , A_{n-1} A_n, A_nA_1. The points A_i and segments A_iA_{i+1}, A_nA_1, $i=1, 2, \ldots, n$, are called respectively the *vertices* and *sides* of the polygon; similarly for a polygonal line.

The terms polygonal line and polygon are used also with meanings which are different from, although closely related to, those given above. A polygon as defined may have one of two senses assigned to it so that the first end and the second end of each side is specified in such a way that the vertex A_i is either the first end of the side A_iA_{i-1} and the last end of the side $A_{i-1}A_i$, and if $i=1$, A_i is the first end of A_1A_2, and the second end of A_nA_1, or vice versa. A polygon with such an assignment of a sense is called an *oriented* or a *sensed polygon*. In an obvious way an oriented polygonal line is defined. Thus two sensed polygons or polygonal lines are associated with each polygon or polygonal line. In the sequel the phrase the oriented (or sensed) side AB of a sensed polygon indicates that A is the first end of the oriented side AB of that oriented polygon, and B the second. Polygonal lines and polygons according to the first definition are referred to as *unoriented* or *unsensed polygonal lines* and *polygons* respectively. In formulating a third meaning of the terms polygonal line and polygon it should be emphasized that the elements involved in the above definition are points and segments associated with symbols so that an unoriented or oriented polygon is neither a set of points and segments nor a set of points. The word polygon also is used to signify either certain sets of points and segments or certain sets of points. The distinctions just pointed out although delicate are logically essential and even practically important. For the purpose of this article the single word "polygon" denotes any set of points which consists of the points which are the associates of the symbols $A_1, A_2, \ldots, A_n$ and the points which belong to the segments which are the associates of the symbols A_iA_{i+1}, $i=1, 2, \ldots, n$ and A_nA_1 of the first definition; *i.e.*, the definition of an unsensed polygon. Similarly in the case of a polygonal line.

The above definitions are of broad scope and define abstractions which are based on the phenomenon of the motion of a particle from point to point along intermediate rectilinear stretches. Important specializations of these ideas are the so-called *simple polygons* or polygonal lines according to any of the definitions given. A simple unoriented polygon is any unoriented polygon which is such that none of its vertices is an end of more than two of its sides and no side of the unoriented polygon contains a vertex or a point which belongs to another side of the unoriented polygon. The definitions of simple unoriented polygonal lines, simple oriented polygonal lines and polygons as well as those of simple polygons and polygonal lines in conformity with the third definition are apparent and consequently are not stated formally. Alternative definitions for the several concepts defined or indicated above may be given; for example a simple polygon may be defined as a finite set of points and segments such that (*a*) every point of the set is the end of two and only two segments of the set, (*b*) each end of every segment of the set is a point of the set, (*c*) no segment of the set contains a point of the set or a point of another segment of the set and (*d*) no (proper) subset of the given set satisfies (*a*), (*b*) and (*c*). It is easy to show that this definition is equivalent to the one indicated in introducing the third formulation of the idea of a polygon and it is valuable in that it admits of immediate generalization to the idea of a polyhedron in space.

Place of Polygons in Mathematics.—The theory of polygons as a special chapter in mathematics is chiefly concerned with the classification of unoriented and oriented polygons all of whose elements,—that is, vertices and sides,—are in the same plane. The corresponding question for space concerns polyhedrons and is taken up in the article on SOLIDS, GEOMETRIC. Polygons whose elements are not in one plane have not as yet formed the subject of any interesting theory. Such polygons, as well as plane polygons, however, serve as important aids, as in the study of continuous curves in general. This is largely because of the fact that any continuous arc contains the vertices of a polygonal line, the length of whose sides are all less than any preassigned positive number, and which is simple if the arc is simple. In particular, the length of an arc of a curve is defined by means of the lengths of the inscribed polygonal lines,—that is, polygonal lines which join the ends of the arc and whose vertices are on the arc and have an order which conforms to one of the two senses along the arc. In the geometry of the Euclidean plane, plane polygons,—that is, those having all of their points in one plane,—take on an added significance because of the fact that the Euclidean plane is separated into two regions by any simple polygon that is contained in it. This is a consequence of the basic fact that a line separates the Euclidean plane. Unless it is stated otherwise it is understood that in the following all configurations are in the Euclidean plane. A *region* is a set of points such that any point of the set is the centre of a circle which has only points of the set in its interior and such that the set is not composed of two sets having the latter property and also having no points in common. It follows easily that any two points of a region are joined by a simple polygonal line which is contained in the region. A precise statement of the important fact mentioned above is that if P is any simple plane polygon, then the plane is composed of P and two regions which have no points in common with each other or with P. One of these regions is of infinite extent and the other is not. A region such as the latter is referred to as a *polygonal region* and also as the *interior* of the polygon concerned and the latter is called the *boundary* of the polygonal region. Every circle which has a point of the boundary of the polygonal region as centre contains points of the region and any point which is such that any circle having it as centre contains points which belong to the region and also points which do not is a point of the boundary of the region. This property of the boundary of any polygonal region is used as the defining property of the boundary of a region in general. As a further consequence should be mentioned the fact that any polygonal region plus its boundary is composed of a finite number of triangles and their interiors, which have no points in common, and the vertices of the triangles are vertices of the bounding polygon. A region which is not a polygonal region is, however, approximated to by polygonal regions according to the following theorem: If Σ is any region, then there exists a sequence of polygonal regions $\Sigma_1, \Sigma_2, \Sigma_3, \cdots, \Sigma_n, \cdots$ such that (*a*) Σ_n and its boundary is contained in Σ and also in Σ_{n+1} for all (positive integral) values of n and (*b*) each point of Σ is contained in all but a finite number of the polygonal regions Σ_n. This theorem is easily proved by using as the polygonal regions regions which are composed of congruent squares which are formed by two sets of parallel lines, the lines of each set being equally spaced and intersecting orthogonally those of the other set. These acts indicate the importance of polygonal lines and polygons in the study of more general configurations.

THE THEORY OF PLANE POLYGONS

The Interior, Exterior and Peripheral Angles of a Plane Polygon.—We now proceed to the special theory of plane polygons. As remarked above, this theory concerns itself largely with unoriented and oriented polygons. In the case of a simple polygon the meaning of "an interior angle of a polygon" is immediate in virtue of the theorem concerning the separation of the plane by the polygon. This meaning leads to an interesting generalization in the case of an oriented polygon. In proceeding to this generalization and to related ideas it should be stated that all of the terms used are not defined with the mathematical completeness that would be possible with a greater allowance of space, but it has been aimed at least to indicate clearly the way to that completeness. Now it can be proved that if P is a simple oriented polygon and A any vertex of P then for the positive (counterclockwise) rotation of any side AB of P about its first end A, in accordance with the sense of P, which transforms the side AB into the other side of P having A as an end and which has a magnitude not exceeding 2π radians, then the points on the intermediate positions of AB which are within a certain distance of A are all in the interior of the polygon determined by P if the sense of P is the same as that of the rotation and all in the exterior in the contrary case. (Note that senses of oriented polygons are compared only in the case of simple oriented polygons.) Accordingly the *interior angle at any vertex* A_i of any oriented polygon P is defined as the positive angle (rotation) which has A_i as its vertex and whose initial side contains the side of P which has A_i

as its first end, say the side A_iA_{i+1}, whose terminal side contains the side with the ends A_i and A_{i-1}, if $i \neq 1$, and A_n, if $i=1$, and whose magnitude does not exceed 2π. (*See* fig. 1.)

Further if A_i is any vertex of an oriented polygon P and the first end of the oriented side A_iA_{i+1} of P then there is a rotation about A_i of the half-line having A_i as its initial point and having the same direction as the oriented side $A_{i-1}A_i$ ($i-1 \equiv n$ if $i=1$), that is the half-line of the line through A_{i-1} and A_i, which has A_i as its initial point and which does not contain A_{i-1}, into the half-line which contains the side A_iA_{i+1} which has a magnitude greater than $-\pi$ and less than or equal to π and there is another such rotation which is positive and has a magnitude not exceeding 2π. The former angle (rotation) is called the *exterior angle* and the latter the *peripheral angle* of the oriented polygon P at the vertex A_i. If α_i, β_i, γ_i are respectively the magnitudes of the interior, exterior and peripheral angles of the oriented polygon P at the vertex A_i then $\alpha_i+\beta_i=\pi$ and $\alpha_i+\gamma_i=\pi$ or 3π according as α_i is or is not less than π. If α_i is less than π then γ_i is and conversely. If the sum of all the β_i is set equal to $2a\pi$ and the sum of all the γ_i to $2a'\pi$ then a and a' are integers or zero as a simple consideration shows and $a'-a$ is the number of interior angles of P whose magnitudes are greater than or equal to π. If P' and P'' are two oriented polygons which differ only in orientation and if α_i', β_i', γ_i' and α_i'', β_i'', γ_i'' are respectively the magnitudes of the interior, exterior and peripheral angles of P' and P'' at the vertex A_i then $\alpha_i'+\alpha_i''=2\pi$, $\beta_i'+\beta_i''=0$ and $\gamma_i'+\gamma_i''=2\pi$. Hence the value of a for P'' is the negative of its value for P' while the value of a' for P'' is the number of vertices of P' (or P'') minus the value of a' for P'.

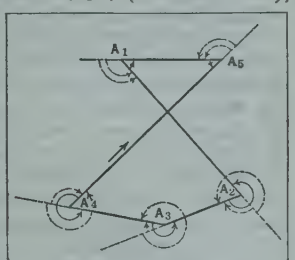

FIG. 1.—CONTINUOUS DEFORMATION OF AN ORIENTED POLYGON, WITH FIVE VERTICES

Classification of Plane Polygons.—In the classification of oriented polygons the numbers a and a' have been used to define the so-called types of such polygons. It is obvious how they may be used in the classification of unoriented polygons. There exist oriented polygons of any number n of vertices for which the value of a is any number whose absolute value does not exceed $\frac{1}{2}(n-1)$ except that for a triangle a cannot be zero. A more detailed scheme of classification is according to the values of a and $q=a'-a$. If all of the interior angles of an oriented polygon have magnitudes which do not exceed π then the polygon is called a *convex oriented polygon.* The unoriented polygon P is convex if and only if P with a sense assigned to it is convex. Both of these definitions are in conformity with the important notions of a *convex simple polygon* and a *convex polygonal region.* A *convex region* is a region such that all of the points of any segment whose ends belong to the region belong to the region also. A simple polygon is said to be convex if it is the boundary of a convex region, which is then a convex polygonal region. As theorems we have: A line which does not contain a side of a convex simple polygon contains not more than two points of the polygon and conversely. Also, no point of a convex simple polygon is on a particular one of the two sides of the line which contains any side of the polygon and conversely.

Another method of classification of unoriented and oriented polygons uses the notion of the continuous deformation of such polygons. Any one of two unoriented polygons with the vertices $A_1, A_2, \ldots, A_n$ and $B_1, B_2, \ldots, B_n$ respectively is deformable continuously into the other so that the vertex A_i corresponds to the vertex B_i and the side A_iA_{i+1} to the side B_iB_{i+1}. To obtain subclasses of unoriented polygons continuous deformations of such polygons, which satisfy any or all of the following conditions, are used: (1) no intermediate polygon of the deformation has two consecutive sides which lie in the same line and which have no points in common; (2) neither of two consecutive sides of any intermediate polygon of the deformation is contained in the other; and (3) no point is common to more than two sides of any intermediate polygon of the deformation. In the case of oriented polygons it is also required that sense be preserved by the deformation. Two oriented polygons that are transformable one into the other by a continuous deformation satisfying the first condition have the same value for a. If instead of the first condition the second is satisfied the oriented polygons have the same value for a'. If the deformation satisfies both the first and second conditions then the two oriented polygons are related so that if the magnitudes of one of two corresponding interior angles is less than π then the same is true of the other. Corresponding results for unoriented polygons follow easily. An interesting classification of unoriented polygons which satisfy the conditions on the intermediate polygons of the deformations satisfying all three conditions and which, in addition, have no vertex as the end of more than two sides and no side containing a vertex or a point belonging to more than two sides is that in which any unoriented polygon in one class is deformable into any other or into the symmetric image of any other in that class by a continuous deformation satisfying all three of the above conditions. For unoriented polygons of 4, 5 and 6 vertices there are respectively 3, 11 and 70 classes under this classification.

Non-metrical and Metrical Theories. Regular Polygons. Area of Polygons.—It should be pointed out that the above theory of the classification of unoriented and oriented polygons holds without essential modification in a more general plane than the Euclidean for only the order relations of the Euclidean plane are essential. Between this theory and the corresponding theory in the projective plane there are, because of the different kinds of linear order, some essential differences, but both theories are non-metrical. By making use of the metric properties of the Euclidean plane the consideration of regular polygons, oriented or not, becomes possible; also the question of the area of polygonal regions arises. An unoriented polygon is *regular* if any side is congruent to any other side and any angle of the polygon, *i.e.*, the figure consisting of a vertex and the two consecutive sides having that vertex as an end, congruent to any other "angle" of the polygon. The regular polygons are convex and there exists a circle circumscribed about and another inscribed in every regular polygon. Those regular polygons that are not simple also are called *star polygons.* If n points which are equally spaced on the circumference of a circle and numbered in order along that circumference are joined by segments so that the i-th point is joined to the $(i+d)$-th point, where d is a fixed positive integer, then the polygon resulting is a regular polygon for which the value of a, defined above, is d. Thus the number of "types" of regular polygons of n vertices is half of the number of positive integers which are less than and prime to n. Other kinds of regular polygons have been studied with particular reference to their classification along the lines explained above. For instance, there are the polygons which have the property that the figure composed of any vertex and the two sides of the polygon which have that vertex as an end is congruent to any other such figure and also the polygons which are such that the figure consisting of any side and two adjacent angles of the polygon is congruent to any other such figure. These polygons have an even number of vertices and a circle is circumscribable about any of those of the former kind and inscribable in any of those of the latter.

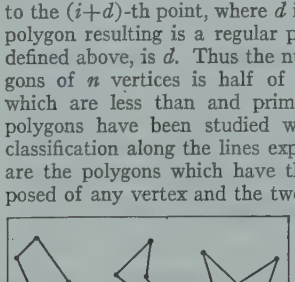

FIG. 2.—DEFORMATION OF A POLYGON OF FOUR VERTICES INTO THREE TYPES

Assuming the fact that the area of any plane simple polygon or rather polygonal region is the sum of the areas of the triangles of any finite set of triangles which have no interior points in common and which are such that every point of the polygonal region belongs to a triangle of the set or to the interior of one and every point of any triangle of the set or of the interior of any belongs to the polygonal region or its boundary the notion of the area of any plane unoriented or oriented polygon is approached. In the case of an unoriented or oriented polygon in general there is no region uniquely determined as in the case of simple polygons. In

the following only the case of oriented polygons is considered for that essentially covers the case of unoriented polygons. If the area of a triangle according to the usual meaning is σ then the area of that triangle with a sense assigned to it is defined as σ or $-\sigma$ according as that sense is positive or negative; *i.e.*, the same or not the same as the counterclockwise sense along the circumference of a circle. Using the symbol $A_1A_2 \cdots A_n$ to denote

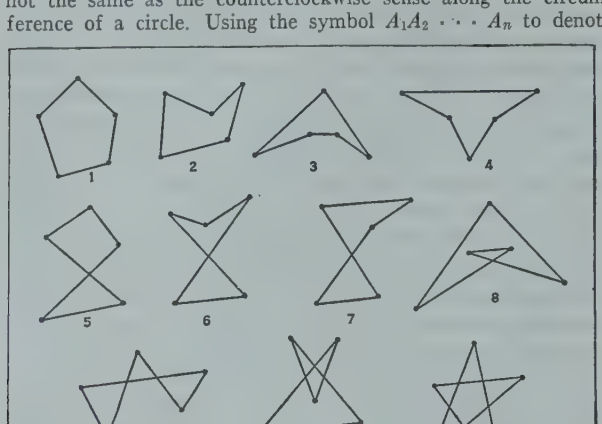

FIG. 3.—DEFORMATION OF A POLYGON OF FIVE VERTICES INTO 11 DIFFERENT TYPES

the oriented polygon with the vertices $A_1, A_2, \cdots, A_n$ and the sensed sides A_iA_{i+1}, the area of the oriented polygon $A_1A_2 \cdots A_n$ is defined as the sum of the areas of the oriented triangles $OA_1A_2, OA_2A_3, \cdots, OA_nA_1$ where O is any point of the plane. It is, of course, proved that the value of the area thus defined does not depend on the position of O and that if $A_1A_2 \cdots A_n$ is simple, this definition agrees with the area of a simple polygon according to the fundamental definition. An oriented polygon P determines a finite number of polygonal regions in its plane which have no points in common and whose boundaries are composed of points belonging to P. One and only one of these regions is of infinite extent. Now the following interesting facts pertain: let the regions, or cells, of finite extent be denoted respectively by $S_1, S_2, \cdots, S_k$, and let the area of the cell S_i according to the fundamental definition of the area of a polygonal region be σ_i so that σ_i is a positive number; then there exists a set of numbers $c_1, c_2, \cdots, c_k$ which are either integers or zero such that the area of the oriented polygon P is $c_1\sigma_1 + c_2\sigma_2 + \cdots + c_k\sigma_k$. Further, c_i is the number of complete positive revolutions minus the number of complete negative revolutions made by the radius vector, having any point O of S_i as its initial point, as its terminal point describes once the oriented polygon P in the assigned sense. c_i is called the coefficient of the cell S_i (*See* ANALYSIS SITUS.)

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POLYGYNY, the system under which a man is married to several women at the same time (Gr. πολύς, many, and γυνή, woman), popularly called polygamy (γάμος, marriage), which derivatively also includes the practice of polyandry. Polygyny is nowhere the exclusive form of marriage, and among most peoples who practise it the large majority of men live in monogamy. It may be modified in a monogamous direction both from the social and the sexual point of view. Frequently one of the wives, generally the one first married, holds a higher position than the rest or is regarded as the principal wife. In some cases this position implies certain sexual privileges; but more often we are told that it is the custom for the husband to cohabit with wives in turn, or that this is actually required of him. Another matter is how far theory and practice coincide. We have reason to suspect that one of the wives is for a time the favourite.

Lower Culture Groups.—Among the uncivilized races polygyny does not seem to be practised on a large scale by any of the lower hunters and food collectors, except some Australian and Bushman tribes, nor by any incipient agriculturists, at least among those of the lower type. On the other hand, a considerable number of these low-hunting and slightly agricultural tribes—such as some of the South American Indians, the aboriginal tribes of the Malay peninsula, most of the Andaman Islanders, the Veddas of Ceylon, certain tribes in the Malay archipelago, most of the Negritos of the Philippine Islands and some at least of the central African pygmies—are represented as strictly monogamous. Among the higher hunters polygyny is more frequent, although in the majority of their tribes it is practised only occasionally; and exclusive monogamy is rare, though perhaps not unknown. Among pastoral peoples there seems to be no one who can be regarded as strictly monogamous; and both among them and the higher agriculturists polygyny is undoubtedly more frequent than among the hunters and incipient agriculturists, although cases of regular monogamy are more frequent among the higher agriculturists than among the higher hunters. The cases in which polygyny is represented as "general" are comparatively much more numerous among African than among non-African pastoral peoples and higher agriculturists. Polygyny is at its height in Africa, both in point of frequency and in number of wives. King Mtēssa of Uganda and the king of Loango are said to have had 7,000 wives. This is apparently the high-water mark of polygyny anywhere.

Archaic Civilizations.—Polygyny, or a sort of concubinage hardly distinguishable from genuine polygyny, is found among most peoples of archaic civilization. In China there are, or have been, besides the legal principal wife, so-called wives "by courtesy" or lawful concubines. In Japan concubinage of the Chinese type existed as a legal institution until 1880. In ancient Egypt polygyny seems to have been permitted but to have been unusual, except in the case of kings. The Babylonian code of Hammurabi assumes that marriage shall be monogamous; yet "if a man has married a wife and a sickness has seized her," he may take a second wife; and if she remained childless he might take a concubine. Among the Hebrews a man could in any circumstances have a plurality of wives, and there was no difference in the legal status of different wives, nor was there any limit to the number of wives a man might take. In Arabia Mohammed ordained that a man's legal wives should be not more than four. Polygyny has been permitted among many of the Indo-European peoples—among ancient Slavs and Teutons, the ancient Irish and the Vedic Indians—though it seems to have been as a rule confined to kings or chiefs or nobles. None of the Hindu lawbooks restricts the number of wives a man is allowed to marry; yet some preference is often shown for monogamy, and at the present day most castes object to their members having more than one wife, except for some cogent reason. On the other hand, there can be little doubt that monogamy was the only recognized form of marriage in Greece; concubinage existed in Athens, but it was well distinguished from marriage, conferring no rights on the concubine. Roman marriage was strictly monogamous; liaisons between married men and mistresses were not uncommon by the close of the republic, but such a relation was not considered lawful concubinage in aftertime.

Christian and Modern Times.—Polygyny has been found even in Christian Europe. No obstacle was put in the way of its practice by kings in countries where it had occurred in the times of paganism. In the middle of the 6th century Diarmait, king of Ireland, had two queens and two concubines. Polygyny was frequently practised by the Merovingian kings. Charlemagne had two wives and many concubines; and one of his laws seems to imply that polygyny was not unknown even among priests. In later times Philip of Hesse and Frederick William II of Prussia contracted bigamous marriages with the sanction of the Lutheran clergy. In 1650, soon after the peace of Westphalia, when the population had been greatly reduced by the Thirty Years' War, the Frankish *Kreistag* at Nuernberg passed the resolution that

thenceforth every man should be allowed to marry two women. The Anabaptists and the Mormons have advocated polygyny with much religious fervour.

Causes.—One cause of polygyny is an excess of marriageable women; we may safely say that whenever there is a marked and more or less permanent majority of women in a savage tribe polygyny is allowed. But while the existence of available women makes polygyny possible, the direct cause of it is generally the man's desire to have more than one wife. There are various reasons for this desire. Among many of the simpler peoples the husband has to abstain from his wife not only for a certain time every month, but during her pregnancy, or at least during the latter stage of it, and after child-birth until the child is weaned, which often means an abstinence lasting for a couple of years or more. Other causes of polygyny are the attraction which female youth and beauty exercise upon the men, the latter's taste for variety, their desire for offspring—which is one of the principal causes of polygyny in the East—and the fact that polygyny contributes to a man's material comfort or increases his wealth, and thereby also his social importance and authority, through the labour of his wives. The usefulness of wives as labourers partly accounts for the increasing practice of polygyny at the higher grades of economic culture. But it should also be noticed that economic progress leads to a more unequal distribution of wealth, and this, combined with the necessity of paying a bride price the amount of which is more or less influenced by the economic conditions, makes it possible for certain men to acquire several wives while others can acquire none at all.

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POLYHEDRON: *see* SOLIDS, GEOMETRIC.

POLYMERIZATION, in chemistry, was originally considered to be any process in which two or more molecules of the same substance unite to give a molecule (polymer) with the same percentage composition as the original substance (monomer), but with a molecular weight which is an integral multiple of the original molecular weight. When the monomer and the polymer are so easily interconvertible that their isolation and chemical distinction are difficult (as in water), the process is usually considered to be association (*q.v.*). The term "polymerization" now applies when the monomer and polymer are easily isolated and distinguished. The term is also commonly applied to the making of polymers which do not conform to the original definition (*see* below).

Many organic materials which contain double or triple bonds in their structural formulas undergo addition polymerization on standing or heating, the original volatile materials becoming less volatile liquids or solids with the same elementary analyses (*see* CHEMISTRY: *Organic Chemistry* for many terms used here, particularly olefins, acetylenes and diolefins). Some of these polymers contain only two or three monomer units; some contain many, and some monomers yield more than one kind of polymer. Some polymers can be converted back to monomers by heating (*see* CYANAMIDE; CYANIC ACID AND CYANATES; FORMALDEHYDE; TERPENES). Phosphonitrile chloride, $P{\equiv}NCl_2$, is an inorganic compound yielding several polymers.

The polymerization of ethylene derivatives (olefins) is of great technical importance and illustrates addition polymerization. For instance, styrene (phenylethylene, $C_6H_5{-}CH{=}CH_2$) is a colourless liquid with an aromatic odour. On standing for several weeks at room temperature or for a few days at 100° C., the pure liquid polymerizes, becoming at first an increasingly viscous solution of polymer in monomer, and finally a clear, odourless, glassy solid. The product is a mixture of polymer molecules of the formula $(C_8H_8)_n$, where n has a wide range of values and averages several thousand. When the monomer is warmed with a fraction of 1% of an initiator such as benzoyl peroxide, $C_6H_5{-}CO{-}O{-}O{-}CO{-}C_6H_5$, a similar polymer is formed, but in a few minutes or hours instead of days or weeks. These processes are chain reactions, starting when styrene is activated thermally, or when the initiator decomposes, to give electrically neutral fragments of molecules with free or unsatisfied valences (free radicals with trivalent carbon atoms). Such a fragment, R—, adds easily to the double bond in the monomer

$$R{-} + H_2C{=}CH{-}C_6H_5 \rightarrow R{-}CH_2{-}CH(C_6H_5){-},$$

forming a larger molecule with the free valence now on the styrene unit. This new free radical adds to another double bond, and so on, so that many monomer units become linked together. Thousands of steps in a single reaction chain may occur in a second, the reaction ending when two radicals interact and mutually satisfy their free valences. Completed polymer molecules thus appear as soon as the polymerization starts. Large polymer molecules containing initiator fragments have nearly, but not exactly, the percentage composition of the monomers. The initiator is frequently called a catalyst (*see* CATALYSIS), although strictly it is not, since it is consumed during its action. To avoid mechanical difficulties in preparing and handling large masses of hard or viscous polymer, technical preparations are frequently carried out in emulsion or suspension in water. The polymer is then obtained as a synthetic latex or as beads.

Some metal halides (aluminum or stannic chlorides, boron trifluoride), strong acids (sulphuric), alkali metals and very strong bases (sodamide) also cause polymerization of olefins, but these initiators are ineffective in the presence of water. Such polymerizations are also chain reactions, but the growing molecules are ions or ion pairs instead of neutral radicals.

When a mixture of two monomers is subjected to polymerization, the product may contain both monomers in each polymer molecule (*i.e.*, copolymerization of the two monomers yields a copolymer) or it may contain only one kind of monomer in each polymer molecule, depending on the monomers and the initiator. Many commercial polymers are actually copolymers, a wider range of properties being possible than with single monomers. GR-S, principal synthetic rubber in the United States, is a copolymer of butadiene with 20%–25% of styrene, and is made in aqueous emulsion. The "cold rubber" made at about 5° C. proved to be generally superior to that made at 50°. Butyl rubber is made by polymerizing isobutylene, $(CH_3)_2C{=}CH_2$, with a small percentage of isoprene at about −100° C. with a metal halide catalyst. Polymers of methyl methacrylate, $H_2C{=}C(CH_3){-}CO{-}O{-}CH_3$, which yield sheets and formed articles of unusual clarity; polymers and copolymers of vinyl chloride, $H_2C{=}CHCl$, and vinyl acetate, $H_2C{=}CH{-}O{-}CO{-}CH_3$, which have wide use in films, coatings and mouldings; copolymers of acrylonitrile, $H_2C{=}CH{-}CN$, which are employed in synthetic fibres and in oil-resistant rubber; and polymers of chloroprene, $H_2C{=}CCl{-}CH{=}CH_2$, which are also oil-resistant rubbers, are important products of addition polymerization.

Condensation polymerization is the process of making products of high molecular weight, commonly called polymers, with the elimination of a small, easily removed molecule (often water) for each step in the process. Thus, the alcohol group of one hydroxy-acid molecule, $HO{-}(CH_2)_x CO{-}OH$, reacts with the acid group of another to give $HO{-}(CH_2)_x{-}CO{-}O{-}(CH_2)_x CO{-}OH + H_2O$, providing that x does not equal 3 or 4 (*see* ESTERS; also CHEMISTRY: *Organic Chemistry*). This first product still contains free alcohol and acid groups and may react further to give molecules containing more and more units, joined end to end. After y such steps, $y + 1$ molecules have condensed with the elimination of y molecules of water. The product therefore differs in composition from the monomer but its physical properties are sufficiently like those of some addition polymers that it is commonly called a polymer. This condensation polymerization is carried to an advanced stage only as water is removed by heating. In further contrast to addition polymerization, only products of low molecular weight are formed at the beginning of the reaction and their growth continues slowly throughout the condensation. An important condensation polymer is the polyamide (*see*

AMIDES), a nylon, containing the repeating unit $-CO-(CH_2)_4CO-NH-(CH_2)_6-NH-$, made by heating adipic acid, $HO-CO-(CH_2)_4-CO-OH$, and hexamethylenediamine, $H_2N-(CH_2)_6-NH_2$, at about 200° C.

In the above examples, each monomer molecule contains two sites of reaction and the polymer molecules are long chains. Such polymers soften on heating and dissolve in solvents. If a monomer contains more than two sites of reaction, the chains may branch and combine into networks, yielding products resistant to heat and solvents. Condensation polymers of this type are formed, for example, from phthalic anhydride and glycerol, phenol and formaldehyde, or urea and formaldehyde. They are widely used in surface coatings and moulded plastic products (*see* RESINS: *Synthetic Resins*).

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(FR. R. M.)

POLYMORPHISM. Many chemical substances, elements as well as compounds, crystallize in two or more distinct atomic arrangements which are differentiated by their X-ray diffraction patterns, outward crystal form, optical properties, energy content, volume, etc., and as such, are separate crystalline phases of the substance, according to the definition laid down by J. W. Gibbs (1876). The name "polymorphism" was applied to this property by E. Mitscherlich (1823), who discovered it in sodium phosphate and sulphur. Another term, "allotropy," attributable to J. Berzelius (1841), was proposed as a name for the supposed different conditions of the same element, both in the pure state and in compounds of which the element forms a part. Subsequent usage tended to confine the term to elements (W. Ostwald, 1893), and included such forms as gaseous oxygen and ozone, the mobile and viscous forms of sulphur, the different forms of phosphorus and the diamond and graphite forms of carbon. In the broadest sense, allotropy was applied by A. Smits (1911) to compounds in studies of "inner equilibria" prevailing therein between different molecular species. All cases of allotropy in the crystalline state are merely examples of polymorphism, and are best described as such. A polymorphic substance may be described as dimorphic, trimorphic, etc., according to the number of distinct crystalline forms.

Polymorphic substances may also be distinguished according to whether or not two given forms are reversibly transformable one into the other. When the transformation is reversible, the change is said to be enantiotropic; if it is found to be unidirectional only under all conditions investigated thus far, it is said to be monotropic. Two phases of one substance in equilibrium form a univariant system according to the phase rule; this means that if pressure and temperature are chosen as the external variables, the equilibrium temperature will depend upon the pressure, the composition being constant. The equilibrium temperature at constant pressure is known as the transition or inversion point. For example, rhombic sulphur is in equilibrium with monoclinic sulphur at 95.6° C., 1 atm., and at 129.9° C., 845 atm. The variation of the transition temperature with the pressure is expressed quantitatively by the Clapeyron equation in the form $dT/dp = T(v_I - v_{II})/L$ where T is the temperature on the Kelvin scale, p the pressure, L the latent heat absorbed and $v_I - v_{II}$ the difference in volume of the high- and low-temperature form, respectively, all per unit mass. dT/dp was measured for numerous enantiotropic transitions by G. Tammann, P. W. Bridgman and others. Since $v_I - v_{II}$ is usually small in comparison with L/T, high pressures are required to produce appreciable changes in the transition temperature; for sulphur in the above example, the average $dT/dp = 0.034°$ per atmosphere. Other examples are: low to high quartz, 0.021; red to yellow HgI_2, 0.0016. Three phases of one substance in equilibrium form an invariant system; this means that the phases can coexist at some one constant pressure and temperature characteristic of the phases present. This invariant point is named the triple point. In polymorphism two of the phases must be different crystalline forms of the substance; the third phase may be another crystal form, or liquid or vapour. For sulphur the triple point rhombic-monoclinic-vapour is 95.6° C. (approx.), 0.00003 atm.; rhombic-monoclinic-liquid, 153.7° C., 1,400 atm. For water, which has seven crystalline phases, the triple point ice I—ice II—ice III is at −34.3° C., 2,100 atm. (*see* ICE).

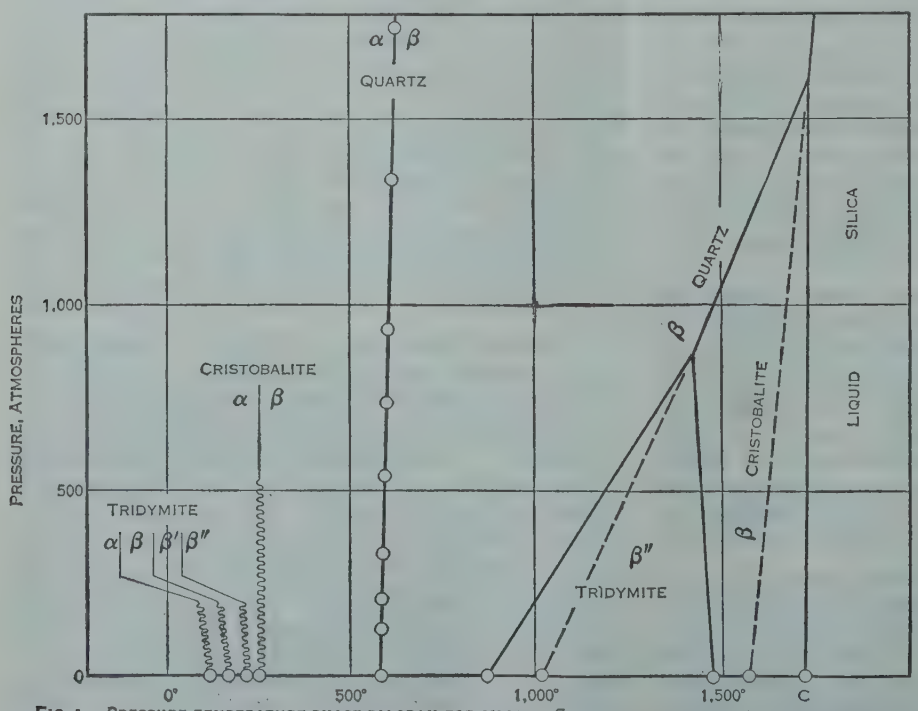

FIG. 1.—PRESSURE-TEMPERATURE PHASE DIAGRAM FOR SILICA. SOLID LINES REPRESENT TRANSITIONS OF PHASES STABLE IN THE RESPECTIVE ADJOINING REGIONS. BROKEN LINES REPRESENT TRANSITIONS OF METASTABLE PHASES. TRIDYMITE AND CRISTOBALITE IN THE REGION OF THEIR ALPHA-BETA TRANSITIONS ARE EACH METASTABLE WITH RESPECT TO ALPHA QUARTZ, WHICH IS HERE THE STABLE PHASE

A polymorphic substance, when mixed with one or more other substances and brought to equilibrium, may have its transition point changed. Both experimental evidence and deductions from the phase rule indicate that this occurs when the polymorph and the added substance form solid solution. If the polymorph crystallizes pure from the mixture or solution, the transition point remains unaltered. Thus, NH_4NO_3, which crystallizes pure from its aqueous solution, is found to invert at 32°, 84° and 125° C., whether alone or in the presence of its aqueous solution. KNO_3, on the other hand, forms solid solutions with NH_4NO_3, and equilibrium mixtures of the two invert at temperatures which depend on the composition of the system. Specifically, *e.g.*, 20% KNO_3 added to NH_4NO_3 lowers the 32° transition to near 0° C.

The enantiotropic transformations considered above are in many respects analogous to melting or freezing, with one important difference. In melting it is rarely observed that a crystal can be superheated above its melting

point, although undercooling on freezing is common. Polymorphic transitions may be both superheated and undercooled; the width of the band of indifference (hysteresis band) varies from a few degrees for prompt transitions to unknown values for very sluggish ones. Transitions in which only minor changes of crystal symmetry occur are often prompt, while those involving marked alterations of structure are usually more or less sluggish. Both varieties of behaviour may be found in the same chemical substance, as in silica (*q.v.*). *See* fig. 1. The three main varieties of silica are quartz, tridymite and cristobalite. These differ considerably in their crystal structures, and are mutually transformed only with great difficulty, quartz to tridymite at 867° C. and tridymite to cristobalite at 1,470° C., at the pressure of one atmosphere. The sluggishness of these transformations is evidenced by the fact that these varieties of silica have been found in coexistence in certain volcanic rocks for geologic ages. On the other hand, there occur one or more relatively rapid transitions between high- and low-temperature forms of each of the main varieties, accompanied by only slight changes in crystal structures; namely, in quartz at 573° C., in tridymite at 118°, 163° and 230° C. and in cristobalite between 200° and 275° C. In the slow transformation of quartz to tridymite or to cristobalite, catastrophic changes in the structure occur which involve the breaking of Si-O-Si bonds, whereas only distortions of structure occur in the rapid transitions of the low- to high-temperature forms in quartz, tridymite or cristobalite.

The enantiotropic transformations may be contrasted with the monotropic transformations, for which no transition temperature had been found experimentally at mid-20th century. The classification is not particularly exact, inasmuch as it is usually based not on the knowledge of the actual stabilities of the phases but rather on empirical findings, usually at atmospheric pressure only. The tendency to transform may be held in abeyance by the same energy barriers that are responsible for the metastable existence of such enantiotropic forms as cristobalite at ordinary temperature. Many cases of monotropism at ordinary pressure occur among organic compounds, as in chloroacetic acid, which can crystallize in three different forms with melting points at 50.2°, 56.2° and 61.3° C., the two lower melting forms being unstable with respect to the highest melting form. An instance of apparent monotropism is offered by calcium carbonate, which is found in nature as the stable calcite (*q.v.*) and as aragonite, which is unstable with respect to calcite at ordinary and higher temperatures. The transformation aragonite to calcite at these temperatures is truly unidirectional. A thermodynamic study of the stabilities of the two indicates, however, that below −60° C. aragonite becomes the stable form. At higher temperatures, the complex aragonite structure, although unstable, inverts only slowly to the simpler structure of calcite. Both aragonite and calcite have been found together in certain fossils. The influence of structure on transformability is shown even more strikingly in diamond and graphite, two forms of carbon (fig. 2). Diamond, the less stable form, has a very rigid cubic structure, with each carbon atom joined to four others by bonds of equal strength, whereas the rhombohedral graphite has one weak bond and three much stronger ones. These give it its layer lattice and lubricating properties. The two lattices have nearly the same energies of cohesion, about 170,000 cal. per mole, which differ by only 500 cal. per mole; the difference is too small to provide the energy of activation for the necessary rearrangement in the strengths of the bonds, and there is no evident tendency to transform at ordinary temperatures. From measurements made at the national bureau of standards, it appears that high pressures and low temperatures increase the thermodynamic stability of diamond; very great pressures would, however, be required to produce artificial diamonds at temperatures high enough for the rate of transformation to become appreciable (much more than 50,000 atm. at 2,000° C.).

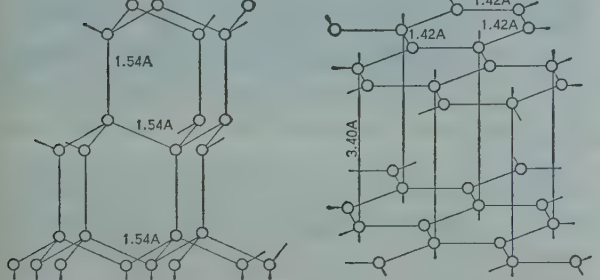

FIG. 2.—ARRANGEMENT OF ATOMS IN THE LATTICE OF (A) DIAMOND, WITH (111) PLANE HORIZONTAL, AND (B) GRAPHITE, WHERE LINES LINK ATOMS OF SUCCESSIVE SHEETS WHICH ARE IN THE SAME VERTICAL COLUMNS. NOTE THE DIFFERENCES IN THE INTERATOMIC DISTANCES IN THE TWO TYPES OF CRYSTAL. SMALL CIRCLES INDICATE LOCATIONS OF CENTRES OF CARBON ATOMS, AND BEAR NO RELATION TO THEIR SIZE

The occurrence of polymorphism and the formation of metastable modifications had not yet been satisfactorily explained in detail at mid-20th century. Qualitatively, the energy change in the transition of one form to another (*i.e.*, the heat of transition) is much smaller than the energy of formation of the individual lattices from the vapour. A number of atomic arrangements of nearly the same energy may be possible for a given substance, such that different lattices in turn become the more stable at different temperatures. The exact calculations are difficult, and only the lattice energies of the simplest crystals have been calculated. The various possible lattices of a substance may differ in the degree of order of arrangement of the atoms; the more symmetrical lattices, such as the cubic, may be considered as less highly ordered than the less symmetrical, such as the monoclinic or triclinic. It may be noted that the less highly ordered lattices tend to occur as stable phases at high temperatures where the disordering action of thermal vibrations is more violent. They often tend also to crystallize first from melts, from solutions or from the vapour, even though other forms may be more stable. Thus, KNO_3 crystallizes from solution in rhombohedra and only later inverts to the more complex orthorhombic stable form; silica almost invariably crystallizes from dry silicate melts as cubic cristobalite rather than as the more complex quartz. Such examples indicate the trend, but apparently there are many exceptions, and little can be said about cases where all the modifications have complex structures. The problem of polymorphism is further complicated by the occurrence of lattices with defects in the atomic arrangement. In the high-temperature forms of AgI, Ag_2S, Ag_2HgI_4 and certain related compounds, some or all of the metal ions are mobile in a still rigid anion lattice, whereas in the low-temperature forms of such substances all the ions are in ordered positions. In heating some alloys, an ordered arrangement of the metal atoms inverts to a random one (Cu_3Au, CuZn, AgZn), and in some other substances, certain radicals or whole molecules change from an ordered orientation to a random one (NH_4Cl, CH_4, NH_4NO_3, $NaNO_3$, HCl). A still further type of disordering is that suffered by quartz on changing from the low- to the high-temperature form, where bent Si-O-Si bonds are straightened. In such cases the final (abrupt) transition is often preceded by a gradual change in structure, volume, specific heat and other properties, extending over many degrees, as the temperature is raised.

Liquid crystals, turbid, viscous, structure possessing phases intermediate between true crystals and true liquids of some long-chain organic compounds, invert promptly to true crystals with a small heat of transition and a small volume change. About 250 examples are known.

Liquid phase transformations, as in sulphur or helium, may be mentioned as examples not of polymorphism but of allotropy in the broader sense. There is no sharp phase transition, but rather a gradual transformation evidenced by a change in physical properties of the liquid over a narrow range in temperature.

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POLYNESIA, the easternmost of the three main divisions of the island groups of the South Pacific, the others being Melanesia and Micronesia (*qq.v.*). It includes the numerous groups and small islands situated south of the equator and falling roughly between 170° E. and 110° W. long. The two islands of New Zealand are the largest and most important homelands of the Polynesians, other groups being the Hawaiian (U. S.), Society and Marquesas (French), Tonga or Friendly Islands (British) and Samoa (British and U. S.). For an account of the structure, geology, climate, flora and fauna, etc., *see* Pacific Islands.

Ethnology.—The Polynesians are a Caucasian people, in contrast to the Negroid Melanesians, their island neighbours to the west, with whom they have intermingled to some extent. They are scattered over the widest expanse of free ocean in the globe; there are so few bits of land between Hawaii and New Zealand, between Easter Island and Tonga, that navigators have crossed this wide body of water without seeing a trace of land. Brown in colour, with black hair, tall in stature, governed by chiefs in hereditary line through the father (in contrast to the matriarchal Melanesians), the Polynesians have been warlike and adventurous in their history, while at the same time responsive to foreign influence. The origin of this Pacific island race has fascinated and perplexed students of ethnology, anthropology and archaeology. Only a people with considerable skill in navigation could have reached these islands; yet they have maintained through centuries a very primitive form of economy, without a trace of commercial intercourse or money. The preponderance of scientific opinion is that the Polynesians migrated from Asia, not from the American continent. The absence of any trace, among the Polynesians, of the religions of the east indicates that the migration took place at a very early period. It seems probable that at some dim prehistoric time they practised a primitive form of "island hopping," moving from one new place of settlement to another in the large canoes which they are traditionally expert in operating until they found their present home in the eastern part of Oceania. There seems to be some reason to believe that Java was the home of these migrants for a time and that they were forced by Malayan invaders to seek a refuge farther east.

Traditions are still retained of a mythical land of the Polynesian forefathers, called Hawaiki (which can be linguistically connected with the word Java as we know it to-day), to which the souls of the dead return. Moreover, the peoples of all the important islands place to the west the locality whence the departed souls commence their journey. Research among the Nagas of Assam, and archaeological research by the French Colonial authorities in Cambodia indicated that there is a linking up with the immigrants, particularly with the Nagas, who apart from their stoneworking, practise many Polynesian customs. The massive stone ruins at Ponape in the Carolines (*see* Micronesia), which are a mystery in their own right, may indicate a stage in the long journey of the Polynesians over thousands of miles of ocean to their present homelands.

Physical Characteristics.—The Polynesians, with their simple outdoor life, often develop fine bodies and are almost always expert swimmers. They are taller than the Melanesians (except for the natives of Fiji, where there is some intermixture of the two races), with long, black hair and black, expressive eyes. Tattooing is much in vogue. The Polynesians attach great importance to the shape of the head, and the head of every baby is moulded into the desired form, flat-backed, dome-topped, sloping-browed and round, by means of a process of massaging. The nostrils are deliberately flattened, which is a tribute to the Negroid Melanesians and is a result of the frequent bringing back of Melanesian wives for the harems of the chiefs after raids on Melanesian islands. The Polynesians, especially the women, tend to become stout as they grow older; this is considered a desirable sign of beauty in a woman.

Religion.—The Polynesian religion, like the Melanesian, is simple and animistic, but is enriched with a larger number of imaginative myths. Survivals of sun worship are found in some of the islands, and this is considered an indication of the Indonesian origin of the natives. A fine wooden reproduction of Tangaroa, god of the sea, is preserved in the British museum, and the Polynesians also adored Ra, the sun god, and Io, the supreme being. However, these supreme deities are far away from the consciousness of the average Polynesian, who is more inclined to worship the spirits of departed chiefs and ancestors and natural objects in which supernatural power is supposed to reside.

Throughout the Pacific islands there is a general fear of the *aitu*, or supernatural beings, who are conceived as possessing some of the qualities both of gods and of ghosts. Every house has its ghost, and Polynesian folklore contains legends of mysterious lights at sea and of sirens who lure unwary youths to destruction. The souls of great men who have died are invoked by the living, and stones and trees are sometimes regarded as sacred and propitiated with offerings of fruit and pigs. In the past, human sacrifices were sometimes offered; but this practice disappeared as the Polynesians came under the rule of foreign powers.

Social Structure.—The Polynesians, in contrast to the Melanesians, displayed a considerable aptitude for social organization. The power of the chief, who is supposed to be in contact with the gods, is very great; in some of the larger islands the landowners constitute a kind of native nobility, while the practice of organizing castes or classes of hereditary carpenters, fishermen and persons engaged in other occupations is quite familiar. Foreign visitors to Polynesian islands are often impressed by the dignity and decorum with which general tribal assemblies are conducted. The liquid Polynesian language, with its many vowels, lends itself to oratory. This language is widely understood throughout Polynesia, while in Melanesia there is a babel of local dialects, people of one island often being unable to understand their neighbours on another.

The Polynesians were less addicted to cannibalism than the Melanesians, although this practice prevailed in the Marquesas islands and in New Zealand. The art of the New Zealand Maori wood carvers is the finest in the South Pacific. In the figure-heads and stern-pieces of the larger Maori canoes and sometimes in the lintels of the doors, one often finds delicate and refined open-work carving, consisting sometimes of tree-fern spirals, sometimes of interlacing human figures.

There are some remarkable stone ruins throughout Polynesia, and an elaborate system of drains was discovered in a swampy region of northern New Zealand. The Polynesians have long been acquainted with the art of working stones; the remains of huge sanctuaries and stone platforms have been found in Hawaii, the Society islands, Rarotonga and even on tiny Easter island. It is possible that the latter represents the remnant of a larger body of land that has been submerged in the ocean, since it is difficult to conceive how the necessarily small population of the present tiny island could have carried out such elaborate construction work. All these stone ruins convey the impression that Polynesia may have possessed a more numerous population and a more developed political and social organization in the past.

Polynesian daily life is strongly affected by the widespread practice of tabu (*q.v.*) which is so prevalent among primitive peoples all over the world. It is in the hands of the kings and priests. For instance, when Captain Cook wanted to set up an observatory on one of the islands, the priests made the proposed site tabu by waving wands over it.

Some chiefs in New Zealand are considered tabu, with the consequence that they must be fed, instead of feeding themselves, and in some Polynesian communities men are given this semi-sacred status. In Rapa, in the southern part of French Oceania, women are supposed to pop morsels of food into the mouths of the men, but are not permitted to eat with them, as this would be considered a profanation. Before 1819 it was an offense punishable with death for a woman in the Hawaiian group to join in the meal of male relatives.

Tongan Group.—This western outpost of Polynesia is one of the healthiest and most prosperous of the island groups. Elementary education was widely developed, and the people are noted for their comparatively high standard of intelligence. The Tongans are among the most daring navigators of Polynesia and have sent out migrants to

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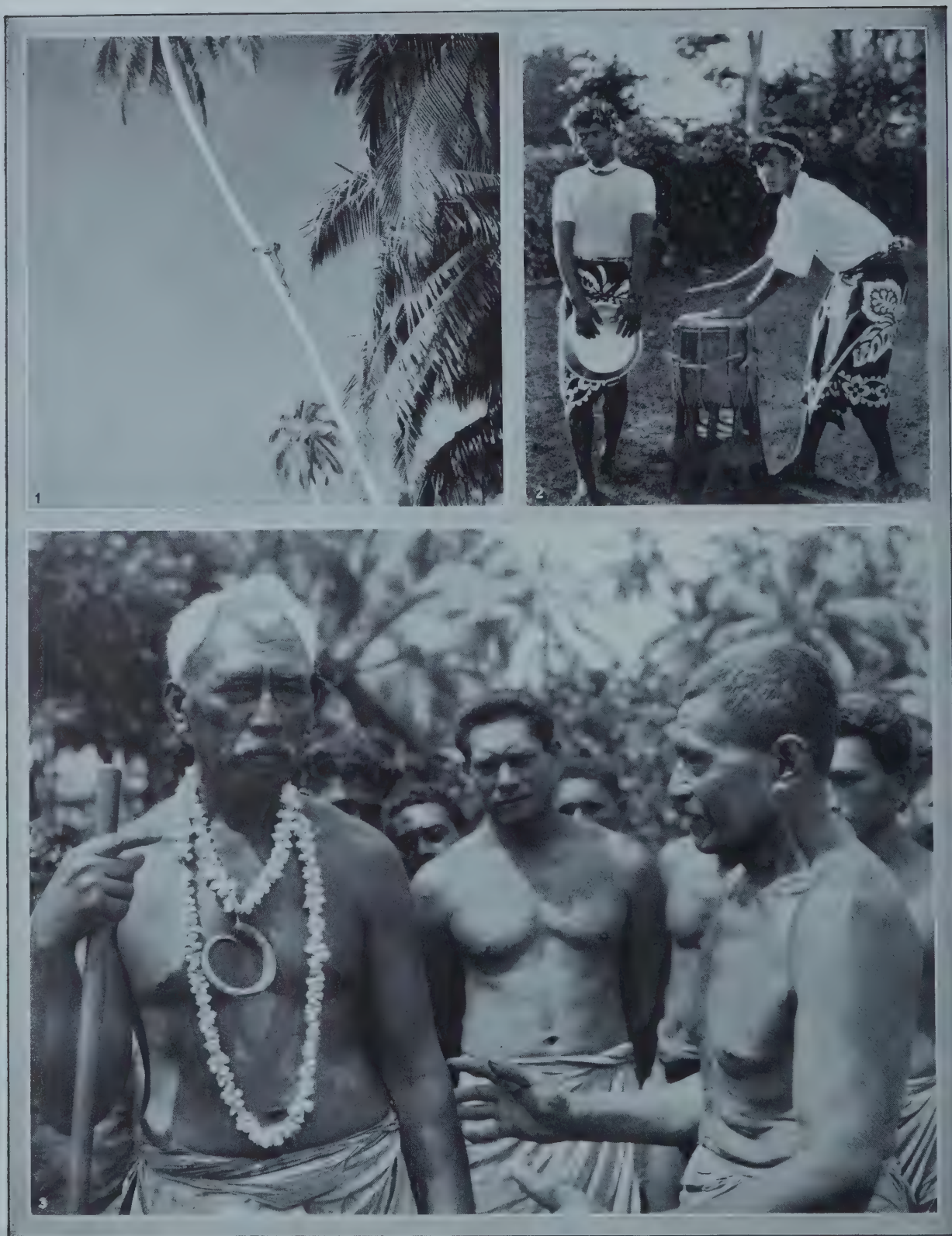
HOUSES AND PALM GROVES OF THE POLYNESIAN ISLANDS

1. A native hut with thatched roof is shown near a grove of coco-nut palms
2. A characteristic native house, built of hardwood posts, bamboos and plaited palm leaves with a reed thatched roof
3. View of a Polynesian harbour bordered with palm trees
4. Harvesting coco-nuts in a palm grove, Tahiti
5. A native village sheltered by palm trees. The houses are built with hardwood posts and bamboos and are roofed with palm or other leaves
6. Natives climbing coco-nut trees in Tahiti. The native loops himself to the tree with rope to prevent falling and climbs by gripping the trunk with his toes

POLYNESIA



BY COURTESY OF (1) THE PARAMOUNT FAMOUS LASKY CORPORATION, (3) THE METRO-GOLDWYN-MAYER PICTURE CORPORATION; PHOTOGRAPH, (2) EWING GALLOWAY

NATIVES OF THE MARQUESAS ISLANDS, POLYNESIA

1. Boy of the Marquesas climbing a coco-nut palm
2. Native orchestra playing, with dishpan and drum
3. Group of Marquesans with their tribal chief (left)

distant islands, such as Rotumah and Ellice, while storm-tossed Tongan canoes landed settlers and raiding parties in the outlying Solomons and New Hebrides. Tongan expeditions to Fiji for the purpose of obtaining wood for war canoes were frequent in the years when there was no foreign authority to enforce law and order in the islands.

Declining Islands of Polynesia.—In some of the islands of French Oceania, especially in Tahiti and in the Marquesas group, one finds the spectacle, at once melancholy and curious, of a formerly virile and physically fit people wasting away and tending toward extinction. The native population of Tahiti, according to the census of 1911, was less than the number of warriors who turned out from two small districts at the time of Cook's second visit to that island. The physical deterioration after that time was also very marked.

There are two main causes for this decline in population (still more striking in the Marquesas islands than in Tahiti) and for the deterioration in health. Foreigners brought with them into these islands infectious diseases for which the natives possessed no immunity and to which they proved very susceptible. Measles, smallpox and phthisis carried out ravages.

Moreover, the deterioration had set in even before the coming of the foreigners brought the scourge of epidemics for which medical science provided remedies only slowly. The second important cause of the decline of some of the Polynesian islands was the indolence of the natives and the gradual evaporation of their vital energies. This indolence was promoted, because life on these islands, with their luxuriant tropical vegetation, could be maintained with extremely little physical effort. The breadfruit tree, which grows abundantly without artificial cultivation, provides the native with almost everything he needs for his simple food and clothing.

Tribal war was a former stimulus to action among the islanders of the South Seas. When war was repressed by the French authorities, the natives in the islands with the most abundant free food supply lost the last antidote to the life of complete sloth that atrophied all their vital faculties and led naturally to overwhelming decline of population through the double effect of a high death-rate and a low birth-rate. It is interesting to note that in the southern islands of French Oceania, where climatic and physical conditions make it necessary for the natives to work for a living, the symptoms of depopulation are absent.

Megalithic Remains.—There is a fascinating reflection of vanished empires, races and civilizations, in the great stone remains found sporadically all the way across the Pacific, from the islands near Japan to tiny Easter island, in eastern Polynesia. There is the deserted Venice of Ponape, there are the stepped pyramids of Samoa, Tonga and Tahiti, the *maraes,* or great stone temples of Rarotonga, the Marquesas and Pitcairn island, refuge of the mutineers against Captain Bligh of the "Bounty." The process reaches a climax in Easter island, which has been described as "the most astonishing collection of mortuary monuments in the world."

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POLYNESIAN LANGUAGES, a general term for one branch of the great Oceanic family of speech, the other branches being Melanesian, Micronesian and Indonesian. These four divisions are so clearly marked off from each other and so definitely spring from one common parent that it is customary to refer to the individual languages of each group as mere dialects. The existing differences between the languages as we know them, however, are such as to justify the use of the term languages.

The principal members of the Polynesian group are (a) Samoan (probably the oldest form of Polynesian speech extant), (b) Maori, (c) Tahitian, (d) Hawaiian, (e) Tongan, (f) Mangarevan, (g) Nukuhivan (of the Marquesas Islands) and (h) the dialects of the Paumotu archipelago. From these main tongues dialects and sub-dialects have developed until Polynesia has almost a hundred variants of the original tongue.

Phonetics.—The Polynesian languages are amazingly rich in vowels with striking consonantal poverty. Although possessing only the five vowels *a, e, i, o, u,* in a short and long form the musical register of the Polynesian voice is so wide as to produce the illusion of numberless variants of these vowels. The *i* in particular is occasionally so shrill that no European can satisfactorily reproduce it.

The consonants are *k, t, p, s,* (*h*), *l,* (*v*), *n̊, n, m, f,* (*v*), (*w*). No single Polynesian tongue contains all these consonants, those in parentheses being alternatives in some languages for the letter immediately preceding. Fakaafo is one of the richest of these tongues having *k, t, p, s, f, v, l, n̊, n, m;* most of the others lack two or three of this number. Maori has, in addition, a compound or aspirated consonant *wh* which sounds very like an aspirated *v,* as in *whaka-,* the prefix of causative verbs. A tabular view of the phonetics of the chief Polynesian languages follows.

A. *Vowels*

Hawaiian	Fakaafo	Samoan	Tongan	Maori	Rarotongan	Mangareva	Paumotu	Tahiti	Nukuhiva
a, o	*a*	*a*	*a, e*	*a, e*	*a*	*a*	*a*	*a*	*a, e*
e	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*
i	*i*	*i*	*i*	*i*	*i*	*i*	*i*	*i*	*i*
o	*o*	*o*	*o*	*o*	*o*	*o*	*o*	*o*	*o*
u	*u*	*u*	*u*	*u, i*	*u*	*u*	*u*	*u, i, o*	*u, o*

Thus, *e, i,* and *o* are constant; *a* and *u* variable. But so jealously are vowel-values guarded by Polynesian speakers that these changes are constant within the bounds set by any particular language and it is possible for the speaker of one idiom to say definitely what form a word will take in another whose phonetic system he knows.

B. *Consonants*

Hawaiian	Fakaafo	Samoan	Tongan	Maori	Rarotongan	Mangareva	Paumotu	Tahiti	Nukuhiva
..	*k*	..	*k*	*k*	*k*	*k*	*k*	..	*k*
k	*t*	*t*	*t*	*t*	*t*	*t*	*t*	*t*	*t*
p	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*
h	*s*	*s*	*h*	*h*	..	..	*h*	*h*	*h*
h	*f*	*f*	*f*	*w, h*	..	..	*f, w*	*f, h*	*f, h*
w	*v*	*v*	*v*	*w*	*v*	*v*	*v, w*	*v*	*v*
l	*l*	*l*	*l*	*r*	*r*	*r*	*r*	*r*	*r*
n̊	*n̊*	*n̊*	*n̊*	*n̊*	*n̊*	*n̊*	*n̊*	..	*n̊, k, n*
n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
m	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*

Variability is much more frequent among the consonants than with the vowels, which are the backbone of Polynesian speech. *k* is constant except in Hawaiian, Samoan and Tahiti speech where it is replaced by a glottal check; *t* is constant except in Hawaiian where it becomes *k, e.g.,* Maori *tañata,* a man, Hawaiian *kanaka,* Nukuhiva *kenata, enata. P, n* and *m* do not change at all and *l* and *r* appear alternately. The Samoan and Fakaafo *s* for *h* in the other languages, betrays the sibilant sound of *h* before a weak vowel (an analogy is found in Luchuan and Japanese *hito, fito,* pronounced *shto*). All the changes illustrated in the table are regular and very few exceptions are found.

Morphology.—Syllables in Polynesian tongues may begin with a consonant or a vowel but must always end in a vowel. From this it results that many vowels come together in words of several syllables; extreme cases are *hooiaioia, mou'a, kauikeaouli.* Here, however, each successive vowel is a syllable, there being no true diphthongs in these languages. There is no vowel elision, and the accent (penultimate), is very light, so that each syllable is clearly enunciated. But owing to the Polynesian distaste for consonants many homophones are created, mostly consisting of two vowels, *e.g.,* Nukuhivan *ua* means "rain," "two," "to heat," "lobster," etc., from elision, the original words being *uka* or *usa, rua, ura,* and *uka.* The genius of the language can be clearly seen from the borrowings from foreign languages, chiefly from English, *e.g.,* the word "quarter" appears as *tuata,* "governor" as *tavana* or *kavana,* "doctor" as *taote,* etc.

In normal words, when compounds are made the accent shifts so as to fall still on the penultimate syllable, *e.g.,* Samoan, *áve* to give, *aveńia* to be given; Hawaiian, *lóhe* to hear, *lohéa* to be heard. But there are exceptions to the rule of penultimate accent, which must be learnt by practice only; most of these, which are not numerous, arise from the difficulty of distinguishing between homophones or from the need of distinguishing a common word from one which has become *tapu* as the name of a

chief or other prominent person.

One phenomenon of Polynesian speech deserves attention, viz., reduplication, complete or partial. Many new words are built up in this way and delicate nuances are conveyed by the doubling of a single syllable. In Maori *haere* conveys the idea "going," *haerehaere* means "roaming about, take a walk"; Samoan *tufa,* "divide," yields, *tufatufa,* "to split up into many pieces," etc.; Maori *inu,* "to drink" gives *iinu,* "to tipple, soak"; Tahiti *parau,* "to speak" gives *paraparau,* "to chatter"; from Tonga *nofo,* "to live" comes *nonofu,* "to live with someone." Adjectives are treated in the same way: Rarotongan *nui,* "big" gives *nunui,* "very big"; Hawaiian *lii,* "small," gives *liilii,* "very small."

Word-building is simple. From *tama,* "a child" and *ariki,* "a chief" is made *tamariki,* "a son" (lit. a princeling, noble child); from *tama,* "a child" and *wahine,* "a woman," comes *tamahine,* "a daughter, a girl"; *uritaata,* "an ape" is made up of *uri,* "a dog," and *taata,* "a man."

The article differs from language to language; the indefinite article is usually identical with the numeral one, (*sa, se*). This is not used, however, unless absolutely necessary, although the definite article (Samoan, *o le* or *le;* Hawaiian, *he;* Maori, *te;* Tahiti, Rarotongan, Mangarevan, Nukuhiva *e*), usually appears before a noun. Maori has a plural article *ṅa* (*nga*), and the other languages have prefixes which mark the noun as plural although nouns undergo no change in form from singular to plural.

There are cases in the language marked by prefixes. The noun as agent is preceded by *ko* (*'o*), the genitive is occasionally still shown by position (as was the original method) although the prefixes *na, a, no, o* are now usually employed. The dative case is shown by a prefixed particle *ki* (before proper names and pronouns *kia*) and the accusative (when it is marked at all) is preceded by *i* or *ia*. The particle preceding the noun in the ablative case is *e* and in one or two languages there are other prefixes, but these do not actually form part of a genuine declension. The vocative case is marked by the syllable *e* preceding the name or noun.

The adjective suffers no change in any of the languages and it follows its noun except when it is used as a predicate when it precedes it; Samoan *laau tele,* "a big tree." When the adjective follows its substantive as attribute, the plural of the whole phrase is accomplished by the reduplication of the adjective: Maori, *ika pai,* "a good fish," *ika papai,* "good fish"; Hawaiian, *hale nui,* "a big house," *hale nunui,* "big houses."

The pronouns are complex in Polynesian speech, there being singular, dual and plural forms with inclusive and exclusive varieties. The normal forms are:—

	1st person	2nd person	3rd person
Singular	*aku*	*koe*	*ia, na*
Dual (inclusive)	*ta-rua*	*ko-rua*	*ra-rua*
Dual (exclusive)	*ma-rua*	*mo-rua*	*na-rua*
Plural (inclusive)	*ta-toru*	*ko-toru*	*ra-toru*
Plural (exclusive)	*ma-toru*	*mo-toru*	*na-toru*

These forms vary according to the dialect and the consonant-changes tolerated therein. There are full and contracted forms for the possessive and demonstrative pronouns which are also complicated. The interrogative pronoun serving many purposes is *wai* (Maori and Hawaiian); *vai* (Tahiti); *hai* (Tongan); and *ai* for the other dialects, used only for living things and for inanimate objects, *aha* (Maori, Hawaiian, Nukuhiva); *ha* (Tongan); *aa* (Rarotongan), and *ā* in the other tongues. There is no relative pronoun in any of the languages—either it remains unexpressed or a circumlocution is employed with the personal or demonstrative pronoun.

The Polynesian verb, like the noun and adjective, undergoes no change in form, and all moods and tenses are indicated by participles prefixed to the root form of the verb. The verb has no special form to distinguish it from other parts of speech and, indeed, many adjectives are used as verbs without change.

The passive voice is constructed from the active by the use of the participle prefix *ia* (*hia, lia, kia, kina, mia,* etc.); the causative is similarly produced by the prefix *fa'a* (*whaka, ha'a, aka,* etc.). A desiderative is formed by the prefix *fia* (*fie, hia*), and one verbal suffix exists whereby a reciprocal form is made (*-aki, -faki, -laki, -taki, -raki*).

The present indicative is shown by the participle *e* or *te,* the future by *a,* and the preterite by *na.* The moods are few and vary greatly between the languages, the most common being *ia* (*kia, ke*) for the conjunctive: *a, ka, kite, pea, poo, ahiri, ina,* etc., for the conditional and *fau* (Tonga only) for the potential. The particle *ana, a'a* makes the participle.

Numerals

	Hawaiian	Fakaafo	Samoan	Tongan	Maori	Rarotonga	Tahiti	Nukuhiva
1	*kahi*	*tasi*	*tasi*	*tahu*	*tahi*	*tai*	*tahi*	*tahi*
2	*lua*	*lua*	*lua*	*ua*	*rua*	*rua*	*rua*	*ua*
3	*kolu*	*tolu*	*tolu*	*tolu*	*toru*	*toru*	*toru*	*tou*
4	*ha*	*fa*	*fa*	*fa*	*wa*	*a*	*ha*	*fa, ha*
5	*lima*	*lima*	*lima*	*nima*	*rima*	*rima*	*rima*	*ima*
6	*ono*	*ono*	*ono*	*ono*	*ono*	*ono*	*ono*	*ono*
7	*hiku*	*fitu*	*fitu*	*fitu*	*witu*	*itu*	*hitu*	*fitu, hitu*
8	*walu*	*valu*	*valu*	*valu*	*waru*	*varu*	*varu*	*vau*
9	*iwa*	*iva*	*iva*	*hiva*	*iwa*	*iva*	*iva*	*iva*
10	*'umi*	*fulu*	*sefulu*	*hoñofulu*	*ñahuru*	*ñauru*	*ahuru*	*onohuu*

The word for "five" (lima) is the general word for "hand" in Polynesia, the word for "ten" is borrowed from Malay *puloh.* The identity between the words of the languages is rarely so close as it is with the numerals and a few terms of relationship. The ordinal numbers are formed by placing the definite article before the cardinals, *e.g.,* Tahiti, *o te rima* (lit. "the five") "fifth"; Samoan, *o le lua,* "the second," etc.

Vocabulary.—The Polynesian tongues are rich in terms of relationship, in names of natural objects, fish, birds, plants, flowers and phenomena of nature, all the winds and zephyrs, all kinds of clouds, waves, streams, hills, shores and so on having special names. There is a shortage of abstract terms, metaphor is common, a concrete noun doing double duty. Maori and Samoan, however, in the philosophical chants (*see* POLYNESIAN LITERATURE) have developed a definitely abstract vocabulary. There is a decided lack of direct, forceful words and in translation from European languages it is difficult to turn decisive phrases into Polynesian equivalents. The vocabularies suffice for all ordinary purposes and a little ingenuity often turns an English phrase into a telling South Seas equivalent.

BIBLIOGRAPHY.—The *Journal of the Polynesian Society* (Wellington, N.Z.), a quarterly publication in which many excellent sketches of the grammar of Polynesian languages have appeared is most important. For early researches into Polynesian speech *see* Wilhelm von Humboldt, *Über die Kawi-Sprache* etc. (1836–39); Lorrin Andrews, *A Grammar of the Hawaiian Language* (Honolulu, 1854); Friedrich Müller, *Grundriss der Sprachwissenschaft,* ii., part 2 (1882). The dictionary *par excellence* is Edward Tregear's *Maori-Polynesian Comparative Dictionary* (Wellington, N.Z. rodak) wherein is to be found the most complete bibliography of Polynesian linguistic works. *See* also Meillet and Cohen, *Les Langues du Monde* (1924), pp. 450–455.

(A. N. J. W.)

POLYNESIAN LITERATURE. A few decades ago this title would have been deemed an anachronism, or worse, but since the publication of the Sacred Songs of the Hula by Dr. N. B. Emerson under the title *Unwritten Literature of Hawaii* (1909), it has been generally conceded that the Polynesians, like other illiterate races, may have a literature in the truest sense of that term. The old Polynesian priests with their extraordinary memories held every word of the old traditions as flawlessly as papyrus or paper could have done; the proof of this lies in the presence, in texts taken down from native lips, of words so archaic that even the hierarchs have forgotten their meanings. It soon came to be realized that this wealth of literature was rapidly dying with the chiefs who were its last repositories, and numerous legends and collections of songs were taken down from the lips of the *kahuna* or sorcerers.

The literature of the Samoan Islands is probably older than that of any other part of Polynesia and is wonderfully akin to the old Maori philosophical chants. The *Creation Song* in Samoan is not only interesting as folklore; it is a marvellously dignified piece of poetic literature.

Long genealogies interspersed with legends of philosophic and historic import became available in Roman script, providing much material for the study of the history and language-development of the Pacific islanders. Many migration songs and legends are known and there is still time to collect others. The whole text of the *'ava* ceremonial and similar ritual texts also became available and there is reason to believe that a close study of others collected would prove of the greatest possible value in the solution of problems of migration and tribal mixing.

Maori literature is of two kinds, philosophic and traditional-historical. The Maori *Chant of Eternity* is, in places, identical with the Samoan *Creation Song* but has a definite individuality. Speculation on life and its problems appears in many of the legends centred round *Maui*, the great common Polynesian ancestor, the divine angler, whose hook caught on the islands of New Zealand and brought them to the surface as an abode for his children. *Hawaiki*, that mysterious far land, renowned in Polynesian song, is vaguely glimpsed, now as a paradise to which men's souls shall go, now as the Eden from which the ancestors of the singers emerged countless centuries before. The stories of the creation of the cosmos and its peopling are all before us in Maori speech, put together with a reverence and delicacy of phrase worthy of any literature.

Hawaiian literature is essentially romantic. The *hula*, a religious performance, was in its essence an ebullition of joyous animal spirits, outflowing toward nature. The abandonment seen by some in the dance and in the words of the songs is largely imaginary although it is undeniable that much of the *hula* and *mele* literature of Hawaii is made up of protracted *double-entendres*. In the Hawaiian one can observe a close love of nature through understanding; the trees wave in a warm breeze and the sunlight glints on azure waves because the singer is happy and because the gods are weaving anew their ancient spell of poetic song. Even the dread voice and searing tongue of Pele, the awful volcano-goddess, can be wooed by song and dance, to rest. The allusions in the songs and prose of Hawaii point to a long cultural experience and deep reverence for tradition. The lyrics of Hawaii rank high among the pure rhapsodies of the world.

The literature of other Polynesian islands is largely a repetition of that outlined above. The traditions of Tonga supply lacunae in the stories of Samoa and New Zealand and those of Tahiti supplement those of Hawaii and the Gambier Islands. In all, however, they are distinctive songs and chants, as full of beauty as they are of scientific interest.

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POLYNOMIAL, in elementary algebra, an expression composed of two or more terms combined by operations of addition or subtraction. Thus $\frac{1}{2}a+7b+c$ and $2+a-\sqrt{(\frac{1}{2}xy)}+z^2$ are polynomials. A polynomial of two terms is called a binomial, and one of three terms is called a trinomial. An expression consisting of a single term is called a monomial.

The word polynomial is often used with a more technical meaning, particularly in higher mathematics, to characterize the manner of dependence of an expression on one or more quantities regarded for the time being as independent variables. Importance attaches then to the nature of the operations performed on the variables, rather than to the number of terms, and monomial expressions of suitable form are admitted as special cases. Under this interpretation, which will be adopted throughout the rest of the article, a polynomial in one variable is a sum of terms, each consisting of a power of the variable multiplied by a coefficient independent of the variable, or, as an extreme case, a single such term; in a polynomial in several variables, each term contains a power of one of the variables or a product of powers of two or more of them. By a power in this connection is meant a power with exponent equal to a positive whole number or zero. The highest exponent that occurs, or, in the case of more than one variable, the highest value attained by the sum of the exponents in a single term, is the degree of the polynomial. Thus ax^2+bx+c is a polynomial of the second degree in x (if $a\neq 0$), and $x^5+3xy^2-8x^3y^4$ is a polynomial of the seventh degree in x and y. The latter is also said to be of the fifth degree in x, and of the fourth degree in y.

Having fundamentally a relative sense, the definition is applicable to characterize the manner of dependence on quantities which may themselves be more or less complicated expressions of any form. Thus ax^2+bx+c, $a(1+\sqrt{x})^2+b(1+\sqrt{x})+c$, $a/x^2+b/x+c$, $a\ (\log x)^2+b\log x+c$ are polynomials with respect to x, $1+\sqrt{x}$, $1/x$, and $\log x$ respectively, though the last three are not polynomials with respect to x; and ax^4+bx^2+c, a polynomial in x, can also be regarded as a polynomial in x^2. The sum, difference, or product of two polynomials is a polynomial; their quotient in general is not. Polynomials and quotients of polynomials are known collectively as rational functions.

In elementary algebra, expressions coming under the more technical definition of polynomials are studied largely in connection with the equations formed by setting them equal to zero. If $f(x)$ denotes the polynomial

$$a_0x^n+a_1x^{n-1}+a_2x^{n-2}+\ \ldots\ +a_{n-1}x+a_n,$$

where $a_0\neq 0$, then the so-called "fundamental theorem of algebra" ensures the existence of a root r of the equation $f(x)=0$. The number r is a complex number, or as a special case a real number, and the fact that $f(r)=0$ implies that $(x-r)$ is a factor of $f(x)$. By a repetition of this argument one can show that $f(x)$ can be factored in the form

$$f(x)=a_0(x-r_1)(x-r_2)\ \ldots\ (x-r_n)$$

where the r_1 are the roots of $f(x)=0$. This factorization is uniquely determined. If the factor $(x-r)$ occurs exactly h times in the factorization then r is said to be a root of multiplicity h of the corresponding equation.

The resolution of a polynomial into linear factors makes essential use of the availability of all complex numbers as coefficients. If a more restricted system of coefficients is employed, such a factorization may not be possible. For example, x^2+1 is irreducible if real numbers only are allowed as coefficients, and x^3-x+2 is irreducible if rational numbers only are allowed. As these examples show, it is necessary in any discussion of factorization to specify the coefficient domain. If this domain is denoted as F it is customary to denote the system of all the polynomials in x with coefficients in F by $F[x]$, and more generally, the system of all polynomials in $x_1,x_2,\ \ldots\ x_m$ with coefficients in F by $F[x_1,x_2,\ \ldots\ x_m]$. If F is a field (*e.g.*, the set of all complex numbers, the set of all real numbers, the set of all rational numbers) then a polynomial belonging to $F[x]$ is called irreducible if it cannot be expressed as a product of polynomials in $F[x]$ of lower degree. Every polynomial in $F[x]$ which is not itself irreducible can be resolved into irreducible factors in this domain and apart from the order of the factors and from constant factors, can be so resolved in only one way. A similar definition of irreducibility can be used in the domain $F[x_1,x_2,\ \ldots\ x_m]$ and there, too, the unique factorization theorem holds. In a slightly modified form the theorem holds also for other polynomial domains. (*See,* for example, A. A. Albert's *Modern Higher Algebra,* 1937.)

It is an important fact in trigonometry that the cosine of n times an angle, when n is a whole number, can be expressed as a polynomial of the nth degree in terms of the cosine of the angle itself; *e.g.*,

$$\cos 2x=2\cos^2 x-1,\ \cos 3x=4\cos^3 x-3\cos x,$$
$$\cos 4x=8\cos^4 x-8\cos^2 x+1.$$

The sine of nx can be expressed as the product of $\sin x$ by a polynomial of degree $n-1$ in $\cos x$; when n is odd, but not when n is even, it can also be expressed as a polynomial of the nth degree in $\sin x$; *e.g.*,

$$\sin 2x=2\sin x\cos x,\ \sin 3x=\sin x\,(4\cos^2 x-1)=3\sin x-4\sin^3 x.$$

The relation between algebra and trigonometry was emphasized by François Vieta (1540–1603), who contributed largely to the advancement of both branches.

Analytic geometry is largely concerned with the geometric interpretation of the equations obtained by setting polynomials in the co-ordinates equal to zero. In the plane, an equation of the first degree, of the typical form $Ax+By+C=0$, represents a straight line; *i.e.*, if (x, y) are the rectangular co-ordinates of a point, all points whose co-ordinates satisfy the equation lie on a straight line, and all points of the line have co-ordinates satisfying the equation. The conic sections (*q.v.*)—ellipse, circle (which may be regarded as a special case of the ellipse), parabola, hyperbola (*qq.v.*), and certain "degenerate" forms (pairs of straight lines)—are represented by equations of the second degree, of the form

$$Ax^2+Bxy+Cy^2+Dx+Ey+F=0,$$

where in particular cases one or more of the coefficients may be equal to zero. René Descartes (*Géométrie,* 1637) and his contemporary, Pierre

de Fermat, are regarded as the founders of analytic geometry (*q.v.*). The curves represented by equations of the third degree were systematically studied by Sir Isaac Newton (1704). In three dimensions, an equation of the first degree, $Ax+By+Cz+D=0$, represents a plane, and one of the second degree a *quadric surface*—ellipsoid, sphere (a special case of the ellipsoid), hyperboloid (of one sheet or of two sheets), paraboloid (elliptic or hyperbolic), cone, cylinder (*qq.v.*), or, as a degenerate form, a pair of planes.

The study of curves and surfaces defined by polynomial equations of arbitrary degree constitutes the field of algebraic geometry. A fundamental concept in the modern development of this subject is that of a polynomial ideal, defined to be a set I of polynomials such that (1) the difference of any two polynomials that belong to I also belongs to I, and (2) the product of any polynomial in I by any polynomial belongs to I. If $u_1(x,y)$, $u_2(x,y)$, . . . $u_r(x,y)$ are fixed polynomials then the totality of polynomials of the form

$$f_1(x,y)u_1(x,y)+f_2(x,y)u_2(x,y)+ \ . \ . \ . \ +f_r(x,y)u_r(x,y)$$

where the f_1 (x,y) range independently over the polynomial domain, is an ideal. The polynomials $u_1(x,y)$, . . . $u_r(x,y)$ are said to form a basis for this ideal. An important theorem due to David Hilbert (1890) asserts that any polynomial ideal has a finite basis.

The theory of the transformation of homogeneous polynomials, or *forms* (*see* ALGEBRAIC FORMS), by linear substitutions in the variables, and of the invariants and covariants associated with such transformation, is an important branch of algebra with numerous applications. For example, if x,y in the polynomial $ax^2+bxy+cy^2$ are expressed, in terms of a new pair of variables u, v, by the relations

$$x=\alpha u+\beta v, \qquad y=\gamma u+\delta v,$$

where $\alpha\delta-\beta\gamma=1$, it is found that $ax^2+bxy+cy^2$ is identically equal to an expression of the form $Au^2+Buv+Cv^2$, in which $B^2-4AC=b^2-4ac$, a fact which is of fundamental significance in analytic geometry. More generally, for any values of α, β, γ, δ,

$$B^2-4AC=(\alpha\delta-\beta\gamma)^2\,(b^2-4ac).$$

The expression b^2-4ac, itself a polynomial in terms of the coefficients a, b, c, is called an invariant.

Polynomials in one variable are the simplest class of functions from the point of view of the calculus, because the rules for their differentiation and integration are particularly simple, and are obtained immediately from the definitions of these processes. The result of differentiating or integrating a polynomial with respect to its independent variable is always a polynomial.

In the modern theory of functions (*see* FUNCTION), any polynomial is a continuous and analytic function of its variables. If a function of a single complex variable z is analytic for every finite value of z, and becomes infinite when z, represented by a point in a plane, goes to infinity in an arbitrary manner, the function is necessarily a polynomial.

Applications.—Apart from their specific properties, polynomials are of fundamental importance from their use in the approximate representation of other functions. The standard functions of elementary analysis can be represented by power series (*see* SERIES), of the form

$$c_0+c_1x+c_2x^2+c_3x^3+ \ . \ . \ . \ \text{(Maclaurin's series)},$$

or, more generally,

$$c_0+c_1(x-a)+c_2(x-a)^2+c_3(x-a)^3+ \ . \ . \ . \ \text{(Taylor's series)},$$

which reduces to the preceding when $a=0$; the sum of an infinite series is by definition the limit approached by the sum of a finite number of its terms, as the number of terms is taken larger and larger, and the sum of a finite number of terms of a power series is a polynomial. Representation by power series can be made the basis for a systematic treatment of analytic functions of a complex variable. Another important form of development in series, theoretically applicable with greater generality, proceeds in terms of the polynomials of Adrien Legendre (1752–1833) or Legendre's coefficients. These may be defined as the coefficients of successive powers of r in the power series for $(1-2xr+r^2)^{-\frac{1}{2}}$. One of their most striking properties is that the product of any two of them, integrated over the interval from -1 to $+1$, gives zero. Legendre polynomials have been found to be of great value in mathematical physics, especially in quantum mechanics. Approximations in terms of the polynomials of Gustave Hermite (1822–1901) are of importance in the theory of probability. Karl Weierstrass (1885) proved that an arbitrary continuous function can be uniformly approximated by a polynomial with any assigned degree of accuracy.

The ordinary process of simple interpolation (*q.v.*), is equivalent to the replacement of the tabulated function by a polynomial of the first degree, over the interval in which the interpolation is performed. Formulas for interpolation by means of higher differences depend for their derivation on the fitting of polynomials of higher degree to the tabulated values. Formulas of numerical integration or mechanical quadrature likewise depend on the fitting of polynomial approximations. In connection with the use of polynomials for interpolation, it is an important fact that, if the values of a polynomial of the nth degree are tabulated for equally spaced values of the variable, the nth differences are constant. Consider for example the following table of values of the polynomial $y=x^2+7x+3$:

$x=0$	$y=3$	$\Delta y=8$	$\Delta^2y=2$
		10	
1	11		2
		12	
2	21		2
		14	
3	33		2
		16	
4	47		2
		18	
5	63		

The first column contains values of x, and the second, the corresponding values of y. The entries in the third column, obtained by subtracting each y from the following, are the first differences. The last column is made up of the differences of the first differences, which are called second differences, and in the present instance are all equal. It is clear that by means of this property the table could be continued further, without direct substitution in the original formula. (*See* CALCULUS OF DIFFERENCES.)

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POLYP, the name applied technically to an individual animal of given form, which is of frequent occurrence among those creatures known as the Coelenterata (*e.g.*, sea anemone, coral polyp, *Hydra*). The word polyp derives from the French *poulpe* (octopus). The form of a polyp is outlined in the article COELENTERATA. (*See* also HYDROZOA; SCYPHOZOA; ANTHOZOA.)

POLYPHEMUS, the most famous of the Cyclops, son of Poseidon and the nymph Thoösa. Odysseus, having been cast ashore on the coast of Sicily, fell into the hands of Polyphemus, who shut him up with 12 of his companions in his cave and blocked the entrance with an enormous rock. Odysseus at length succeeded in making the giant drunk, blinded him by plunging a burning stake into his eye while he lay asleep, and with six of his friends (the others having been devoured by Polyphemus) made his escape by clinging to the bellies of the sheep let out to pasture. *See* CYCLOPES; ACIS; ODYSSEUS.

POLYPODIUM, an inclusive genus of ferns containing about 600 species, widely distributed throughout the world, but specially developed in the tropics. Sometimes it is divided into ten or more "natural" genera. The name is derived from Gr. πολύς, many, and πόδιον, a little foot, on account of the foot-like appearance of the rhizome and its branches. The species differ greatly in size and general appearance and in the character of the frond; the sori or groups of spore cases (*sporangia*) are borne on the back of the leaf, are globose and naked, that is, are not covered with a membrane (*indusium*). The common polypody (*P. vulgare*) of Europe, Asia and western North America is widely diffused in the British Isles, where it is found on walls, banks, trees, etc.; the creeping, densely scaly rootstock bears deeply pinnately cut fronds, the fertile ones bearing on the back the bright yellow naked groups of sporangia. It is also known as adder's foot, golden maidenhair and woodfern. There are a large number of varieties, differing chiefly in the form and division of the pinnae; var. *cambricum* (originally found in Wales) has the pinnae themselves deeply cut into narrow segments; var. *serratum* has the pinnae serrate. Besides the well-known polypody of eastern North America (*P. virginianum*), very similar to the foregoing, several other species occur in the southern and western states.

POLYPUS, a term signifying an outgrowth which is attached by a narrow neck to the walls of a cavity lined with mucous membrane, such as the nose, bladder or rectum. (*See* TUMOUR.)

POLYTECHNIC. This term, common to many languages, is ordinarily used, by itself or with the word "institute" or, more rarely, "school," to denote an educational establishment equipped to teach many subjects (Greek πολύς, "many"), but mainly if not exclusively scientific and technological studies and processes (τέχνη), "art" or "craft"). It has also been used occasionally to describe other kinds of establishment designed to encourage inter-

est in the arts and sciences, and in one instance at least has been applied to a large shop with many departments.

In general, a polytechnic institute offers instruction to students beyond school age, though it may include a secondary school organized as a separate department. But the exact significance of the name varies almost with every establishment or, as in England, group of establishments. In France, where it appears to have been first used, the name *école polytechnique* was applied in 1795 to the École des Travaux Publics, founded a year previously in Paris by the National convention to advance scientific knowledge and in particular to train engineers for the army. The sobriquet, originating by way of protest against the almost exclusive devotion to literary and abstract studies then common to French places of higher education, became and remained the institution's official title; but the École Polytechnique stayed predominantly a school of military and civil engineering and therefore, strictly speaking, rather a monotechnic than a polytechnic. Similarly, the Faculté Polytechnique of Mons, Belg., is restricted to engineering studies, though the range is wide; and the same applies to the Polytekniske Laereanstalt at Copenhagen, Den. The Istituti Politecnici at Milan and Turin, It., and the Polytechneion at Athens, Gr., have faculties of architecture as well as engineering. The famous Eidgenössische Technische Hochschule (Swiss Federal Institute of Technology), frequently referred to as the Zürich Polytechnikum, is as good an example of a polytechnic in the literal sense as can be found. It is organized in 12 schools which include, in addition to civil, mechanical, electrical and agricultural engineering, subjects as varied as forestry and pharmacy; and there is also a department of optional subjects embracing literature, history, economics, politics and philosophy. All the foregoing institutions are either universities in their own right or hold university status. The location, character and status of educational establishments in Communist Europe were liable to change at a moment's notice, but at mid-20th century there were reported to be polytechnic institutes in Poland at Warsaw, Gdańsk, Gliwice, Lodz and Wroclaw (Breslau) and in Rumania at Bucharest, Jassy and Timişoara. Most if not all of these appear to have been degree-granting institutions and mainly if not entirely devoted to technological studies.

London.—In England the title "polytechnic" is almost restricted to the members of a group of educational institutions founded in London during the latter part of the 19th century with the dual purpose of providing vocational and other educational facilities for young working people and of promoting definite religious, social and civic ideals. These London polytechnics and their distinctive aims and organization derive from the initiative of Quintin Hogg (1845–1903), who as a young man of 19 shortly after leaving Eton college began a lifetime of evangelistic and educational pioneering by teaching street urchins to read. His first "classroom" was under the archways of the Adelphi on the north side of the Thames. In 1871 he opened a Youths' Christian institute in Castle street (moved to larger premises in Long Acre in 1878) for young shop assistants and artisans between the ages of 16 and 21. This he developed to provide, in addition to the optional Bible classes and other religious exercises which were the basis of his enterprise, a wide range of educational, social and athletic activities including, despite lack of support from employers and opposition from trade unions, classes for instruction in the building and other trades.

So successful was he that by 1880 he was looking for larger premises. As it happened, about this time there was offered for sale a building in Regent street called the Royal Polytechnic institution. It had been opened in 1838 to advance "practical science" and for many years enjoyed much popularity as a resort where the demonstration of scientific novelties was pleasantly tinctured with entertainment. Hogg bought it, retained the name and reopened his institute there in Sept. 1882, with accommodation for 2,000 members. By the end of the winter session there had been 6,800 applications for membership. As he refused to increase the modest fees or to accept any subventions which involved compromise of the religious principles on which he based his work, Hogg for some years incurred heavy financial losses. But this did not deter him from continuing to build up the "Poly," as it soon came to be affectionately called, into a many-sided educational and social institution, providing instruction "in subjects ranging from the domestic arts to carriage-building, photography, and goldsmith's work" (Ethel M. Hogg, *Quintin Hogg, a Biography*, London, 1904) and offering its members reading rooms, library, gymnasium, billiard room, refectory, concerts, country excursions and a wide range of athletic activities. Members were also encouraged to co-operate in the management of the Poly and in the maintenance of good discipline. From the start women were admitted to classes, and in 1885 a separate institute was opened for them under the direction of Mrs. Hogg. In 1886 a school was started for boys and girls which gave special attention to manual, domestic and commercial subjects.

The resounding success of the Regent Street polytechnic naturally suggested the foundation of other establishments on the same model, and happily funds became available. In 1878 a royal commission had been appointed to inquire into the parochial charities in the City of London; it was felt that because of the increase in their value and the decrease, or disappearance, of the kind of beneficiaries whom they were founded to aid, the total annual income was far greater than was needed to provide adequately for all the designated objects of these charities. The outcome of the commission's report was the City of London Parochial Charities act, 1883. This provided that the charities in 107 of the city parishes (that is, in all save five of the largest) should after seven years be administered by a corporate body to be called the Trustees of the London Parochial Charities. A scheme was drawn up by the charity commissioners whereby that part of the income from the consolidated charities which was allocated to secular purposes was to go toward the establishment and maintenance of "industrial" and recreative institutes similar to Hogg's polytechnic and Walter Besant's People's palace in the Mile End road, for the benefit of the poorer classes of the working population of London. The commissioners' offer of these funds was made conditional upon the raising by voluntary effort of an amount approximately equal to the capitalized value of the endowment. Local committees were set up, valuable sites were given by private benefactors, and subscriptions were received from livery companies, charities and individuals. A total sum of more than £500,000, including grants made by the charity commissioners and the Trustees of the London Parochial Charities, was raised for capital expenditure. As a result, between 1891 and 1896 six new polytechnics opened their doors: Chelsea (1895), Woolwich (1891), Borough (1892), Battersea (1894), Northampton (in St. John street; 1896) and Northern (1896). A seventh was planned in the scheme, but lack of local support, delay in securing possession of the site and the incidence of World War I prevented the North-Western from opening before 1929.

The Trustees of the London Parochial Charities, as conditions for making grants toward the maintenance of the polytechnics, "laid down as their principles that the institutions which benefited should give instruction in the principles of the arts and sciences which underlie crafts and in the application of such principles to particular trades, that they should be a supplement and not in substitution for the workshop or place of business, that they might give instruction suitable for intending emigrants and hold lectures and concerts, encourage gymnastics, drill, swimming, and other forms of bodily exercise, and institute clubs and societies, libraries, museums and reading rooms, that their educational facilities should be equally open to both sexes, that the fees should be small, and that drinking, smoking and gambling should be prohibited" (R. L. Archer, *Secondary Education in the XIX Century*, Cambridge University Press, 4th impression, 1937). Membership was restricted, except in special cases (not to exceed 5% of the total), to persons between the ages of 16 and 25.

Large as they were, the funds available from the London Parochial Charities trust were quite inadequate to maintain the great establishments to which they were committed. But aid was at hand from another source. In 1893 the London county council, empowered under the Technical Instruction act, 1889, to make limited grants in aid of technical education and also having had funds placed at its disposal for the purpose by the Local Taxation (Customs and Excise) act, 1890, devoted a considerable portion of the latter to the development and sustenance of the polytechnics. Thereafter an increasing percentage of their revenue came from public funds. The Education act, 1902 (as applied to London by its act of 1903), by making the council responsible for all education in its area, tended to diminish distinctions between the grant-aided polytechnics and the wholly maintained technical institutes set up by the council. The Education act, 1921, which empowered the council (in common with the other local authorities) to promote social and physical well-being and to co-ordinate all forms of education within its area, continued the process of assimilation; and the Education act, 1944, by transforming these powers into statutory duties, advanced it still further. The distinction between a polytechnic and a major technical college in London became increasingly managerial rather than educational.

The London county council from the start endeavoured to secure

that the educational facilities in the polytechnics and technical institutes should be so disposed as best to meet the particular needs of any given district; and the governing bodies of the polytechnics from time to time accepted suggestions to this end from the council involving important revisions of their educational programs. For example, facilities for more specialized technologies were concentrated at individual establishments. Thus Battersea has in addition to important departments of engineering and chemistry one of hotel training and domestic science; Chelsea a department of pharmacy and a school of art; and the Regent Street Polytechnic schools of architecture and commerce and a department of management studies. The Borough houses the National College of Heating, Ventilating, Refrigeration and Fan Engineering, established in 1948 to give technological education at the highest level to selected persons in these industries. Similarly, the Northampton houses the National College of Horology and Instrument Technology (established 1947); and the Northern, temporarily, the National College of Rubber Technology (established 1948). The location of these national colleges was a tribute to the outstanding work previously done by the respective polytechnics in the technologies concerned. The Northern contains also a department of radio and musical instrument technology, and the Northampton one of furriery.

Five of the polytechnics—Battersea, Chelsea, Northampton, Northern and Woolwich—prepare students in some subjects for internal degree examinations of the University of London. These polytechnics are not organically linked with the university, but the faculties concerned have on their staffs members whom it accepts as "recognized teachers." This arrangement dates from the reconstitution of the university in 1902. (H. C. D.)

United States.—The term "polytechnic" as used in the United States generally refers to a postsecondary educational institution offering various curricula in technology, science and possibly agriculture. There is no essential difference between a polytechnic institute and an institute of technology. One characteristic which differentiates a polytechnic institute from a liberal arts college is that the curricula in the institutes have been designed to prepare students for positions in engineering, applied science and agriculture upon graduation. The occupational objectives of the institutes' courses of training are thus more clearly defined than is the case with the liberal arts colleges. In the institutes a student spends as much as three-fourths to four-fifths of his time on technical and professional studies in the field of his specialization, and the remainder of the time is devoted to English and the social sciences.

The term was first given prominence in the United States by Benjamin Franklin Greene, second president of Rensselaer Polytechnic institute, who in 1849 wrote a report to his board of trustees entitled *The True Idea of a Polytechnic Institute*. In this he summarized the progress of technical education in Europe and made recommendations concerning the reorganization of Rensselaer. He envisioned a "series of special schools for the training of Architects, Civil Engineers, Mining Engineers and other Scientific Technists—all united under a common organization." The curriculum of this school was to be divided into two parts: a preparatory school which students would enter at 10 to 12 years of age and which would include the studies necessary to matriculation; and the polytechnic institute proper. The institute curriculum was to be three years in length and consisted of courses in the general school and the technical schools. The former embraced mathematics, English, pure science and philosophy. The latter contained the applied subjects common to all the engineering specialties, as well as the specific subjects required in architecture, civil engineering and mining engineering.

In addition to suggesting the subjects to be included in the curriculum, Greene also suggested the addition of other schools, emphasized the importance of general education and went into detail regarding the residences for faculty and students, buildings for instruction and museum collections of many kinds. His report had widespread influence on the later development of Rensselaer Polytechnic institute.

The 1950–51 *Education Directory* of the U.S. office of education listed 12 institutions of higher learning including "polytechnic" as an integral part of the name. These schools varied widely in the number and level of curricula offered, type of control and number of students enrolled. Alabama Polytechnic institute with more than 7,000 students, for instance, is probably more like a university than a strictly technical institution. Curricula are offered which lead to degrees in agriculture, architecture, chemistry, education, engineering, home economics, pharmacy, science and literature and veterinary medicine. Contrasted with this would be Wyomissing Polytechnic institute, with about 400 students and a limited number of two-year vocational-technical curricula. The offerings of other institutes range between these two extremes. One factor common to these institutions, however, is the occupational emphasis of the curricula to the end that their graduates will be equipped to perform successfully in the fields for which they are being trained.

See Federal Security Agency, Office of Education, *Education Directory, Part 3, Higher Education* (1950–51); *The True Idea of a Polytechnic Institute; A Facsimile Reprint from the Report of Benjamin Franklin Greene, Director of Rensselaer Polytechnic Institute, 1846–1858* (1949). (L. F. Sh.)

POLYTONALITY, a comparatively recent addition to musical terminology, signifying the simultaneous employment of conflicting keys. (*See* Harmony; Key.)

POLYXENA, daughter of Priam and Hecuba. The shade of Achilles appeared to the returning Greeks in the Thracian Chersonese and demanded Polyxena, who was put to death on his tomb. As a prominent leader he claimed a prominent female prisoner for his share of the booty, as Agamemnon did Cassandra (*q.v.*). Hence, in Philostratus, Dictys and other late authors, the story of a romantic affection between Achilles and Polyxena.

POLYZOA or Bryozoa, a group of animals in which the individuals bud and remain attached to each other to form colonies

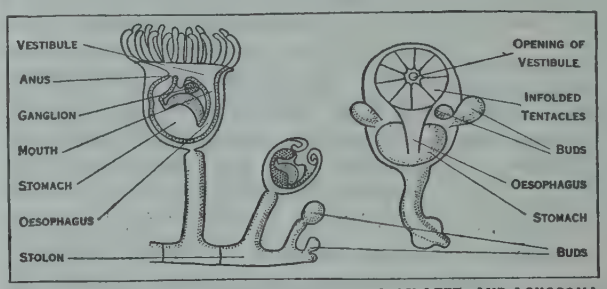
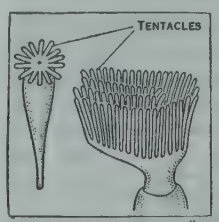


FIG. 1.—ENTOPROCTA; SHOWING PEDICELLINA ON LEFT, AND LOXOSOMA ON RIGHT

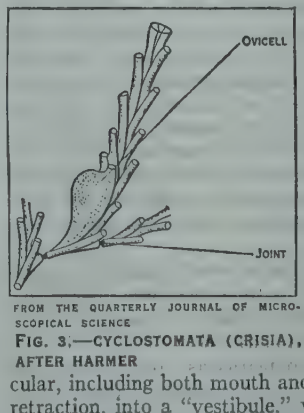
which are sometimes plantlike, suggesting the name Bryozoa, "moss animals." More frequently the colonies are encrusting and resemble the growth of lichens. The alternative name, Bryozoa, is used by all except British zoologists. Certain embryological and morphological characters suggest remote relationships to the Mollusca, Rotifera and especially to the Brachiopoda, with which latter group they have sometimes been classed as Molluscoidea. The tendency today is to separate them in a distinct phylum. They are pre-eminently marine, but there are a few fresh-water species. The individuals, or "zooecia," are seldom more than a millimetre in length, but the colonies, seldom more than an inch or so, may rarely reach more than a foot across. The body wall of the individual is usually well calcified, and fossil species are numerous as far back as the Ordovician.



FROM KRAEPELIN, "DIE SÜSSWASSER BRYOZOEN IN ABHANDLUNGEN AUS DEM GEBIETE DER NATURWISSENSCHAFTEN" (FRIEDERICHSEN, DE GRUYTER)

FIG. 2.—ECTOPROCTA Left, Gymnolaemata (*Paludicella*), right, Phylactolaemata (*Lophopus*)

It is probable that as their study advances they will take an increasingly important part in the determination of the geological age of strata. They may be defined as aquatic animals, forming colonies by budding, with ciliated tentacles which can be infolded or retracted into a depression of the body wall, with a U-shaped alimentary canal and a ganglion lying between the mouth and anus. Specific excretory organs are found in the Entoprocta alone.



FROM THE QUARTERLY JOURNAL OF MICROSCOPICAL SCIENCE

FIG. 3.—CYCLOSTOMATA (CRISIA), AFTER HARMER

Classification.—Sub-class I. Entoprocta.—Lophophore (the part bearing the tentacles) circular, including both mouth and anus. Tentacles infolded, during retraction, into a "vestibule," which can be closed by a circular muscle. Body wall not calcified, body cavity absent. Definite excretory organs present. Reproductive organs continuous with ducts, which open into the vestibule. (*See* Kamptozoa as an alternative name.)

Loxosoma (fig. 1), marine, is unique among the Polyzoa in the fact that the colony consists merely of a single individual, with

its system of buds, which are produced in two series, each bud breaking off on reaching maturity. It is of minute size, and nearly always occurs on other animals, Sponges, Polychaet and Sipunculid worms, Ascidians or even Polyzoa. As in other Entoprocta, the individual consists of a muscular stalk bearing a "calyx" or body, which contains the viscera and bears the tentacles. *Pedicellina* (fig. 1), marine, has the individuals arranged in a linear series on an attached, narrow "stolon." The calyces are deciduous and can be regenerated, a process analogous to the formation of "brown bodies" in the Ectoprocta. *Urnatella*, a fresh water species.

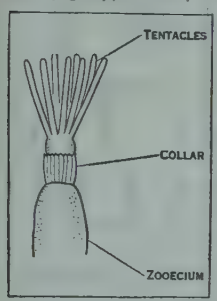


FIG. 4.—CTENOSTOMATA, (BOWERBANKIA)

Sub-class II. Ectoprocta.—Lophophore circular or shaped like a horseshoe (fig. 2), including the mouth but not the anus. Tentacles retractile into a delicate, flexible "introvert" ("tentacle-sheath") of the body-wall (fig. 6). Remainders of the body-wall membranous or calcified, the body-cavity spacious, containing the reproductive organs, which are not continuous with ducts. Specific excretory organs absent. Zooecia usually closely apposed to their neighbours, with which they are in organic connection by means of threads of living tissue, traversing "communication-pores" in the separating walls. There is naturally no evidence as to the anatomy of the two exclusively fossil Orders.

Tribe I. Gymnolaemata. Lophophore circular (fig. 2), without an "epistome" or lip. Body-cavities not continuous with one another, body-wall not muscular.

Order 1. Trepostomata. Fossil, Palaeozoic. Zooecia long, coherent, their cavity traversed by many transverse partitions, which become more numerous near the terminal orifice. Surface of colony with regularly distributed elevations or "monticules." The reference of these organisms, which include the Monticuliporidae, to the Polyzoa has been disputed, but the characters of the primary individual of the colony are in favour of this association.

Order 2. Cryptostomata. Fossil, Palaeozoic. Zooecia usually shorter than in the Trepostomata, sometimes with transverse partitions. Orifice at the bottom of a vestibular shaft, which may be traversed by diaphragms. This order, which includes the net-like Fenestellidae, has been regarded by palaeontologists as ancestral to the Cheilostomata.

Order 3. Cyclostomata. Zooecia elongated, prismatic or cylindrical (fig. 3), with terminal, typically circular orifice, of the full width of the tubular part. The ovicells are modified, greatly enlarged zooecia, and, in the recent species investigated, contain numerous embryos, produced by the division of a single, primary embryo. The polypide is protruded with the aid of a "membranous sac," which surrounds it. The Cyclostomata are known from early Palaeozoic strata (Ordovician) onwards and are represented in the Cretaceous by specially numerous species; their highly calcareous zooecia being well preserved as fossils. They form a comparatively small proportion of the recent marine fauna, in which *Crisia, Tubulipora, Idmonea, Entalophora, Hornera* and *Lichenopora* are represented by many species.

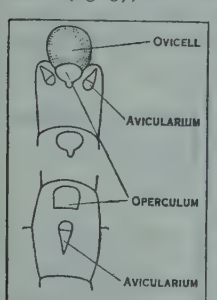


FIG. 5.—AVICULARIA AND OVICELL OF ENCRUSTING CHEILOSTOMATA

Order 4. Ctenostomata. Walls soft and uncalcified, the orifice being closed by a membranous "collar" (fig. 4), with folded walls, which surrounds it. Encrusting or erect and broadly lobed, the zooecia connected with one another (*Alcyonidium, Flustrella*); or erect and delicate, the zooecia arising separately from a connecting stem (*Amathia, Bowerbankia*). The preceding are marine, but *Victorella* and *Paludicella*, belonging to the second group, occur in fresh water. Certain Palaeozoic fossils (*Rhopalonaria, Vinella*) have been referred to this order.

Order 5. Cheilostomata. Much or little calcified, the orifice closed by a chitinous operculum (fig. 5). Polymorphism usually occurs, certain individuals being modified as "avicularia" or "vibracula." A prominent, globular "ovicell" is commonly found at the distal ("upper") end of the fertile zooecium, serving as an external brood-cavity in which an egg develops. This order is first known in the Mesozoic period (Jurassic), but its species become extremely numerous in the Cretaceous. In the Tertiary period,

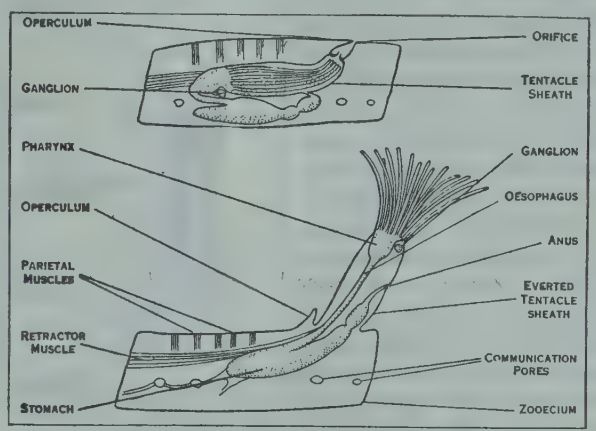


FIG. 6.—CHEILOSTOMATA ANASCA (ELECTRA), SHOWING ABOVE, POLYPIDE RETRACTED; BELOW, POLYPIDE EXPANDED

as at present, it is the dominant group of Polyzoa, chiefly marine but occasionally found in brackish water. Representative genera are: *Membranipora, Flustra, Onychocella, Cellaria, Scrupocellaria, Bugula, Schizoporella, Retepora, Cellepora.*

Tribe II. Phylactolaemata. Lophophore horseshoe-shaped (fig. 2), except in *Fredericella*, the mouth guarded by a lip or "epistome." Body-wall muscular, uncalcified, the body-cavities continuous with one another. Reproduction sexual and by means of "statoblasts" (fig. 12), internal buds protected by a chitinous shell. *Fredericella, Plumatella, Lophopus, Cristatella.* The colony can move slowly from place to place in the last two.

Structure of Ectoprocta.—The colony may assume several distinct forms: (*a*) Encrusting, the zooecia in close contact with one another, usually in a single layer, attached to a stone or seaweed by the basal surface, the orifices on the exposed or "frontal" surface, sometimes becoming multilaminar by the addition of new

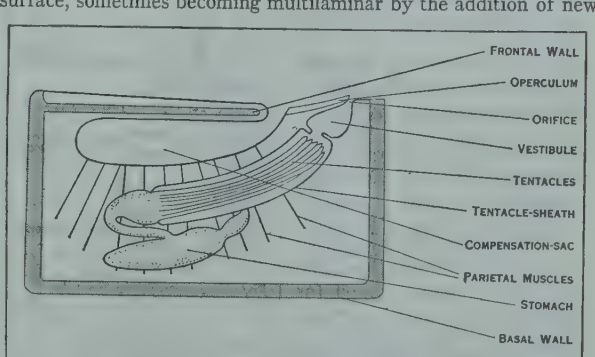
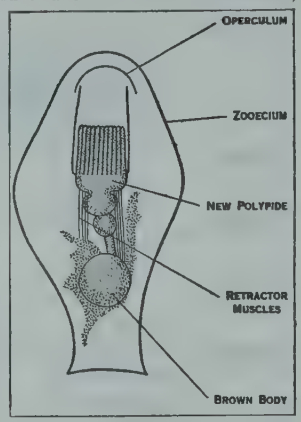


FIG. 7.—CHEILOSTOMATA ASCOPHORA, ILLUSTRATING THE METHOD OF PROTRUSION OF THE POLYPIDE

layers, each of which completely covers its predecessor, sealing the orifices; (*b*) erect, with broad lobes or branches, unilaminar or bilaminar, the zooecia correspondingly opening on one or both surfaces. Both these conditions are found in *Flustra* and its allies, in which there is little calcification and the branches are flexible. *Retepora* is a highly calcified unilaminar type, the branches of which form an elegant network. In other genera the branches are cylindrical, the orifices arranged all round the curved surfaces; (*c*) erect and more slender, resembling Hydroids, mostly unilaminar or with cylindrical branches, often with flexible joints; (*d*)

not rigidly attached, unilaminar, discoidal or conical.

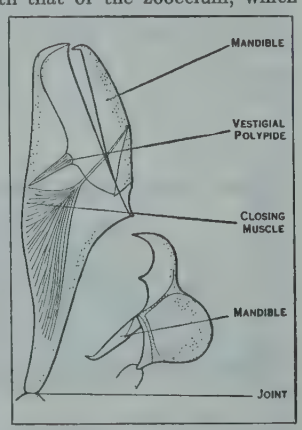
The zooecium of the Cheilostomata (fig. 6) resembles a shallow box, having the "orifice" near the distal end, the one further from the base or commencement of the colony. The orifice is the external opening of a thin-walled "tentacle-sheath," really a flexible, uncalcified part of the body-wall, pushed into the body-cavity. The tentacles arise from the blind end of the retracted sheath; and these parts, with the U-shaped alimentary canal and the nerve-ganglion which lies between the mouth and anus, constitute the "polypide." Retraction of the tentacles takes place rapidly by means of retractor muscles, but protrusion is a more gradual process and is effected by "parietal muscles," the contraction of which increases the fluid pressure in the body-cavity and forces out the tentacles. Some part of the body-wall must accordingly be flexible, and in the division Anasca (fig. 6) this is the whole or part of the frontal surface. In the Ascophora (fig. 7) most of the frontal wall is calcified and rigid, but the part which lies on the proximal side of the operculum has been pushed in as a very delicate "compensation-sac," into the basal wall of which the parietal muscles are inserted. The contraction of these muscles dilates the sac, into which water enters from the outside, and the mechanism of protrusion is thus the same as in the Anasca. In the erect Ctenostomata the whole body-wall is flexible, and the parietal muscles produce their effect by passing from one part of it to another, across the body-cavity. In the Phylactolaemata the flexible body-wall is itself muscular. The calcareous Cyclostomata have a special, rather complicated arrangement for protrusion (*see* Borg, 1926).



FROM THE "QUARTERLY JOURNAL OF MICROSCOPIC SCIENCE"

FIG. 8.—CHEILOSTOMATA; REGENERATION OF THE POLYPIDE (CARBASEA), AFTER HARMER

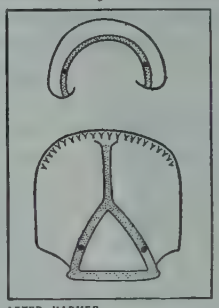
Regeneration of the Polypide.—The duration of life of the polypide does not correspond with that of the zooecium, which has a succession of polypides. This curious fact is probably the result of the absence of definite excretory organs, the function of which seems to be performed largely by the stomach. The wall of this organ becomes charged with brown granules (probably excretory), and after a time the entire polypide degenerates, decreasing in size and ultimately becoming a small, rounded "brown body" (fig. 8), which owes its colour to these granules. The substances of nutritive value have probably been absorbed, for future use, by the cells which surround the degenerating polypide. An internal polypide-bud is simultaneously developed, and in some species its stomach envelopes the brown body, which passes into its cavity and is rejected with the faeces. In other cases the brown body remains as an inert mass in the zooecium, and the occurrence of several brown bodies indicates a corresponding number of degenerated polypides.



AFTER HARMER

FIG. 9.—CHEILOSTOMATA; LEFT, STALKED AVICULARIA OF CORNUCOPINA, RIGHT, OF BUGULA

Polymorphism.—In the majority of Cheilostomata, certain zooecia have merely a vestige of a polypide, and the operculum, now known as the "mandible," and its muscles become modified for prehension. These units are known as "avicularia," from their resemblance to the head of a bird, in *Bugula* (fig. 9) and other genera in which they attain their highest development. The avicularia may be "vicarious," in series with the zooecia, which they may surpass in size, the mandibles being often much larger than the opercula (fig. 10); or they are "adventitious" (fig. 5), when they occur as appendages of ordinary zooecia. They are either "sessile," closely attached to the zooecia (fig. 5) or stalked (fig. 9), and they show a wide range of form, in different species. The "vibracula" (fig. 11), which are found in a small number of Cheilostomata, have the operculum transformed into a long "seta," which sweeps through the water. In *Caberea* the vibracula of a branch have been observed to move in unison, but this is exceptional. The avicularia and vibracula appear to be defensive organs, and they doubtless ward off the attacks of some predacious animals. They probably prevent the overgrowth of the colony by encrusting organisms, by discouraging the attachment of larvae, and they may also serve to keep the colony clean, by dislodging foreign particles which might otherwise settle on it.



AFTER HARMER

FIG. 10.—CHEILOSTOMATA (STEGANOPORELLA) Above, operculum, below, mandible of avicularium

Reproduction.—The reproductive organs occur in the body-cavity in Ectoprocta; and organs of both sexes may be produced by a single zooecium, simultaneously or successively. The colony seems to be generally bisexual, even when testes and ovaries are found in different zooecia. The ciliated larvae, in this group, rarely possess an alimentary canal. If this is present they are known as *Cyphonautes*, a common constituent of the floating fauna, especially of coastal waters. If it is absent the tissues are charged with nutritive yolk. In either case, the larva attaches itself, loses its larval organs and becomes the "ancestrula" or first zooecium of the colony, developing a polypide as an internal bud. The ancestrula buds off other zooecia, which repeat the process, thus building up the colony; and the zooecia develop their polypides in the same way as the ancestrula. In species with a *Cyphonautes* the egg develops in the water, but in most cases it develops in the parent colony. The characteristic "ovicells" of Cheilostomata (fig. 5) are external brood-spaces into which the egg passes when it is laid, and are formed in part by the distal end of the fertile zooecium, but principally by the frontal surface of the succeeding zooecium. The egg passes from the body-cavity to the exterior (in the few cases where the process has been observed) through the "intertentacular organ," a ciliated tube between the bases of the two tentacles nearest the anus, or through a pore found in the same position. The Cheilostome ovicell nearly always contains a single egg, but in the Cyclostomata the ovicell (fig. 3) contains very numerous embryos, which have been produced by the fission of a primary embryo, developed from an egg. In Phylactolaemata the polypide is produced by the larva while it is still free, several polypides occurring in *Cristatella* before the larva attaches itself. Another form of reproduction is found in this group, where the zooecium produces internal buds from the "funiculus," a cord connecting the blind end of the stomach with the body-wall. These special buds are known as "statoblasts" (fig. 12), and each is protected by a strong chitinous shell, the outer part ("annulus") of which is modified as a ring containing air-

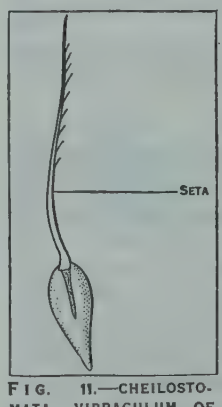
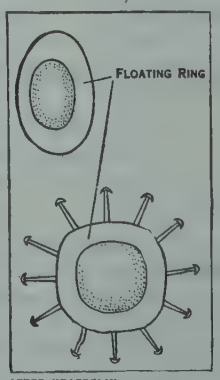


FIG. 11.—CHEILOSTOMATA. VIBRACULUM OF CABEREA



AFTER KRAEPELIN

FIG. 12.—STATOBLASTS OF PHYLACTOLAEMATA Above, *Plumatella*; below, *Pectinatella*

cells which enable the statoblast to float on the surface of the water when it becomes free. In temperate latitudes this happens in the late summer or autumn, and the statoblast develops into a new colony in the ensuing spring.

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(S. F. H.; R. C. O.)

POMBAL, SEBASTIÃO JOSÉ DE CARVALHO E MELLO, MARQUESS OF (1699–1782), Portuguese statesman, was born at Soure near Pomba, on May 13, 1699. In 1739 he was sent as Portuguese ambassador to London, where he remained until 1745. He was then transferred to Vienna. In 1749 he took up the post of secretary of state for foreign affairs and war. Though he came into power only in his 51st year, without previous administrative experience, he was able to reorganize Portuguese education, finance, the army and the navy. He also built up new industries, promoted the development of Brazil and Macao, and expelled the Jesuits. His complete ascendancy over the mind of King Joseph dates from the time of the great Lisbon earthquake (Nov. 1, 1755). In Sept. 1770 he was made marquess of Pombal. Soon after the death of King Joseph, in 1777, Pombal was dismissed from office; and he was only saved from impeachment by the death of his bitterest opponent, the queen-mother, Mariana Victoria, in Jan. 1781. On Aug. 16, a royal decree forbade him to reside within 20 leagues of the court. He died at Pombal on May 8, 1782.

See in addition to the works dealing with the period 1750–77 and quoted under PORTUGAL: *History;* S.J.C.M. (Pombal), *Relação abreviada*, etc. (Paris, 1758); *Memoirs of the Court of Portugal*, etc. (1765); *Anecdotes du ministère de Pombal* (Warsaw, 1781); *Administration du marquis de Pombal* (4 vols., Amsterdam, 1787); *Cartas . . . do marques de Pombal* (3 vols., Lisbon, 1820–24); J. Smith, Count of Carnota, *Memoirs of the Marquess of Pombal*, etc. (1843); F. L. Gomes, *Le Marquis de Pombal*, etc. (1869); B. Duhr (S.J.), *Pombal*, etc. (Freiburg im Breisgau, 1891); C. J. de Menezes, *Os Jesuitas e o marques de Pombal* (Oporto, 1893).

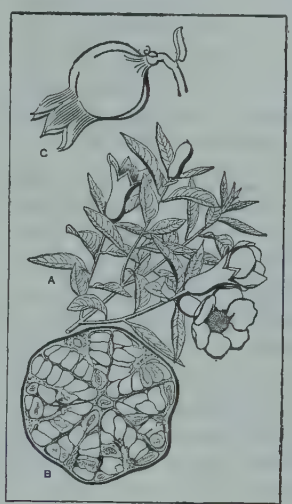
POMEGRANATE. Throughout the orient this fruit has since earliest times occupied a position of importance alongside the grape and the fig. It is produced by a bush or small tree, *Punica granatum*, only member of the family Punicaceae.

King Solomon possessed an orchard of pomegranates; and when the children of Israel, wandering in the wilderness, sighed for the abandoned comforts of Egypt, the cooling pomegranates were remembered longingly. Centuries later, the prophet Mohammed remarked sententiously: "Eat the pomegranate, for it purges the system of envy and hatred." It will thus be seen that this fruit is of exceptional interest because of its historic background. While the pomegranate is considered to be indigenous in Persia and perhaps neighbouring countries, its cultivation long ago encircled the Mediterranean and extended through Arabia, Afghanistan and India. There is something in the character of the juicy subacid pomegranate which makes it particularly agreeable to inhabitants of hot arid regions—which are precisely those in which it attains its greatest perfection.

The ancient Semitic name *rimmon* was adopted by the Arabs as *rumman*, from which the Portuguese in turn formed *romão* or *roman*. From the early Roman names *malum punicum* (apple of Carthage) and *granatum* have come the modern botanical binomial and the common name *granada*, used in Spanish-speaking countries.'

The plant, which may attain 15 or 20 ft. in height, has elliptic to lanceolate bright green leaves about 3 in. long, and handsome axillary orange-red flowers borne toward the ends of the branchlets. The calyx is tubular, persistent, 5- to 7-lobed; the petals lanceolate, inserted between the calyx-lobes. The ovary is embedded in the calyx-tube and contains several locules in two series, one above the other.

The fruit is the size of an orange and often larger, obscurely six-sided, with a smooth leathery skin which ranges from brownish yellow to red in colour. Within it is divided into several cells, containing many thin transparent vesicles of reddish juicy pulp, each surrounding an angular elongated seed. A ripe pomegranate has a delightful subacid flavour.



POMEGRANATE (PUNICA GRANATUM), A. BRANCH WITH FLOWERS. B. TRANSVERSE SECTION THROUGH FRUIT SHOWING SEEDS, C. YOUNG FRUIT

Presumably the plant was introduced into the new world by the early Spanish colonists. It is commonly cultivated in gardens from the warmer parts of the United States to Chile. Small commercial plantings have been made in California. Though it will grow in a wide range of climates, good fruit is produced only where high temperatures and dry atmosphere accompany the ripening period. Deep, rather heavy loams are probably the best soils. Propagation is effected by seeds, cuttings and layers: the first-named can readily be grown, but choice varieties cannot be reproduced in this manner. Commercial propagation is by hardwood cuttings 10 to 12 in. long, which can be rooted in the open ground.

The varieties of the pomegranate are numerous. Ibn-al-Awam, a Moor who wrote in the 13th century, described some ten which were grown in southern Spain at that time. The three leading ones which have been cultivated commercially in the United States are Wonderful, Paper-Shell and Spanish Ruby. There are also dwarf forms which produce fruit of no value but are grown for their handsome scarlet flowers. (W. Po.)

POMERANIA (German, *Pommern*), a territory of Germany and a maritime province of Prussia, bounded on the north by the Baltic, on the west by Mecklenburg, on the south by Brandenburg, and on the east by Poland. Its area, with the border province (Grenzmark Posen-Westpreussen), is 14,870 sq.mi. and the population in 1939 was 2,405,048, showing a density of 162 inhabitants to the square mile. Pomerania is one of the flattest parts of Germany, although east of the Oder it is traversed by a range of low hills, and there are also a few isolated eminences to the west. Off the west coast, which is very irregular, lie the islands of Rügen, Usedom and Wollin; the coast of Farther Pomerania is smooth in outline and is bordered with dunes, or sandbanks. Besides the Oder and its affluents, the chief of which are the Peene, the Ücker and the Ihna, there are several smaller rivers flowing into the Baltic; a few of these rivers are navigable for ships, but the greater number only carry rafts.

The soil of Pomerania is for the most part thin and sandy, but patches of good land are found here and there. The principal crops are potatoes, rye and oats, but wheat and barley are grown in the more fertile districts; tobacco, flax, hops and beetroot are also cultivated. Horses for farmwork, sheep for both wool and mutton, cattle, pigs, geese (for flesh and feathers) are features of local agriculture. Owing to the long line of coast and the numerous lakes, fishing forms an important industry. Linen weaving is practised as a domestic industry. Shipbuilding is

carried on at Stettin and at several places along the coast. The chief commercial ports of Pomerania are Stettin, Stralsund and Swinemünde. Education is provided for by a university at Greifswald and by numerous schools.

History.—In prehistoric times the southern coast of the Baltic seems to have been occupied by Celts, who afterwards made way for tribes of Teutonic stock. These in their turn were replaced, about the end of the 5th century A.D. by Slavonic tribes, the Wilzi and the Pomerani. The name of Pomore, or Pommern, meaning "on the sea," was given to the district by the latter of the tribes about the time of Charlemagne. Originally it seems to have denoted the coast district between the Oder and the Vistula. Afterwards Pomerania extended much farther to the west, while being correspondingly curtailed on the east, and a distinction was made between Slavinia, or modern Pomerania, and Pomerellen. The latter, corresponding substantially to the so-called Polish corridor, remained subject to Poland until 1309, when it was divided between Brandenburg and Teutonic Order.

The history of Pomerania, as distinct from that of Pomerellen, consists mainly in a succession of partitions and in constant hostilities with the elector of Brandenburg, who claimed to be its immediate feudal superior. During the Thirty Years' War Pomerania was devastated and by the peace of Westphalia the elector of Brandenburg acquired eastern Pomerania (Hinterpommern), and the western part (Vorpommern) was awarded to Sweden. In 1720 Swedish Pomerania was curtailed by extensive concessions to Prussia, but the district to the west of the Peene remained in the possession of Sweden until the general European settlement of 1815. Then Sweden assigned her German possessions to Denmark in exchange for Norway, whereupon Prussia, partly by purchase and partly by the cession of the duchy of Lauenburg, finally succeeded in uniting the whole of Pomerania under her rule.

See F. W. Barthold, *Geschichte von Rügen und Pommern* (Hamburg, 1839–45); the *Codex Pomeraniae diplomaticus,* edited by K. F. W. Hasselbach and J. G. L. Kosegarten (Greifswald, 1862); H. Berghaus, *Landbuch des Herzogtums Pommern* (1865–76); K. Mass, *Pommersche Geschichte* (Stettin, 1899); J. Bugenhagen, *Pomerania,* edited by O. Heinemann (Stettin, 1900); M. Wehrmann, *Geschichte von Pommern* (Gotha 1904–6).

POMFRET, JOHN (1667–1702), English poet, born at Luton, became rector of Maulden, Bedfordshire, in 1695, and of Millbrook in the same county in 1702. His poems were printed in Johnson's *English Poets* (1779, vol. xxi.).

POMMER or **BOMBARD,** the alto, tenor and basses of the shawm or schalmey family, and the forerunners respectively of the cor-anglais, bassoon or fagotto, and double bassoon or contrafagotto. (*See* Bassoon and Oboe.)

POMO. This group of American Indians, speaking seven dialects of Hokan (*q.v.*) lineage, on Russian river and Clear lake, California, is noted for its basketry, which is perhaps the finest and most varied made on the continent. The general culture was central Californian as typified by the Maidu (*q.v.*). The Pomo have decreased from about 8,000 to 800. *See* S. A. Barrett, *Univ. Calif. Publ. Am. Arch. Ethn.,* vols. vi., vii. (1908); E. W. Gifford, *ibid.,* vol. xviii. (1926); E. M. Loeb, *ibid.,* xix. (1926).

POMONA, an old Italian goddess of fruit and gardens. Pomona had a special priest at Rome, the *flamen Pomonalis,* and a sacred grove near Ostia, called the Pomonal.

POMONA, a city of Los Angeles county, California, U.S.A., 30 mi. E. of Los Angeles, at an altitude of 850 feet. It is served by the Santa Fe, the Southern Pacific, and Union Pacific railways, and by motor coach lines. The population was 35,405 in 1950; in 1940 it was 23,539 by the federal census. It is one of the principal shipping points in the state for citrus fruits and walnuts. At Claremont, 4 mi. N., is Pomona college, incorporated under the auspices of the Congregational churches of Southern California in 1887. Pomona was founded by fruit-growers in 1875 and was chartered as a city in 1875.

POMONA or **MAINLAND,** central and largest island of the Orkneys, Scotland. Pop. (1931) 13,352. It is 25 mi. long from N.W. to S.E. and 15 mi. broad from E. to W.; area, 190 sq.mi.; but where the coast is cut into, on the N. by Kirkwall Bay and on the S. by Scapa Flow, the land is less than 2 mi. across. The west coast is almost unbroken, the bays of Birsay and Skaill being the only bays of any importance, but the east and south shores are much indented. The highest points of the watershed from Costa Head to the Scapa shore are Milldoe to the north-east of Isbister and Wideford Hill to the west of Kirkwall. There are also a few eminences towards the southwest, Ward Hill (880 ft.) in the parish of Orphir being the highest peak in the island. There are numerous lakes, some of considerable size and most of them abounding with trout. Kirkwall, the capital of the Orkneys, and Stromness are the only towns.

In Harray, the only parish in the Orkneys not trenched at some point by the sea, Norse customs have survived longer than elsewhere in the group save in North Ronaldshay.

The antiquities of Pomona are of great interest. The examples of Pictish remains include *brochs,* chambered mounds and weems, or underground dwellings afterwards roofed in. North-east of Stromness, and within a mile of the stone circles of Stenness, stands the great barrow or chambered mound of Maeshowe. The tumulus has the form of a blunted cone, 300 ft. in circumference, and at a distance of 90 ft. from its base is encircled by a moat. The ground-plan shows that it was entered from the west by a passage, which led to a central apartment, the walls of which ended in a beehive roof. The barrow is variously ascribed to the Stone Age and to 10th century Norsemen.

The stone circles forming the Ring of Brogar and the Ring of Stenness lie 4½ m. N.E. of Stromness. The Ring of Brogar, once known as the Temple of the Sun, stands on a raised circular platform of turf, surrounded by a moat and a grassy rampart. The ring originally comprised 60 stones, varying from 9 to 14 ft. in height, set up at intervals of 17 ft. Only 13 are now erect. The Ring of Stenness—the Temple of the Moon of local tradition—is of similar construction. The Stone of Odin, the great monolith, pierced by a hole at a height of 5 ft. from the ground, which figures so prominently in Scott's *Pirate,* stood 150 yd. to the north of the Ring of Stenness.

POMORZE or **POMERANIA** (*i.e.,* "along the sea"), a province of Poland, bounded on the N. by the Baltic, on the E. by East Prussia, on the S. by the provinces of Warsaw and Poznan, on the W. by Germany. Area, 7,733 sq.mi.; pop. (1946), 1,406,500. Germany seized the province in 1939.

Pomorze, which has been, in modern times, very incorrectly called West Prussia and the "Polish corridor," consists of two quite distinct units. West of the Vistula is eastern Pomerania, which was colonized by Poland when West Pomerania became a German colony, was seized by the Teutonic Order in 1309, recovered by Poland in 1466 and held till 1773, when it was seized by Prussia. East of the Vistula is the territory of Chelmno or Kulm, a Polish border province ceded to the Teutonic Order in the 13th century and recovered in 1466. Both these territories remained mainly Polish despite the colonizing efforts of the Prussian government in the 19th century. Danzig, which had a German majority, was made into a Free State by the treaty of Versailles; mixed areas decided their future by a plebiscite, and the remaining territory was reunited to the other parts of Poland, to which it was essential as the only outlet of Poland on the sea. The Prussian rule of over 140 years left a German minority, forming 11% of the population; the Poles formed 89% (1935).

Pomorze is mainly an agricultural country, its industries depending on agriculture. Together with Poznan, it was formerly one of the chief sources of foodstuffs for Germany. The peasant is highly educated and well organized, the agricultural co-operative societies having been a great economic and national asset. Forestry is well organized in the great Tuchola forest. Distilling, brewing and sugar refining are important industries. The province is famous for stockbreeding, having a greater number of sheep per acre than any other part of Poland. The fisheries are extensive, but not well organized. The province is well served by railways. A constantly growing traffic by rail and river descends to Danzig and the new port of Gdynia. The chief towns are Gdynia (pop. 103,000 in 1950), Torun (pop. 68,085 in 1946), Grudziadz (pop. 36,805) in the east; Chojnice, Puck, Tuchola,

Starograd and Swiecie in the west. Pomorze, tactically difficult to defend, was rapidly conquered by Germany in World War II.

POMPADOUR, JEANNE ANTOINETTE POISSON LE NORMANT D'ÉTIOLES, MARQUISE DE (1721–1764), mistress of Louis XV., was born in Paris on Dec. 29, 1721, and baptized as the legitimate daughter of François Poisson, an officer in the household of the duke of Orleans, and his wife, Madeleine de la Motte, in the church of St. Eustache; but she was educated at the charge of a wealthy financier and farmer-general of the revenues, Le Normant de Tournehem. He declared her "un morceau de roi," and specially educated her to be a king's mistress. This idea was confirmed in her childish mind by the prophecy of an old woman, whom in after days she pensioned for the correctness of her prediction. In 1741 she was married to a nephew of her protector and guardian, Le Normant d'Étioles, who was passionately in love with her, and she soon became a queen of fashion. The king met her at a ball given by the city to the dauphin in 1744, and he was immediately subjugated. She at once gave up her husband, and in 1745 was established at Versailles as "maîtresse en titre." Louis XV. bought her the estate of Pompadour, from which she took her title of marquise (raised in 1752 to that of duchess).

She was hardly established firmly in power before she began to mix in politics. Knowing that the French people of that time were ruled by the literary kings of the time, she paid court to them, and tried to play the part of a Maecenas. Voltaire was her poet in chief, and the founder of the physiocrats, Quesnay, was her physician. The command of the political situation passed entirely into her hands; she it was who brought Belle-Isle into office with his vigorous policy; she corresponded regularly with the generals of the armies in the field, as her letters to the Comte de Clermont prove; and she introduced the Abbé de Bernis into the ministry in order to effect a very great alteration of French politics in 1756. The continuous policy of France since the days of Richelieu had been to weaken the house of Austria by alliances in Germany; but Mme. de Pompadour changed this hereditary policy for the alliance with Austria which brought on the Seven Years' War, with all its disasters.

But it was to internal politics that this remarkable woman paid most attention. She made herself indispensable to Louis. She died on April 15, 1764, at the age of forty-two.

See Capefigue, *Madame la marquise de Pompadour* (1858); E. and J. de Goncourt, *Les Maîtresses de Louis XV.*, vol. ii. (1860); and Campardon, *Madame de Pompadour et la cour de Louis XV. au milieu du dix-huitième siècle* (1867). Far more valuable are Malassis's two volumes of correspondence, *Correspondance de Madame de Pompadour avec son père M. Poisson, et son frère M. de Vandières*, etc. (1878), and Bonhomme, *Madame de Pompadour, général d'armée* (1880), containing her letters to the Comte de Clermont. *See* also P. de Nolhac, *La Marquise de Pompadour* (1903).

POMPEII, an ancient town of Campania, Italy, near the river Sarnus, almost at the foot of Mt. Vesuvius. Its foundation was ascribed by Greek tradition to Heracles, in common with the neighbouring city of Herculaneum, but it was not a Greek colony. Strabo, in whose time it was a populous and flourishing place, tells us that it was first occupied by the Oscans, afterwards by the Tyrrhenians (*i.e.*, Etruscans), to whom it probably owes its rectangular ground plan, and Pelasgians, and lastly, by the Samnites. (*See* CAMPANIA.) No doubt, Pompeii shared the fate of the neighbouring cities, and afterwards passed in common with them under the yoke of Rome. But its name is only mentioned incidentally during the wars of the Romans with the Samnites and Campanians only when a Roman fleet landed near Pompeii in 309 B.C. and made an unsuccessful marauding expedition up the river valley as far as Nuceria. At a later period, however, it took a prominent part in the Social War (91–89 B.C.), when it withstood a long siege by Sulla, and was one of the last cities of Campania that were reduced by the Roman arms. The inhabitants were admitted to the Roman franchise, but a military colony was settled in their territory in 80 B.C. by Sulla (*Colonia Cornelia Veneria Pompeianorum*), and the whole population was rapidly Romanized. Before the close of the republic many Roman nobles acquired villas in the neighbourhood, among them Cicero, whose letters abound with allusions to his Pompeian villa. The same fashion continued under the empire, and during the first century of the Christian era, Pompeii had become a flourishing place with a considerable population. In A.D. 59 a tumult took place in the amphitheatre between the citizens and visitors from Nuceria. Many were killed and wounded on both sides. The Pompeians were punished for this violent outbreak by the prohibition of all theatrical exhibitions for ten years. A painting on the walls of one of the houses represents this event.

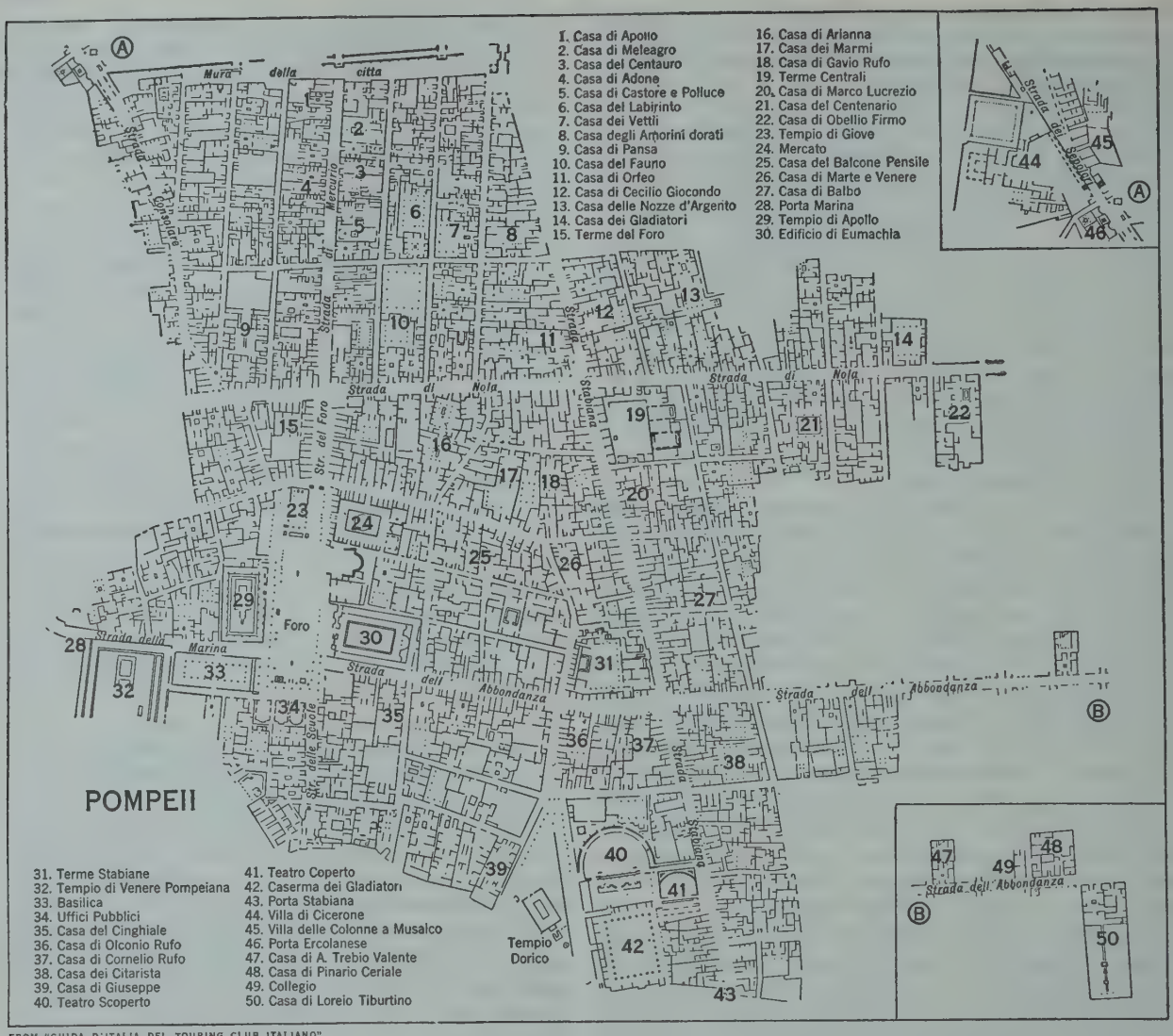
Four years afterwards (A.D. 63) an earthquake vented its force especially upon Pompeii, a large part of which, including most of the public buildings, was either destroyed or so seriously damaged as to require to be rebuilt. The inhabitants were still actively engaged in repairing and restoring it, when the whole city was overwhelmed by the great eruption of Vesuvius (*q.v.*), A.D. 79. Pompeii was merely covered with a bed of lighter substances, cinders, small stones and ashes, which fell in a dry state, while at Herculaneum the same substances, being drenched with water, hardened into a sort of tufa, which in places is 65 ft. deep. The whole of this superincumbent mass, attaining to an average thickness of from 18 to 20 ft., was the product of one eruption, though the materials may be divided generally into two distinct strata, the one consisting principally of cinders and small volcanic stones (called in Italian *lapilli*), and the other and uppermost layer of fine white ash, often consolidated by the action of water from above so as to take the moulds of objects contained in it (such as dead bodies, woodwork, etc.), like clay or plaster of Paris. It was found impossible to rebuild the town, and its territory was joined to that of Nola. But the survivors returned to the spot, and by digging down and tunnelling were able to remove all the objects of value, even the marble facing slabs of the large buildings.

In the middle ages, however, the very site was forgotten. Ruins and inscriptions were found by the architect Domenico Fontana in making an underground aqueduct across the site in 1594–1600, but only in 1748 a more careful inspection of this channel revealed the fact that beneath there lay entombed ruins far more accessible than those of Herculaneum. Only in 1763 systematic excavations were begun; the work, which had received a vigorous stimulus during the period of the French government (1806–14), was prosecuted under the Bourbon kings (1815–61). Since 1861 it has been carried on under the Italian government on a system devised by G. Fiorelli, according to which the town is for convenience divided into 6 or 9 regions, which are subdivided into *insulae* (blocks), the gates, streets and houses being also named for convenience, though often incorrectly.

The town was situated on rising ground less than a mile from the foot of Vesuvius. This eminence is itself due to an outflow of lava from that mountain, during an eruption in prehistoric times, for we know that Vesuvius had been quiescent ever since the Greek settlements in this part of Italy.

The area occupied by the ancient city was of an irregular oval form, and about 2 m. in circumference. It was surrounded by a wall, which is still preserved for more than two-thirds of its extent, but no traces of this are found on the side towards the sea, and there is no doubt that on this side it had been already demolished in ancient times, so as to give room for the free extension of houses and other buildings in that direction. It consisted of two parallel stone walls with buttresses, about 15 ft. apart and 28 in. thick, the intervening space being filled with earth, and there being an embankment on the inner side. These walls are strengthened at intervals by numerous towers, occupying the full width of the wall. They appear to have been added at a later period, probably that of the Social War. Similar evidences of the addition of subsequent defences are to be traced also in the case of the gates, of which five have been cleared, while at least one (and perhaps three) more are unexcavated.

The general plan of the town is very regular, the streets being generally straight, and crossing one another at right angles or nearly so. But exceptions are found in the south-west corner, where a small irregular group of streets represents the original Oscan settlement, and on the north-west in the street



FROM "GUIDA D'ITALIA DEL TOURING CLUB ITALIANO"

leading from the Porta Ercolanese (gate of Herculaneum) to the forum, which, though it must have been one of the principal thoroughfares in the city, was crooked and irregular, as well as very narrow, in places not exceeding 12 to 14 ft. in width. Another exception is to be found in the Strada Stabiana (Stabian Street) or Cardo, which, owing to the existence of a natural depression which affects also the line of the street just east of it, is not parallel to the other north and south streets. The other main streets are in some cases broader, but rarely exceed 20 ft. in width, and the broadest is about 32 ft., while the back streets running parallel to the main lines are only about 14 ft. (the standard width of a Roman highroad). They are uniformly paved with large polygonal blocks of hard basaltic lava, fitted very closely together, though now in many cases marked with deep ruts from the passage of vehicles in ancient times. They are also in all cases bordered by raised footways on both sides, paved in a similar manner; and for the convenience of foot-passengers, these are connected from place to place by stepping-stones raised above the level of the carriage-way. The careful investigation in recent years of the buildings in the eastern portion of the Strada dell' Abbondanza has shown that previous conceptions of the appearance of the exterior of the houses were entirely erroneous. The upper stories were diversified by balconies, open loggias, colonnades, etc., while the lower portions of the façades were painted, often with scenes of considerable interest. The streets were also diversified by fountains, small water-towers and shrines.

The first-mentioned of the two principal streets was crossed, a little before it reached the forum, by the street which led directly to the gate of Nola (Strada delle Terme, della Fortuna, and di Nola). Parallel to this last to the south is a street which runs from the Porta Marina through the forum, and then, with a slight turn, to the Sarno gate, thus traversing the whole area of the city from east to west (Via Marina, Strada dell' Abbondanza, Strada dei Diadumeni). These two east and west streets are the two *decumani*.

The population of Pompeii was mixed; both Oscan and Greek inscriptions are still found up to the last, and evidences of the presence of Jews are not lacking—such are a wall-painting, probably representing the Judgment of Solomon, and a scratched inscription on a wall, "Sodoma, Gomora." From the number of skeletons discovered, about 2,000 persons may have perished in the city itself in the eruption of A.D. 79.

The whole portion of the city which lies to the west of the Strada Stabiana, towards the forum and the sea, has been completely excavated. It is over one-half of the whole extent, and that the most important portion, inasmuch as it includes the forum, with the temples and public buildings adjacent to it, the thermae, theatres, etc. The greater part of that on the other side of the Strada Stabiana remains still unexplored, with the exception of the amphitheatre, a small space in its immediate

neighbourhood and the buildings on each side of the Strada dell' Abbondanza and the Strada di Nola.

The forum at Pompeii was the centre of the life and movement of the city. Hence it was surrounded on all sides by public buildings or edifices of a commanding character. It was not, however, of large size, only 467 ft. in length by 126 in breadth (excluding the colonnades). The nature of its pavement, composed of broad flags of travertine, into which was let an inscription in large bronze letters, shows that it was only intended for foot-passengers. It was adorned with numerous statues. It was surrounded on three sides by a series of porticos supported on columns; and these porticos were originally surmounted by an upper storey, traces of the staircases leading to which still remain. Both this portico and the adjacent buildings were undergoing a process of restoration after the earthquake of 63, involving material changes in the original arrangements, which was still incomplete at the time of their final destruction. The north end of the forum, where alone the portico is wanting, is occupied in great part by the imposing temple of Jupiter, Juno and Minerva, or Capitolium. It was raised on a *podium* 10 ft. high, and had a portico with six Corinthian columns in front. This magnificent edifice had, however, been evidently overthrown by the earthquake of 63, and is in its present condition a mere ruin, the rebuilding of which had not been begun at the time of the eruption. On each side of it were two arches, affording an entrance into the forum, but capable of being closed by gates. On the east side of the forum were four public edifices. The first (from the north), is a *macellum* or meat-market, consisting of a rectangular court surrounded by a colonnade, with a twelve-sided roofed building (*tholus*) in the centre. On the south side were shops, and in the centre of the east side a chapel for the worship of the imperial house. Next to this comes the sanctuary of the Lares of the city, a square room with a large apse; and beyond this a small temple. Beyond this again, bounded on the south by the Strada dell' Abbondanza, is a large and spacious cloth-exchange, erected by a priestess named Eumachia. It is an open court, oblong, surrounded on all four sides by a colonnade; in front is a portico facing the forum, and on the other three sides there is a corridor behind the colonnade with windows opening on it. On the south side of the Strada dell' Abbondanza was the Comitium. At the south end of the forum are three halls side by side, similar in plan with a common façade —the central one, the curia or council chamber, the others the offices respectively of the duumvirs and aediles, the principal officials of the city; while the greater part of the west side is occupied by two large buildings—a basilica, which is the largest edifice in Pompeii, and the temple of Apollo, which presents its side to the forum. The former, a building of the 2nd cent. B.C., was an oblong edifice divided by columns into a central hall and a corridor running round all the four sides with a tribunal opposite the main entrance; and, unlike the usual basilicae, it had, instead of a clerestory, openings in the walls of the corridor through which light was admitted, it being almost as lofty as the nave. The temple was an extensive edifice, having a comparatively small *cella*, raised upon a *podium*, and standing in the midst of a wide space surrounded by a portico of columns, outside which again is a wall, bounding the sacred enclosure. Between this temple and the basilica the Via Marina leads off direct to the Porta Marina.

The remains of five other temples have been discovered. The most interesting, though the least perfect, is not only by far the most ancient edifice in Pompeii, but a true Greek temple (6th century B.C.). Unfortunately only the foundation and a few Doric capitals and other architectural fragments remain; they were coated with brightly painted stucco. The reverence attached to it in later periods is shown by its being left standing in the midst of a triangular space adjoining the great theatre, which is surrounded by a portico, so as to constitute a kind of forum (the so-called Foro Triangolare). Not far off, and to the north of the great theatre, stood a small temple, dedicated to Isis, rebuilt after the ruinous earthquake of 63. It is interesting as the only temple of Isis that has come down to us in a good state of preservation. The decorations were of somewhat gaudy stucco. The plan is curious, the internal arrangements being adapted for the performance of the peculiar rites of this deity. Close to this was the small temple of Zeus Milichius. The temple of the Fortune of Augustus (Fortuna Augusta), which stood north of the Forum, suffered very severely from the earthquake, but we learn from existing remains that its walls were covered with slabs of marble, and that the columns of the portico were of the same material. The fifth temple, that of Venus Pompeiana, to the west of the basilica, was in process of rebuilding at the time of the eruption. Before the earthquake of 63 it must have been the largest temple of the whole city. It was surrounded by a large colonnade, and the number of marble columns in the whole block has been reckoned at 296. Venus was the protectress of the young men of Pompeii, who had formed a society for gymnastics and other sports. They met in a hall (the Schola Iuventutis Pompeianae) in the Strada dell' Abbondanza.

All the temples above described, except that ascribed to Hercules, which was approached by steps on all four sides, agree in being raised on an elevated *podium* or basement—an arrangement usual with all similar buildings of Roman date. Among the other public buildings, the most conspicuous are the theatres, of which there were two, placed, as was usual in Greek towns, in close juxtaposition with one another. The largest of these, which was partly excavated in the side of the hill, was in great part cased with marble, with seats of the same material for about 5,000 spectators. It was erected in Roman times by two members of the same family, M. Holconius Rufus and M. Holconius Celer, both of whom held important municipal offices at Pompeii during the reign of Augustus. Their work was only a reconstruction of a more ancient edifice (probably 5th cent. B.C.), while its first alteration belongs to the "tufa" period, and three other periods in its history can be traced. The smaller theatre (for 1,500 spectators) was erected by two magistrates specially appointed for the purpose by the decuriones of the city, soon after the establishment of the Roman colony under Sulla. It was permanently covered.

Adjoining the theatres is a large rectangular enclosure, surrounded by a portico, at first the colonnade connected with the theatres, and converted, about the time of Nero, into the barracks of the gladiators. Remains of armour and weapons were found in some of the rooms, and in one, traces of the stocks used to confine insubordinate gladiators with three skeletons in them (63 were found in the whole building). The amphitheatre was erected by the same two magistrates who built the smaller theatre, C. Quinctius Valgus and M. Porcius when no permanent edifice of a similar kind had yet been erected in Rome itself, and is indeed the oldest structure of the kind known to us. It is in great part excavated in the surface of the hill, instead of the seats being raised on arches. Nor are its dimensions (460 by 345 ft.) such as to place it in the first rank, nor are there any underground chambers below the arena. The seating capacity was about 20,000 (for illustration *see* AMPHITHEATRE).

Among the more important public buildings of Pompeii were the public baths (*thermae*). Three different establishments of this character have been discovered, the first, the baths near the forum, though the smallest of the three, is in some respects the most complete and so well preserved that we trace without difficulty all the separate apartments described to us by Roman authors—the *apodyterium, frigidarium, tepidarium, caldarium,* and so on. (*See* BATHS.) The greater thermae (the so-called "Stabian" baths), which were originally built in the 2nd century B.C., and repaired about 80 B.C., are more extensive and combine a palaestra in the centre and other apartments for exercise or recreation. An inscription records the repair and restoration of the edifice after the earthquake of 63. These two establishments were inadequate to supply the wants of the inhabitants, and a third edifice, the so-called central baths, at the corner of the Strada Stabiana and the Strada di Nola, but on a still more extensive scale, intended for men only, was in course of construction in A.D. 79.

Far more interesting is the insight afforded us by the numerous private houses and shops into the ordinary life and habits of the population of an ancient town. The houses at Pompeii are gen-

erally low, rarely exceeding two storeys in height; the upper storey is generally of a slight construction, and occupied by small rooms, serving as garrets, or sleeping places for slaves. From the mode of destruction of the city these upper floors were in most cases crushed in and destroyed. The principal living rooms, as well as those intended for the reception of guests or clients, were all on the ground floor, the centre being formed by the *atrium*, or hall, which had an opening in the centre—the *compluvium*, so-called because the rain from the roofs was collected by it and fell into a basin (the *impluvium*). In the larger houses it was often surrounded with columns. Into this opened other rooms, the entrances to which, rarely protected by doors, were only closed by curtains. At the back was a garden. Later, under Greek influences, a peristyle with rooms took the place of the garden.

All the apartments and arrangements described by Vitruvius and other ancient writers may be readily traced in the houses of Pompeii, and in many instances these have for the first time enabled us to understand the technical terms and details transmitted to us by Latin authors. We must not, however, hastily assume that the examples thus preserved to us by a singular accident are to be taken as representing the style of building in all the Roman and Italian towns—in fact, the excavations at Ostia (*q.v.*) have shown us the contrary. We know from Cicero that Capua was remarkable for its broad streets and widespread buildings, and it is probable that the Campanian towns in general partook of the same character. At Pompeii indeed the streets were not wide, but they were straight and regular, and the houses of the better class occupied considerable spaces, presenting in this respect no doubt a striking contrast, not only with those of Rome itself, but with those of many other Italian towns, where the buildings would necessarily be huddled together from the circumstances of their position. Even at Pompeii itself, on the south side of the city, where the ground slopes somewhat steeply towards the sea, houses are found which consisted of three storeys or more, and with the inner walls painted black (with white designs on them) owing to the brilliancy of the light.

The excavations have provided examples of houses of every description, from the humble dwelling-place of the artisan or proletarian, with only three or four small rooms, to the stately mansions of Sallust, of the Faun, of the Golden Cupids, of the Silver Wedding, of the Vettii, of Pansa, etc.—the last of which is among the most regular in plan. But the general similarity in their plan and arrangement is very striking, and in all those that rise above a very humble class the leading divisions of the interior, the *atrium, tablinum, peristyle*, etc., may be traced with unfailing regularity. In all the more considerable houses in Pompeii the front, where it faces one of the principal streets, is occupied with shops, usually of small size, and without any communication with the interior of the mansion. In general the shop had a very small apartment behind it, and probably in most cases a sleeping chamber above it, reached by a staircase. The front of the shop was open to the street, but was capable of being closed with wooden shutters. Not only have the shops of silversmiths been recognized by the precious objects of that metal found in them, but large quantities of fruits of various kinds preserved in glass vessels, various descriptions of corn and pulse, loaves of bread, moulds for pastry, fishing-nets and many other objects too numerous to mention, have been found in such a condition as to be identified without difficulty. Inns and wine-shops appear to have been numerous; one of the latter we can see to have been a *thermopolium*, where hot drinks were sold. Bakers' shops are also frequent, though arrangements for grinding and baking appear to have formed part of every large family establishment. In other cases, however, these were on a larger scale, provided with numerous querns or hand-mills of the well-known form, evidently intended for public supply. Other establishments on a large scale were *fullonicae* (fullers' shops), where all the details of the business were illustrated by paintings still visible on the walls. Dyers' shops, a tannery and a shop where colours were ground and manufactured are of special interest, as is also the house of a surgeon, where numerous surgical instruments were found, some of them of a very ingenious and elaborate description, but all made of bronze. A blacksmith's shop was also found, with many tools that had been brought in for repair: here were discovered the remains of a *groma*, the instrument used by Roman land-surveyors, which has been successfully reconstructed (Della Corte in *Monumenti dei Lincei*, 1922). Another curious discovery was that of the abode of a sculptor, containing his tools, as well as blocks of marble and half-finished statues.

Of the numerous works of art discovered in the course of the excavations the statues and large works of sculpture, whether in marble or bronze, are inferior to those found at Herculaneum, but some of the bronze statuettes are of exquisite workmanship, while the profusion of ornamental works and objects in bronze and the elegance of their design, as well as the finished beauty of their execution, are such as to excite the utmost admiration—more especially when it is considered that these are the casual results of the examination of a second-rate provincial town, which had, further, been ransacked for valuables (as Herculaneum had not) after the eruption of 79. The same impression is produced in a still higher degree by the paintings with which the walls of the private houses, as well as those of the temples and other public buildings, are adorned, and which are not merely of a decorative character, but in many instances present us with elaborate compositions of figures, historical and mythological scenes, as well as representations of the ordinary life and manners of the people, which are full of interest to us, though often of inferior artistic execution. It has until lately been the practice to remove these to the museum at Naples; but the present tendency is to leave them (and even the movable objects found in the houses) *in situ* with all due precautions as to their preservation, which adds immensely to the interest of the houses; indeed, with the help of careful restoration, their original condition is in large measure reproduced. In some cases it has even been possible to recover the original arrangement of the garden beds, and to replant them accordingly, thus giving an appropriate framework to the statues, etc., with which the gardens were decorated, and which have been found *in situ*. The same character of elaborate decoration, guided almost uniformly by good taste and artistic feeling, is displayed in the mosaic pavements, which in all but the humbler class of houses frequently form the ornament of their floors. One of these, in the House of the Faun, well known as the battle of Alexander, presents us with the most striking specimen of artistic composition that has been preserved to us from antiquity.

The architecture of Pompeii presents in general a transitional character from the pure Greek style to that of the Roman Empire. The temples (as already observed) have always the Roman peculiarity of being raised on a *podium* of considerable elevation; and the same characteristic is found in most of the other public buildings. All the three orders of Greek architecture—the Doric, Ionic and Corinthian—are found freely employed in the various edifices of the city, but rarely in strict accordance with the rules of art in their proportions and details; while the private houses naturally exhibit still more deviation and irregularity. In many of these indeed we find varieties in the ornamentation, and even in such leading features as the capitals of the columns, which remind one rather of the vagaries of mediaeval architecture than of the strict rules of Vitruvius or the regularity of Greek edifices. One practice which is especially prevalent, so as to strike every casual visitor, and dates from the early years of the empire, is that of filling up the flutings of the columns for about one-third of their height with a thick coat of stucco, so as to give them the appearance of being smooth columns without flutings below. The architecture of Pompeii suffers from the inferior quality of the materials generally employed. No good building stone was at hand; and the public as well as private edifices were constructed either of volcanic tufa, or lava, or Sarno limestone, or brick (the latter only used for the corners of walls). In the private houses even the columns are mostly of brick, covered merely with a coat of stucco. Marble was sparingly employed.

These materials are used in several different styles of construction belonging to the six different periods which Mau traces in the architectural history of Pompeii.

1. That of the Doric temple in the Foro Triangolare (6th cen-

tury B.C.) and an old column built into a house in Region vi., Insula 5; also of the older parts of the city walls—date uncertain (Sarno limestone and grey tufa).

2. That of the limestone atriums (outer walls of the houses of ashlar-work of Sarno limestone, inner walls with framework of limestone blocks, filled in with small pieces of limestone). Date before 200 B.C.

3. Grey tufa period; ashlar masonry of tufa, coated with fine white stucco; rubble work of lava. The artistic character is still Greek, and the period coincides with the first (incrustation) style of mural decoration, which (coming from Asia Minor or Greece perhaps by way of Sicily) aimed at the imitation in stucco of the appearance of a wall veneered with coloured marbles. No wall paintings exist, but there are often fine floor mosaics. To this belong a number of private houses (*e.g.*, the House of the Faun), and the colonnade round the forum, the basilica, the temples of Apollo and Jupiter, the large theatre with the colonnades of the Foro Triangolare, and the barracks of the gladiators, the Stabian baths, the Palaestra, the exterior of the Porta Marina, and the interior of the other gates—all the public buildings indeed (except the Doric temple mentioned under [1], which do not belong to the time of the Roman colony). Date, end of 2nd century B.C.

4. The "quasi-reticulate" period—walling faced with masonry not yet quite so regular as *opus reticulatum,* and with brick quoins, coinciding with the second period of decoration (the architectural, partly imitating marble like the first style, but without relief, and by colour only, and partly making use of architectural designs framing pictorial scenes, which are conceived as seen through openings). It is represented by the small theatre and the amphitheatre, the baths near the forum, the temple of Zeus Milichius, the Comitium and the original temple of Isis, but only a few private houses. This style probably owes much to Hellenistic theatrical decoration. Date, from 80 B.C. until nearly the end of the Republic.

5. The period from the last decades of the Republic to the earthquake of A.D. 63. No homogeneous series of buildings—we find various styles of construction (quasi-reticulate, *opus reticulatum* of tufa with stone quoins, of the time of Augustus, *opus reticulatum* with brick quoins or with mingled stone and brick quoins, a little later); and three styles of wall decoration fall within its limits: the later stage of the second, already mentioned, the third or ornate, with its freer use of ornament and its introduction of designs which suggest an Egyptian origin (originating in the time of Augustus), and the fourth or intricate, with a return to architectural forms, dating from about A.D. 50. Marble first appears as a building material in the temple of Fortuna Augusta (*c.* 3 B.C.).

6. The period from the earthquake of A.D. 63 to the final destruction of the city, the buildings of which can easily be recognized. The only wholly new edifice of any importance is the central baths.

Outside the Porta Ercolanese, or gate leading to Herculaneum, is found a house of a different character from all the others, undoubtedly a large villa; its remains are of interest as aiding us in understanding the description of ancient authors, such as Vitruvius and Pliny, of the numerous appurtenances frequently annexed to houses of this description.

In the cellar of this villa were discovered no less than twenty skeletons, and fourteen in other parts of the house. Almost all the skeletons and remains of bodies found in the city were discovered in similar situations, in cellars or underground apartments—those who had sought refuge in flight having apparently for the most part escaped from destruction, or having perished under circumstances where their bodies were easily recovered by the survivors. It has been found possible in many cases to take casts of the bodies found.

An interesting farm-house (few examples have been so far discovered in Italy) is that at Boscoreale excavated in 1893–94, which contained the treasure of one hundred and three silver vases now in the Louvre. The villa of P. Fannius Synhistor, not far off, was excavated in 1900; it had fine wall paintings, which were exported, and sold by auction in Paris (some now in the Louvre, while others are in New York). (*See* F. Barnabei, *La Villa pompeiana di P. Fannio Sinistore;* Rome, 1901.) Another, closer to Pompeii, in the so-called Villa Item, contains remarkable life size frescoes representing scenes of initiation into the mysteries of Dionysus or of Orpheus.

The road leading towards Herculaneum is bordered on both sides for a considerable extent by tombs, in many instances monuments of considerable pretension, and of a highly ornamental character, which present in the highest degree the advantage common to all that remains of Pompeii, their perfect preservation.

There appears to have been in the same quarter a considerable suburb, outside the gate, extending on each side of the road towards Herculaneum, apparently much resembling those which are now found from thence to Naples. Other suburbs were situated at the harbour and at the saltworks (*salinae*).

No manuscripts have been discovered in Pompeii. Inscriptions have been found in considerable numbers, and give much information concerning the municipal arrangements of the town, as well as the construction of various edifices and other public works. The most interesting of these are such as are written in the Oscan dialect, which appears to have continued in official use down to the time when the Roman colony was introduced by Sulla. From that time the Latin language was the only one officially employed. Still more curious are the numerous writings painted upon the walls, which have generally a semi-public character, such as recommendations of candidates for municipal offices, advertisements, etc., and the scratched inscriptions (*graffiti*), which are generally the mere expression of individual impulse and feeling, frequently amatory, and not uncommonly conveyed in rude and imperfect verses. In one house also a whole box was found filled with written tablets—diptychs and triptychs—containing the record of the accounts of a banker named L. Caecilius Iucundus.

See A. Mau, *Pompeii: its Life and Art* (trans. by F. W. Kelsey, 2nd ed., New York and London, 1902; 2nd revised edition of the German original, *Pompeii in Leben und Kunst,* Leipzig, 1908) with *Anhang* (1913), with full references; and, for later excavations, *Notizie degli Scavi* and *Römische Mitteilungen, passim.* A. W. Van Buren in *Classical Journal* xv. (1919–20) 404–416, and *Companion to Pompeian Studies* (American Academy in Rome, 1927); W. Engelmann, *New Guide to Pompeii* (Leipzig, 1925); A. Ippel, *Pompeii,* ib. id.; T. Warscher, *Pompeii, ein Führer durch die Ruinen.* For the inscriptions on the tablets and on the walls, *Corpus inscriptionum latinarum,* vol. iv. For the paintings, *see* E. Pfuhl, *Masterpieces of Greek Drawing and Painting* (tr. J. D. Beasley, London 1926); M. Della Corte, *Case ed abitanti a Pompeii* (*Pompeii,* 1926). (E. H. B.; T. A.)

POMPEIUS, GNAEUS, surnamed STRABO (squint-eyed), Roman statesman, father of the triumvir. He was successively quaestor in Sardinia (103 B.C.), praetor (94), propraetor in Sicily (93) and consul (89). He fought with success in the Social War, and was awarded a triumph for his services. Probably towards the end of the same year he brought forward the law (*lex Pompeia de Gallia transpadana*), which conferred upon the inhabitants of that region the privileges granted to the Latin colonies. During the civil war between Marius and Sulla he seems to have shown no desire to attach himself definitely to either side. He set out for Rome; the engagement which he fought before the Colline gate, although hotly contested, was indecisive. Soon afterwards he was killed by lightning (87).

See Plutarch, *Pompey,* 1; Appian, *Bell. civ.* i. 50, 52, 66–68, 80; Vell. Pat. ii. 21; Livy, *Epit.* 74–79; Florus iii. 18.

POMPEIUS, GNAEUS, surnamed MAGNUS (*c.* 75–45 B.C.), the elder son of the triumvir. In 48 B.C. during the civil war he commanded his father's fleet in the Adriatic. After the battle of Pharsalus he set out for Africa with the remainder of the Pompeian party, but, meeting with little success, crossed over to Spain. Having been joined by his brother Sextus, he collected a considerable army, the numbers of which were increased by the Pompeians who fled from Africa after the battle of Thapsus (46). Caesar, who regarded him as a formidable opponent, set out against him in person. A battle took place at Munda on March 17, 45, in which the brothers were defeated. Gnaeus managed to escape, but was soon (April 12) captured and put to death.

See Pseudo-Oppius, *Bellum hispaniense,* 1–39; Lucan, *Pharsalia,* ix. 120; Dio Cassius, xliii. 28–40.

POMPEIUS, SEXTUS, surnamed MAGNUS (75–35 B.C.), the younger son of the triumvir. After his father's death he continued the struggle against the new rulers of the Roman empire. From Cyprus, where he had taken refuge, he made his way to Africa, and after the defeat of the Pompeians at Thapsus (46) crossed over to Spain. After Caesar's victory at Munda (45), he abandoned Corduba (Cordova), though for a time he held his ground in the south, and defeated Asinius Pollio, the governor of the province. In 43 he was proscribed by the triumvirate and put himself at the head of a fleet manned chiefly by slaves or proscribed persons, with which he made himself master of Sicily, and from thence ravaged the coasts of Italy. Rome was threatened with a famine, as the corn supplies from Egypt and Africa were cut off by his ships, and it was thought prudent to negotiate a peace with him at Misenum (39), which was to leave him in possession of Sicily, Sardinia and Achaea, provided he would allow Italy to be freely supplied with corn. But the arrangement could not be carried into effect, as Sextus renewed the war and gained some considerable successes at sea. However, in 36 his fleet was defeated and destroyed by Agrippa at Naulochus off the north coast of Sicily. After his defeat he fled to Mytilene, and from there to Asia Minor. In the attempt to make his way to Armenia he was taken prisoner by Antony's troops, and put to death at Miletus.

See Dio Cassius, xlvi.–xlix.; Appian, *Bell. civ.* iv. 84–117, v. 2–143; Vell. Pat. ii. 73–87; Plutarch, *Antony;* Livy, *Epit.* 123, 128, 129, 131; Cicero, *Philippica,* xiii., and many references in *Letters to Atticus.*

POMPEY, the common English form of Pompeius, the name of a Roman plebeian family.

POMPEIUS, GNAEUS (106–48 B.C.), the triumvir, the first of his family to assume the surname MAGNUS, was born on Sept. 30, in the same year as Cicero. When only 17 he fought together with his father in the Social War. He took the side of Sulla against Marius and Cinna, but for a time, in consequence of the success of the Marians, he kept in the background. On the return of Sulla from the Mithridatic War Pompey joined him with an army of three legions, which he had raised in Picenum. Thus early in life he connected himself with the cause of the aristocracy, and a decisive victory which he won in 83 over the Marian armies gained for him from Sulla the title of *imperator.* He followed up his successes in Italy by defeating the Marians in Sicily and Africa, and on his return to Rome in 81, though he was still merely an *eques* and not legally qualified to celebrate a triumph, he was allowed by general consent to enjoy this distinction, while Sulla greeted him with the surname of *magnus,* a title he always retained and handed down to his sons. Latterly, his relations with Sulla were somewhat strained; after Sulla's death he resisted the attempt of the consul M. Aemilius Lepidus to repeal the constitution. In conjunction with A. Lutatius Catulus, the other consul, he defeated Lepidus when he tried to march upon Rome, and drove him out of Italy (77). He retained his army, and jockeyed the senate into sending him to Spain *pro consule* (though he had as yet held no magistracy) to deal with Sertorius. Pompey was fighting in Spain from 76 to 71. After Sertorius had fallen a victim to assassination, Pompey easily defeated his successor Perperna and put an end to the war. On his way back he met and cut up a body of slaves, part of Spartacus' defeated forces, in flight northwards. He demanded a triumph, and permission to stand for the consulate.

The Consul.—The senate was inclined to grudge it, so he entered into a coalition with Crassus, and as both had armies at the gates, there was no more to be said. Pompey and Crassus were consuls together in 70, and that year saw the work of Sulla undone; the tribunate and censorship were restored, and the administration of justice was shared between the Senate, the equites, and the *tribuni aerarii.*

Pompey rose still higher in popularity, and on the motion of the tribune Aulus Gabinius in 67 he was entrusted with an extraordinary command over the greater part of the empire, specially for the extermination of piracy in the Mediterranean, by which the corn supplies of Rome were seriously endangered, while the high prices of provisions caused great distress. He was completely successful; the price of corn fell immediately on his appointment, and in 40 days the Mediterranean was cleared of the pirates. Next year, on the proposal of the tribune Manilius, his powers were still further extended, the care of all the provinces in the East being put under his control for three years together with the conduct of the war against Mithridates VI., who had recovered from the defeats he had sustained from Lucullus and regained his dominions. Both Caesar and Cicero supported the tribune's proposal, which was easily carried in spite of some opposition in the senate. Pompey was entirely successful. Mithridates was beaten and driven into the Crimea, and there was a general settlement of affairs in the East. Syria and Palestine were annexed in 64 and 63. Tigranes of Armenia submitted and was confirmed as a vassal king, and an agreement was reached with Phraates of Syria whereby the Euphrates marked the boundary between them.

Pompey, now in his 45th year, returned to Italy in 61 to celebrate the most magnificent triumph which Rome had ever witnessed, as the conqueror of Spain, Africa and Asia.

Politics.—This triumph marked the turning-point in his career. As a soldier everything had gone well with him; as a politician he was a failure. He found a great change in public opinion, and the people indifferent to his achievements abroad. The senate had a unique chance to secure his support, but refused to ratify the arrangements he made in Asia or to provide money and lands for distribution amongst his veterans. In these circumstances he drew closer to Caesar on his return from Spain, and became reconciled to Crassus. The result was the first triumvirate. He was married to Caesar's daughter Iulia, and as yet the relations between the two had been friendly. Pompey was now in fact ruler of the greater part of the empire, while Caesar had only the two provinces of Gaul. But being no political tactician, Pompey made no use of this advantage, and all this time the balance of power was steadily turning in Caesar's direction. The senate and the aristocracy disliked and distrusted Pompey, but they felt that, should things come to the worst, they might still find in him a champion of their cause. Hence the joint rule of Pompey and Caesar was not unwillingly accepted, and anything like a rupture between the two was greatly dreaded as the sure beginning of anarchy throughout the Roman world. In 55 Pompey was consul again, in accordance with the arrangement with Caesar when the triumvirate was renewed at Luca in 56. As proconsul he should have left for his province, but he remained in charge of the corn-supply, virtually master of Rome, and governed Spain by his *legati.* With the death of Pompey's wife Iulia (54) and of Crassus (53) the relations between him and Caesar became strained, and soon afterwards he drew closer to the conservative party and married into the house of Scipio. In 52, in the utter disorder that followed the death of Clodius, he was elected sole consul, carried through the trial of Milo, and started a programme of administrative and provincial legislation threatening Caesar's position.

Civil War.—The crisis arrived with the approaching end of Caesar's command at the end of 50. Pompey nearly compromised by accepting the Parthian command and leaving Rome, but Marcellus forced his hand, and civil war began. Pompey, wisely or unwisely, abandoned Italy. His cause, with that of the senate and aristocracy, was finally ruined by his defeat by Julius Caesar in 48 in the neighbourhood of Pharsalus. That same year he fled with the hope of finding a safe refuge in Egypt, but was treacherously murdered by one of his old centurions as he was landing. He was five times married, and three of his children survived him—Gnaeus, Sextus, and a daughter Pompeia.

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Modern: Histories of Rome in general (*see* ROME: *Ancient History ad fin.*); works quoted under CAESAR and CICERO. Also G. Boissier *Cicero and His Friends* (Eng. trans., A. D. Jones, 1897); J. L. Strachan-Davidson's *Cicero* (1894); Warde Fowler's *Julius Caesar* (1892); C. W. Oman, *Seven Roman Statesmen of the Later Republic* (1902); notes in Tyrrell and Purser's *Correspondence of Cicero.*

POMPONAZZI, PIETRO (PETRUS POMPONATIUS) (1462–1525), Italian philosopher, was born at Mantua on Sept. 16, 1462, and died at Bologna on May 18, 1525. He took his M.D.

at Padua in 1487 and was elected extraordinary professor of philosophy. From about 1495 to 1509 he occupied the chair of natural philosophy and when the schools of Padua closed, he took a professorship at Ferrara where he lectured on the *De anima.* From 1512 to his death he was at Bologna where he produced all his important works. In 1516 appeared his *De immortalitate animi,* which gave rise to a storm of controversy between the orthodox Thomists, the Averroists headed by Agostino Nifo, and the so-called Alexandrist School. The treatise was burned at Venice, and Pomponazzi himself ran serious risk of death. Two pamphlets followed, the *Apologia* and the *Defensorium,* wherein he explained his paradoxical position as Catholic and philosophic materialist. His last two treatises, the *De incantationibus* and the *De fato,* were posthumously published in an edition of his works printed at Basel.

See A. H. Douglas, *Philosophy and Psychology of Pietro Pomponazzi* (1910); J. A. Symonds, *The Renaissance in Italy;* L. Ferri, *La Psicologia di P. Pomponazzi* (1877); Überweg, *Grundriss der Gesch. der Philosophie* p. 1–3.

POMPOSA, an abbey of Emilia, Italy, in the province of Ferrara, 2 m. from Codigoro, which is 30 m. E. of Ferrara in the delta of the Po. The fine church, a work of the 6th century, rebuilt in the 11th, with interesting sculptures and terra cotta decorations on the façade and a splendid Romanesque campanile 163 ft. high (1063) contains a good mosaic pavement (1036) and interesting frescoes of the 14th century—a "Last Judgment" of the school of Giotto and others; and there are also paintings in the refectory. It was abandoned in 1650 on account of malaria.

See G. Agnelli, *Ferrara e Pomposa* (Bergamo, 1902), and F. R. Hiorns in *Journal of the Royal Institute of British Architects* xxxiv. (1927) 355 *sqq.*

POMPTINE MARSHES, a low tract of land in the province of Rome, Italy, varying in breadth between the Volscian mountains and the sea from 10 to 16 m., and extending north-west to south-east from Velletri to Terracina (40 miles). In ancient days this tract was fertile and contained prosperous cities (Suessa Pometia, Ulubrae—perhaps the mod. Cisterna—etc.), but it had already become unhealthy at the end of the Republican period. Attempts to drain the marshes were made by Appius Claudius in 312 B.C., when he constructed the Via Appia through them and at various times during the Roman period. A canal ran through them parallel to the road and was used in preference to the road during the Augustan period. Trajan repaired the road, and Theodoric did the same some 400 years later. But in the middle ages it had fallen into disrepair. Popes Boniface VIII., Martin V., Sixtus V., and Pius VI. all attempted to solve the problem, the last-named reconstructing the road admirably. By a law passed in 1919 the special provisions for the obligatory improvement of the Roman Campagna had been extended to the Pomptine territory.

See T. Berti, *Paludi pontine* (Rome, 1884); R. de la Blanchère, *Un Chapitre d'histoire pontine* (Paris, 1889).

PONCA CITY, a city of Kay county, Okla., U.S., on the Arkansas river, at an altitude of 1,000 ft., 90 mi. N. by E. of Oklahoma City. It is on federal highways 60 and 77; has a municipal airport; and is served by the Rock Island and the Santa Fe railways.

The population in 1950 was 20,180. It is the second largest city in the historic Cherokee Strip; the trading point for six Indian tribes; and the centre of a large oil-producing district. The two large refineries located there, the Continental Oil company and the Cities Service Oil company, have a combined capacity of 80,000 bbl. per day. Other industries in the city process agricultural products (wheat, dairy products and poultry); manufacture clothing, oil field drilling bits, farm equipment, and service diesel engines. The city is the home of the famous "Pioneer Woman" statue and Pioneer Woman State park, presented to the people of Oklahoma by Gov. E. W. Marland.

The first white settlement in what is now Oklahoma was Camp Ferdinand, a few miles northeast of Ponca City on the Arkansas river, established by French traders in the middle of the 18th century. Early in the 1880s, before Oklahoma was opened to white settlement, the town of Rock Falls was established 25 mi. N.W. of Ponca City, but the settlers were forced out of the territory by United States soldiers. Ponca City itself was established on Sept. 16, 1893, at the time of the opening of the Cherokee Strip. It took its name from the Ponca Indians, who were moved to Oklahoma by the government in 1879 and whose reservation lies 6 mi. S. of Ponca City. In 1950 the assessed valuation of the city was $10,000,000 and of the school district $28,000,000. The city's net bonded indebtedness was $527,000 and the value of municipally owned property was $3,441,000. The school district had a net bonded indebtedness of $401,000, and the value of school property was $2,000,000. There are no city taxes, all costs of operating the city government being met by the profit from the municipally owned water and light plants.

PONCE, the largest and most important city on the southern coast of Puerto Rico and the second city in size and importance on the island. The population in 1950 was 99,190. The population of the municipal district in 1950 was 126,451. Historians state that the city of Ponce was founded in 1762 and was made independent from the old town of San Blas de Illiscas (modern Coamo) in 1778. After that its growth increased and its importance was greatly magnified. Ponce was one of the first places at which U.S. forces landed in Puerto Rico during the Spanish-American War. They took possession of the city, after having entered into an agreement with the Spanish forces who withdrew into the interior of the island.

Ponce has an agreeable climate, the temperature being moderated by the constant breezes prevailing during the greater part of the year. Industrially and commercially it is one of the foremost cities of the island.

Ponce is the principal shipping port on the Carribbean sea, and has a large commerce with the southern islands and the northern countries of South America. Extensive improvements of the harbour were made under the direction of U.S. agencies.

Ponce is a well-managed city and its streets, plazas, parks and recreation grounds are well-kept and attractive. Its public buildings and private residences are well-built.

The city is on the line of the American railroad, and is the terminus of important highways, north, east and west. There is regular air service from San Juan. There are several banks and some important commercial and industrial firms, producing cigars and cigarettes, bay rum, mineral waters, hats, shoes, clothing, laces, embroidery, cut diamonds, foundry and iron products, ice, brick, chocolate, soap and candy. In 1948 the University of Santa María, a Catholic private institution, was founded at Ponce with donations for construction and operation.

(H. M. T.; J. L.-Ee.)

PONCE DE LEÓN, JUAN (*c.* 1460–1521), discoverer of Florida, was born in Servas, Spain, about 1460. He took part in the Moorish wars and then sailed for America with Columbus on his second voyage (1493). In 1509 he conquered Porto Rico and was appointed governor. As soon as the island was under control and pacified he set out with three ships to search for the land of "Bimini," wherein, as the Indian legend told him, there was a fountain with waters of marvellous curative power. On Mar. 27, 1513, he discovered the mainland which he named Florida because the day was Easter Sunday (*Pascua Florida*). He landed north of the present site of St. Augustine on April 2, and on April 8 took possession in the name of the Spanish king. He afterwards explored the coast southward to the cape and up the west shore of the peninsula to at least 27° 30′, and perhaps to where the coast trended westward. He returned to Spain in 1514, and received an appointment from Ferdinand V. as governor of "The Island of Florida." In 1521 he set out to conquer and colonize his possession but the fierceness of the natives prevented his success. In a sharp engagement Ponce de León was mortally wounded and his force driven to the ships. He died in Cuba in June 1521.

See F. A. Ober, *Ponce de León* (1908); Justin Windsor, *Narrative and Critical History of America,* vol. ii. chap. iv. (1886); "The Track of Ponce de León," *Amer. Geog. Soc. Bulletin, xlv.,* pp. 721–735 (1913); *Boletin histórico de Puerto Rico, Año I;* pp. 118–161 (1914).

PONCELET, JEAN VICTOR (1788–1867), French mathematician and engineer, was born at Metz on July 1, 1788. From 1808 to 1810 he attended the *École polytechnique*, and afterwards, till 1812, the *École d'application* at Metz. He then became lieutenant of engineers, and took part in the Russian campaign, during which he was taken prisoner and was confined at Saratov on the Volga until 1814, when he returned to France. During his imprisonment he began his researches on projective geometry which led to his great treatise on that subject. This work, the *Traité des propriétés projectives des figures*, which was published in 1822 (2d ed., 2 vols. 1865–66), is occupied with the investigation of the projective properties of figures (*see* GEOMETRY), and entitles Poncelet to rank as one of the greatest of those who took part in the development of the new geometry of which G. Monge was the founder. Poncelet developed the principle of Duality, and discovered the circular points at infinity, so causing the principle of continuity to be recognized. From 1815 to 1825 he was occupied with military engineering at Metz; and from 1825 to 1835 he was professor of mechanics at the *École d'application* there. In 1834 he became a member of the *Académie;* from 1838 to 1848 he was professor to the faculty of sciences at Paris, and from 1848 to 1850 commandant of the *École polytechnique*. He died at Paris on Dec. 22, 1867.

Poncelet's works include *Cours de méchanique, appliquée aux Machines* (1826); and *Mémoire sur les roues hydrauliques à aubes courbes* (1826). *See* J. Bertrand, *Éloge historique de Poncelet* (1875).

PONCHIELLI, AMILCARE (1834–1886), Italian musical composer, was born near Cremona on Sept. 1, 1834, and studied at the Milan Conservatoire. He attained his fame with *La Gioconda* (1876), written to a libretto founded by Arrigo Boito upon Victor Hugo's tragedy, *Angelo, Tyran de Padoue*. *La Gioconda* was followed by *Il Figliuol prodigo* (1880) and *Marion Delorme* (1885). In 1881 Ponchielli was made maestro di cappella of Piacenza cathedral. He died at Milan on Jan. 17, 1886.

POND, JOHN (*c.* 1767–1836), English astronomer-royal, was born about 1767 in London. After leaving Trinity college, Cambridge, he settled at Westbury near Bristol, and began to determine star-places with a fine altitude and azimuth circle of 2½ ft. diameter by E. Troughton. His demonstration in 1806 (*Phil. Trans.* xcvi. 420) of a change of form in the Greenwich mural quadrant led to the introduction of astronomical circles at the Royal Observatory, and to his own appointment as its head. He was elected a fellow of the Royal Society on Feb. 26, 1807; he married and went to live in London in the same year, and in 1811 succeeded Maskelyne as astronomer-royal.

Under Pond the instrumental equipment at Greenwich was completely changed, and the number of assistants increased from one to six. The superior accuracy of his determinations was attested by S. C. Chandler's discussion of them in 1894, in the course of his researches into the variation of latitude (*Astron. Journ.* Nos. 313, 315). Pond received many academic honours. He published eight folio volumes of *Greenwich Observations*, translated Laplace's *Système du monde* (in 2 vols. 8vo., 1809), and contributed thirty-one papers to scientific collections. His catalogue of 1,112 stars (1833) was of great value. He retired in 1835 and died at Blackheath on Sept. 7, 1836, and was buried beside Halley in the churchyard at Lee.

See *Mem. Roy. Astron. Soc.* x. 357; *Proc. Roy. Soc.* iii. 434; *Penny Cyclopaedia* (De Morgan); F. W. Bessel, *Pop. Vorlesungen*, p. 543; *Report Brit. Assoc.* i. 128, 136 (Airy); Sir G. Airy's *Autobiography*, p. 127; *Observatory*, xiii. 204, xxii. 357; *Annual Biography and Obituary* (1837); R. Grant, *Hist. of Phys. Astron.* p. 491; Royal Society's *Cat. Scient. Papers;* Maunder, *The Royal Observatory Greenwich*.

POND, a small pool of standing water; the name is usually applied to one for which the bed has been artificially constructed. The term is a variant of "pound" (*q.v.*), an enclosure.

PONDICHERRY, the capital of the French possessions in India, situated on the Coromandel or eastern coast, 122 mi. by rail S. of Madras. The territory, which is entirely surrounded by the British district of South Arcot, has an area of 113 sq.mi., with a population (1941) of 204,653. It is ruled by a governor, with a privy council, and a general council, and is represented in the French senate and chamber. The chief crops are dry grains, rice, earth-nuts and a little indigo. The territory is traversed by a branch of the South Indian railway from Villapuram. The town (pop. [1941] 53,101) is well laid out with fine public buildings, and lit by electricity; the water-supply is derived from artesian wells. There is a college, and a fine Court of Appeal building was erected.

Pondicherry was founded in 1683 by François Martin, on the site of a village given him by the governor of Gingee. In 1693 the Dutch took Pondicherry, but restored it, with the fortifications greatly improved, in 1697, at the peace of Ryswick. In 1748 Admiral Boscawen laid siege to it without success, but in 1761 it was taken by Colonel Coote from Lally. In 1763 it was restored to the French. In 1778 it was again taken by Sir Hector Munro, and its fortifications destroyed. In 1783 it was retransferred to the French, and in 1793 recaptured by the English. The treaty of Amiens in 1802 restored it to the French, but it was retaken in 1803. In 1816 it was restored to the French.

PONDO, a Kafir people who have given their name to Pondoland, the country comprising much of the seaboard of Kaffraria, Cape province, immediately to the south-west of Natal.

PONDWEED, a popular name for *Potamogeton natans*, a cosmopolitan aquatic plant found in ponds, lakes and ditches, with broad, more or less oblong-ovate, olive-green, floating leaves. The name is also applied to other species of *Potamogeton*, one of the characteristic genera of lakes, ponds and streams all over the world, but more abundant in temperate regions, embracing about 90 species. It is the principal genus of the family Potamogetonaceae, and contains plants with slender branched stems, and submerged and translucent, or floating and opaque, alternate or opposite leaves, often with membranous united stipules. The small flowers are borne above the water in axillary or terminal spikes; they have four stamens, which bear at the back four small herbaceous petal-like structures, and four free carpels, which ripen to form four small green fleshy fruits, each containing one seed within a hard inner coat; the seed contains a large hooked embryo. An allied genus *Zannichellia*, occurring in fresh and brackish ditches and pools in Great Britain and nearly throughout North America, and also widely elsewhere in temperate and tropical regions, is known as horned pondweed, from the curved fruit.

FROM STRASSBURGER, "LEHRBUCH DER BOTANIK FUR HOCHSCHULEN" (GUSTAV FISCHER)
PONDWEED (POTAMOGETON NATANS), SHOWING FLOWERING STEM AND LEAVES

See P. Ascherson and P. Graebuer, "Potamogetonaceae," *Pflanzenreich* 31 (iv, ii): 1–184, fig. 1–36 (1907).

PONGEE, a plain-weave fabric made of *tussah* or wild silk, originated with the Chinese in ancient times. Its sphere of usefulness has been broadened due chiefly to the increase in standard width from 18 to 36 or more inches, and the variety of colours extended. The Japanese buy from the Chinese the wild silk and work it up in their own plants. *Shantung*, a variety of pongee, derives its name from the province which is the centre of the wild silk industry. It differs from true pongee in that the former must be a plain weave, while Shantung may include many types, even adding coloured threads for decoration. Because of the ease with which they can be laundered and their durability pongees are among the most practical of silks.

PONIARD, a dagger, particularly one of small size, used for stabbing at close quarters. The French word *poignard*, from which the English is a 16th century adaptation, is formed from *poing*, fist, in which the weapon is grasped. (*See* DAGGER.)

PONIATOWSKI, the name of a Polish princely family of Italian origin, tracing descent from Giuseppe Torelli, who married about 1650 an heiress of the Lithuanian family of Poniatov, whose name he assumed.

STANISLAUS PONIATOWSKI (1677–1762), only belonged to the

family by adoption, being the reputed son of Prince Sapieha and a Jewess. He was born at Dereczyn in Lithuania, and was adopted by Sapieha's intendant, Poniatowski. Attaching himself to the party of Stanislaus Leszczynski, he became major-general in the army of Charles XII. of Sweden, who also employed him as diplomatic intermediary to the Sultan. He next became governor of the duchy of Zweibrücken, Bavaria. After the death of Charles XII. in 1718 he visited Sweden; and was subsequently reconciled with Leszczynski's rival on the throne of Poland, Augustus II., who made him grand treasurer of Lithuania in 1724. On the death of Augustus II. he tried to secure the reinstatement of Leszczynski, but presently gave his allegiance to Augustus III., by whom he was made governor of Cracow. He died at Ryki on Aug. 3, 1762.

His second son Stanislaus Augustus became king of Poland. (*See* STANISLAUS II.) Of the other sons, Casimir (1721–1780) was his brother's chancellor; Andrew (1735–1773) became feldzeugmeister in the Austrian service; and Michael (1736–1794) became archbishop of Gnesen and primate of Poland. Joseph Anthony (*q.v.*), son of Andrew, became one of Napoleon's marshals.

STANISLAUS PONIATOWSKI (1757–1833), son of Casimir, was grand treasurer of Lithuania, starost of Podolia and lieutenant-general of the royal army. In 1793 he settled in Vienna, and subsequently in Rome, where he made a magnificent collection of antique gems, subsequently sold. He died in Florence, Feb. 13, 1833, and the Polish and Austrian honours became extinct.

His natural, but recognized, son, JOSEPH MICHAEL XAVIER FRANCIS JOHN PONIATOWSKI (1816–1873), was born at Rome and in 1847 was naturalized as a Tuscan subject. He received the title of prince in Tuscany (1847) and in Austria (1850). He represented the court of Tuscany in Paris from 1848, and he was made a senator by Napoleon III., whom he followed to England in 1871. He also wrote numerous operas. He died on July 3, 1873. His son, Prince Stanislaus Augustus, married and settled in Paris. He was equerry to Napoleon III., and died in Jan. 1908.

PONIATOWSKI, JOSEPH ANTHONY (1763–1813), Polish prince and marshal of France, son of Andrew Poniatowski and the countess Theresa Kinsky, was born at Warsaw in 1763. He served with distinction in the imperial forces against the Turks in 1788, then becoming major-general and subsequently lieutenant general in the Polish army under his uncle, King Stanislaus. In 1789 he commanded the Ukrainian division; and after the proclamation of the constitution of May 3, 1791, was made commander-in-chief. Aided by Kosciuszko, he conducted the operations against Russia with much skill, but when the king acceded to the confederation of Targowica (*see* POLAND: *History*), at the same time guaranteeing the adhesion of the army, Poniatowski, and most of the other generals threw up their commissions and emigrated. During the Kosciuszko rising he again fought gallantly for his country under his former subordinate, and after the fall of the republic lived in retirement. After the evacuation of the Polish provinces by Prussia, Poniatowski became commander of the National Guard, and on the creation of the grand duchy of Warsaw he was nominated war minister.

During the war of 1809, he operated successfully against the Austrians. In Napoleon's campaign against Russia in 1812 Poniatowski commanded the fifth army corps; and after the disastrous retreat of the grand army remained faithful and formed a new Polish army of 13,000 men, with which he joined the emperor at Lützen. In 1813 he guarded the passes of the Bohemian mountains and defended the left bank of the Elbe. As a reward for his brilliant services at Leipzig he was made a marshal of France and entrusted with the duty of covering the retreat of the army, in the course of which he perished, fighting heroically against overwhelming odds. His relics were conveyed to Poland and buried in Cracow Cathedral, where he lies by the side of Tadeusz Kosciuszko and Jan Sobieski. Poniatowski's *Mes souvenirs sur la campagne de 1792* (Lemberg, 1863) is of historical value.

See *Correspondence of Poniatowski* (ed. E. Raczynski, Posen, 1843); Bronislaw Dembinski, *Stanislaus Augustus and Prince Joseph Poniatowski in the light of their Correspondence* (Fr.; Lemberg, 1904); Szymon Askenazy, *Prince Joseph Poniatowski* (Pol.; Warsaw, 1905).

PONS, JEAN LOUIS (1761–1831), French astronomer, was born at Peyres (Hautes Alpes) on Dec. 24, 1761. He entered the Marseilles observatory in 1789, and in 1819 became the director of the new observatory at Marlia near Lucca, which he left in 1825 for the observatory of the museum at Florence. Here he died on Oct. 14, 1831. He spent his time searching for comets, of which he discovered a record number; some bear his name, *e.g.*, Pons-Winnecke's comet.

See M. R. A. Henrion, *Annuaire biographique*, i. 288 (1834); *Memoirs Roy. Astron. Soc.* v. 410; R. Wolf, *Geschichte der Astronomie*, p. 709; J. C. Poggendorff, *Biog. lit. Handwörterbuch.*

PONSARD, FRANÇOIS (1814–1867), French dramatist, was born at Vienne, Isère, on June 1, 1814, and studied law. His translation of *Manfred* was published in 1837. His play *Lucrèce* was represented at the Théâtre Français on April 1, 1843. This date marks a reaction against the romantic style of Dumas and Hugo. He received, in 1845, the Academy's prize for a tragedy "to oppose a dike to the waves of romanticism." Ponsard combined the liberty of the romantics with the sober style of earlier French drama. The success of his plays was aided by the impersonation of many of the principal rôles in them by Rachel. He followed up *Lucrèce* with *Agnès de Méranie* (1846), *Charlotte Corday* (1850), and others. *L'Honneur et l'argent*, one of his most successful plays, was acted in 1853, and he became an academician in 1855. In 1866 he obtained great success with *Le Lion Amoureux*, another play dealing with the revolutionary epoch. His *Galilée*, which excited great opposition in the clerical camp, was produced in 1867. He died in Paris on July 7, 1867.

His *Oeuvres complètes* were published in Paris (3 vols., 1865–76). *See* C. Latreille, *La Fin du théâtre romantique et François Ponsard d'après des documents inédits* (1899).

PONSONBY OF SHULBREDE, ARTHUR AUGUSTUS WILLIAM HARRY PONSONBY, 1ST BARON (1871–1946), British author and politician, was born on Feb. 16, 1871, and educated at Eton and at Balliol college, Oxford. In 1894 he entered the diplomatic service, and after holding posts in Constantinople and Copenhagen, returned in 1902 to join the staff of the foreign office. In 1906 he became principal private secretary to Sir Henry Campbell-Bannerman, and in 1908 was elected Liberal M.P. for Stirling. He represented this constituency until 1918, and in 1922 was elected Labour member for the Brightside division of Sheffield, and held minor posts in the Labour governments of 1924 and 1929–31. He was raised to the peerage in 1930, and was leader of the opposition in the house of lords from 1931 to 1935. He died at Hindhead, Surry, March 24, 1946.

His works include *The Decline of Aristocracy* (1912); *Democracy and Diplomacy* (1915); *Wars and Treaties (1815–1914)* (1917); *Now is the Time* (1925); *Life Here and Now* (1936).

PONSONBY, English family. PONSONBY, JOHN (1713–1789), Irish politician, was born on March 29, 1713. In 1739 he entered the Irish parliament, where he became first commissioner of the revenue (1744), a privy councillor (1746), and in 1756 Speaker. Belonging to one of the great families which at this time monopolized the government of Ireland, Ponsonby was one of the principal "undertakers," men who controlled the whole of the king's business in Ireland, and he retained the chief authority until the marquess Townshend became lord-lieutenant in 1767. A struggle for supremacy between the Ponsonby faction and the party dependent on Townshend followed, which caused Ponsonby to resign the speakership in 1771. He died on Dec. 12, 1789. His wife was Elizabeth, daughter of William Cavendish, 3rd duke of Devonshire, a connection of advantage to the Ponsonbys.

Ponsonby's third son, GEORGE PONSONBY (1755–1817), lord chancellor of Ireland, was born on March 5, 1755, and educated at Trinity College, Cambridge. A barrister, he became a member of the Irish parliament in 1776 and was chancellor of the Irish exchequer in 1782, afterwards taking part in the debates on the question of Roman Catholic relief, and leading the opposition to the union of the parliaments. Ponsonby represented Wicklow and then Tavistock in the united parliament; in 1806 he was lord chancellor of Ireland, and from 1808 to 1817 he was the official leader of the opposition in the House of Commons.

He left an only daughter when he died in London on July 8, 1817.

George Ponsonby's elder brother, WILLIAM BRABAZON PONSONBY, 1st Baron Ponsonby (1744–1806), was also a leading Whig politician, being a member of the Irish and, after 1800, of the British parliament. In 1806, shortly before his death, he was created Baron Ponsonby of Imokilly. On the death of his grandson, WILLIAM BRABAZON PONSONBY (1807–1866), the barony became extinct.

PONTA DELGADA, the capital of an administrative district, comprising the islands of St. Michael's and St. Mary in the Portuguese archipelago of the Azores. Pop. (1940) 21,048. Ponta Delgada is built on the south coast of St. Michael's, in 37° 40′ N. and 25° 36′ W. Its mild climate and the fine scenery of its mountain background render it very attractive to visitors; it is the commercial centre and the most populous city of the archipelago.

Great improvements in the harbour were effected after 1860 by the construction of a breakwater 2,800 ft. long.

PONT-À-MOUSSON, a town of northern France in the department of Meurthe-et-Moselle, 17 mi. N.N.W. of Nancy by rail. Pop. (1946) 10,278. Dating from the 9th or 10th century, Pont-à-Mousson constituted a lordship, which was made a marquisate in 1354. It was from 1572 to 1763 the seat of a well-known university. The Moselle, which is canalized, divides the town into two quarters, united by a 16th-century bridge. The church of St. Martin dates from the 13th, 14th and 15th centuries. The lower ecclesiastical seminary occupies the building of an old Premonstratensian convent.

PONTANUS, JOVIANUS (1426–1503), Italian humanist and poet, was born in 1426 at Cerreto, in the duchy of Spoleto, and educated, after the death of his father in a civil disturbance, at Perugia. At the age of 22 he went to Naples, where he remained for the rest of his life. He became a friend of the famous scholar Antonio Beccadelli, and was introduced by him to Alphonso the Magnanimous, who made him tutor to his sons. Thereafter he was political adviser, military secretary and chancellor to the Aragonese dynasty. He illustrates very clearly the importance of men of letters in Italy. He arrived in Naples a penniless scholar, and became almost immediately one of the most important men in the kingdom. He founded an academy for the meetings of scholars in Naples, which lasted long after his death. In 1461 he married Adriana Sassone, who bore him one son and three daughters and died in 1491. Soon after this he married a girl from Ferrara, known to us only as Stella. He was passionately fond of wife and children, and much of his verse, especially *Eridanus,* written after his second marriage, tells of his love for them.

Pontanus outlived Stella also, and died in 1503 at Naples, where a group of life-size terra-cotta figures is still to be seen on his tomb at Monte Oliveto church. Pontanus had a good Latin style and the faculty, rare among his contemporaries, of expressing the facts of modern life, the actualities of personal emotion, in language sufficiently classical yet always characteristic of the man. His ambitious *Urania* embodies the astronomy of the day. His most original compositions in verse, however, are elegiac and hendecasyllabic pieces on personal topics—the *De conjugali amore, Eridanus, Tumuli, Naeniae, Baiae, etc.*—in which erotic freedom is condoned by a passionate sincerity. Pontanus' prose and poems were printed by the Aldi at Venice. For his life *see* Ardito, *Giovanni Pontano e i suoi tempi* (Naples, 1871); for his place in the history of literature, J. A. Symonds, *Renaissance in Italy* (1875, etc.).

PONTARLIER, a frontier town of eastern France, 36 mi. S.E. of Besançon. Pop. (1946), 12,722. It is situated 2,750 ft. above sea level on the Doubs, about 4 mi. from the Swiss frontier, and forms an important strategic point at the mouth of the defile of La Cluse, one of the principal passes across the Jura.

Pontarlier is the junction of railway lines to Neuchâtel, Lausanne, Lons-le-Saunier, Dôle and Besançon. At Pontarlier the French army of the east made its last stand against the Prussians in 1871 before crossing the Swiss frontier.

The distillation of herbs, largely grown for kirsch and other liqueurs, is the chief industry.

PONT AUDEMER, a town of northwestern France, in the department of Eure, 39 mi. N.W. of Evreux, on the railway to Honfleur. Pop. (1946) 6,119. The town owes its name to Audomar, a Frankish lord, who in the 7th or 8th century bridged the Risle there. The church of St. Ouen, which has fine stained glass of the 16th century, combines the late Gothic and Renaissance styles; its choir is Romanesque. Manufacturing includes malleable metal founding, glue, leather goods and paper and cotton spinning. There is trade in flax, wool, grain, cattle, cider, paper, iron, wood and coal. The port has a length of more than one-half mile on the Risle, which is navigable for small vessels from this point to the Seine (10 mi.).

PONTECORVO, a city of Lazio, It., in the province of Frosinone, on the Garigliano, about 48 mi. from Caserta and 3 mi. from Aquino on the railway from Rome to Naples. Pop. (1936) 14,437 (town and the commune). The principality of Pontecorvo (about 40 sq.mi. in extent), once an independent state, belonged alternately to the Tomacelli and the abbots of Monte Cassino. Napoleon bestowed it on Bernadotte in 1806, and in 1810 it was incorporated with the French empire.

PONTÉCOULANT, LOUIS GUSTAVE LE DOULCET, COMTE DE (1764–1853), French politician, was born at Caen on Nov. 17, 1764. He entered the army in 1778. A moderate supporter of the revolution, he was returned to the convention for the department of Calvados in 1792 and became commissary with the army of the north. He attached himself to the party of the Gironde, and in Aug. 1793 was outlawed. He refused to defend his compatriot Charlotte Corday, who wrote him a letter of reproach on her way to the scaffold. He returned to the convention on March 8, 1795, and became its president in July; he was for several months a member of the council of public safety. He was elected to the council of 500, but was suspected of royalist leanings, and spent some time in retirement before the consulate. Becoming senator in 1805, and count of the empire in 1808, he organized the national guard in Franche-Comté in 1811 and the defense of the northeastern frontier in 1813. He sat in the upper house under the restoration. He died in Paris on April 3, 1853.

See his *Souvenirs historiques et parlementaires 1764–1848,* 4 vol. (1861–65).

PONTEFRACT (pronounced and sometimes written "Pomfret"), market town, municipal borough, in the West Riding of Yorkshire, Eng., 21 mi. S.W. from York, served by the London Midland Region railway. Pop. (1951) 23,173. Area, 7.6 sq.mi. It is well situated on an eminence near the junction of the Aire and the Calder. The most important remains are those of the famous castle, situated on a rocky height and containing eight round towers. The remains are principally of Norman date, and an unusual feature is the existence of various subterranean chambers in the rock. Below the castle is All Saints church, which suffered severely during the siege of the castle but still retains some work of the 12th century. In 1837 the tower and transepts were fitted for divine service. In Southgate is an ancient hermitage and oratory, cut from the solid rock, which dates from 1396. At Monkhill there are the remains of a Tudor building called the Old hall. A grammar school of ancient foundation, renewed by Elizabeth and George III, occupies modern buildings. The town hall (18th century) occupies the site of one erected in 1656, which succeeded the old moot hall dating from Saxon times. Among other buildings are the courthouse, the market hall, the assembly rooms and large barracks. The foundation of the principal almshouse, that of St. Nicholas, dates from before the Conquest. Trinity hospital was founded by Sir Robert Knolles (d. 1407). At Ackworth is a Society of Friends' school (1778), in the foundation of which John Fothergill (1712–80) was a prime mover. There are extensive gardens and nurseries in the neighbourhood of Pontefract, and liquorice is grown for the manufacture of the celebrated Pomfret cakes. The town possesses iron foundries, sack and matting manufactories, tanneries, breweries, corn mills and brick and terra-cotta works.

The remains of a Roman camp have been discovered near Pon-

tefract. At the time of the Domesday Survey Tateshall (now Tanshelf, a suburb of the town) was the chief manor while Kirkby, afterwards the borough of Pontefract, was one of its members. The change of status was probably owing to the founding by Ilbert de Lacy, of a castle at Kirkby. The town was known as Pontefract in 1140 when Archbishop Thurstan died there. The manor remained in the Lacy family until it passed by marriage to Thomas, duke of Lancaster, who was beheaded after the battle of Boroughbridge. His estates were restored to his brother Henry, earl of Lancaster, on the accession of Edward III., and the manor thereafter formed part of the duchy of Lancaster. The town took part in most of the rebellions in the north of England, and in 1399 Richard II. was imprisoned and secretly murdered in the castle. During the Wars of the Roses the town was loyal to Henry VI., and several of the Yorkist leaders were executed here after the battle of Wakefield. It was taken by Robert Aske, leader of the Pilgrimage of Grace, in 1536. In 1642 the castle was garrisoned for Charles I. and sustained four sieges, the second in 1644, being successful, but two years later it was retaken by the royalists, who held it until after the execution of the king, when they surrendered to General Lambert and the castle was destroyed.

Roger de Lacy in 1194 granted a charter and in 1484 Richard III. incorporated the town. The market rights are still held under his charter. The privilege of returning two members to parliament which had belonged to Pontefract at the end of the 13th century was revived in 1620–21. Between 1885 and 1918 it returned one member, when its representation was merged in that of the county, its name being given to the division.

PONTEVEDRA, a maritime province of northwestern Spain, before 1833 a part of Galicia. Pop. (1950), 661,432; area, 1,695 sq.mi., with a density of population, 390.2 inhabitants per square mile. The surface is mountainous. The coast line is deeply indented; navigation is rendered difficult by fogs in summer and storms in winter. Large agricultural fairs are held in the chief towns, and there is export of cattle, hams, salt meat and fish, eggs, breadstuffs, leather and wine. Vigo is the chief port and there are harbours at Bayona, Carril, Marin, Villagarcia and elsewhere among the deep estuaries of the coast. At Tuy the Spanish and Portuguese railways meet.

PONTEVEDRA, the capital of the Spanish province of Pontevedra; on the Tuy-Corunna railway, and on the river Lerez, which here enters the Ria de Pontevedra, an inlet of the Atlantic. Pop. (1950) 20,200 (mun., 51,933). The name of the town is derived from the ancient Roman bridge (*pons vetus*) of twelve arches, which spans the Lerez near its mouth. Pontevedra is mainly built of granite, and still partly enclosed by mediaeval fortifications. There is an active trade in grain, wine and fruit; cloth, hats, leather and pottery are manufactured.

PONTIAC (*c.* 1720–1769), famous chief of the Ottawa Indians and leader in the "Conspiracy of Pontiac" in 1763–64, was born about 1720, probably on the Maumee river, in what is now northwestern Ohio. His father was an Ottawa, and his mother an Ojibwa. By 1755 he had become a chief of the Ottawa and a leader of the loose confederacy of the Ottawa, Potawatomi and Ojibwa. As an ally of France, he possibly commanded the Ottawa in the defeat (1755) of Gen. Braddock. In 1760 he met Maj. Robert Rogers, then on his way to occupy Michilimackinac and other forts surrendered by the French, and agreed to let the English troops pass unmolested on condition that he should be treated with respect by the British. Like other Indians he soon realized the difference between French and English rule—that the Indians were no longer welcomed at the forts and that they would ultimately be deprived of their hunting grounds by encroaching English settlements. French hunters and traders encouraged Indian disaffection with vague promises of help from France; and in 1762 Pontiac enlisted the support of practically all the Indian tribes from Lake Superior to the lower Mississippi for a joint move to expel the British. He arranged for each tribe to attack the fort nearest to it in May 1763, and then to combine to wipe out the undefended settlements. Pontiac himself decided to capture Detroit, but his carefully laid plans for a surprise attack on May 9 were betrayed to the commanding officer, Maj. Gladwin, and he was forced to lay siege to the fort. The siege continued for five months, marked by desultory attacks and sorties. Schooners sent through Lake Erie with supplies and provisions were captured by the Indians, but Pontiac could not prevent reinforcements from Fort Niagara under Capt. Dalzell from reaching Detroit. However, when the besieged made a night attack on the Indian encampment, Pontiac, apprised of their coming, inflicted heavy losses on them at Bloody Run, July 31. The Indians were unused to making long sieges and, after a few months, several of the associated tribes made peace. With his own Ottawa, Pontiac continued to camp around Detroit until Oct. 30 when, hearing that no aid from the French could be expected owing to the signing of the peace treaty with the English, he withdrew to the Maumee river.

Pontiac's larger plan was more successful. Of the 12 fortified posts attacked by the Indians, all but four were captured; most of the garrisons were massacred; several relief expeditions were nearly annihilated, and the frontiers were desolated and plundered. Col. Bouquet, however, succeeded in defeating the Indians at Bushy Run, when on his way to relieve Forts Pitt and Ligonier, and in 1764, he led a second expedition into Ohio from Pennsylvania, and forced the Indian tribes to sue for peace and release their prisoners. Pontiac still hoped to arouse other tribes to continue the fight, but after another year he saw that the English were the real masters of the situation and, on behalf of the tribes lately banded in his league, he concluded a treaty of peace and amity with Sir William Johnson at Oswego, N.Y., July 25, 1766. Pontiac, laden with gifts from the enemy, returned to his home on the Maumee. He met his death in 1769 at the hands of an Illinois Indian bribed by an English trader to murder him at Cahokia (nearly opposite St. Louis). His death occasioned a bitter war among the Indians, and the Illinois group was all but annihilated by his avengers. Pontiac was one of the most remarkable men of the Indian race in American history, possessing a commanding energy and force of mind combined with subtlety and craft, and a power of organization.

BIBLIOGRAPHY.—*See* Francis Parkman, *The Conspiracy of Pontiac* (Boston, 1851; 10th ed., 1905); *Handbook of American Indians* (Bureau of American Ethnology, vol. ii., 1910).

PONTIAC, a city of Illinois, U.S., on the Vermilion river, 92 mi. S.W. of Chicago; the county seat of Livingston county. It is on highways 66, 116 and 23, and is served by the Gulf, Mobile and Ohio, the Illinois Central and the Wabash railways. Pop. 8,990 in 1950; 1940 population 9,585 by the federal census. It is the trading and shipping point for a rich agricultural region. Creameries, hatcheries, shoe, heel and glove factories, hybrid seed companies, limestone quarries and printing are its chief industries. It is the seat of a state penitentiary. The city was founded in 1837 and incorporated in 1872.

PONTIAC, a city of Michigan, U.S., 26 mi. N.W. of Detroit, on federal highways 10 and 24 and state highway 59; the county seat of Oakland county. It is served by the Grand Trunk Western railroad and by intercity motor coach and truck lines. The population in 1950 was 73,681; in 1940, 66,626, by federal census. Pontiac is an important automobile manufacturing centre in the midst of a picturesque summer resort region. There are 11 state parks and 1 county park in the county, which contains more than 400 lakes. At Orchard lake (5 mi. S.E.) is Apple Island, formerly the home of the famous Chief Pontiac, and on its shores are ancient burial grounds of the Sac, Huron and Wyandot Indians. The city's industries include automobiles, motor trucks, motor coaches, automobile engines, bodies, parts and accessories, drop forgings, tools and dies, paints and varnishes. The city has a land area of 19.8 sq.mi. and had an assessed property valuation in 1950 of $140,965,315.

There are more than 800 retail establishments. The city operates a municipal airport, 6 parks, 1 golf course, 26 schools with an enrolment of 14,837, and a public library. The Eastern State hospital for the insane is there. Pontiac was first settled in 1818, became the county seat in 1820 and was chartered as a city in 1861.

PONTIANUS, pope from 230 to 235. He was exiled to Sardinia by the emperor Maximinus, and in consequence of this sen-

tence resigned (Sept. 28, 235). He was succeeded by Anteros.

PONTIFEX. The *collegium* of the *pontifices* was the most important priesthood of ancient Rome, being specially charged with the administration of the *jus divinum; i.e.,* that part of the civil law which regulated the relations of the community with the deities recognized by the State officially, together with a general superintendence of the worship of gens and family. The name is clearly derived from *pons* and *facere,* but whether this indicates any special connexion with the sacred bridge over the Tiber (*Pons Sublicius*) cannot now be determined. The college existed under the monarchy, when its members were probably three in number; they may be considered as legal advisers of the *rex* in all matters of religion. Under the republic they emerge into prominence under a *pontifex maximus,* who took over the king's duties as chief administrator of religious law, just as his chief sacrificial duties were taken by the *rex sacrorum;* his dwelling was the *regia,* "the house of the king." During the republican period the number of *pontifices* increased, probably by multiples of three, until after Sulla (82 B.C.) we find them 15; for the year 57 B.C. we have a complete list of them in Cicero (*Harusp. resp.* 6, 12). Included in the *collegium* were also the *rex sacrorum,* the *flamines,* three assistant *pontifices* (*minores*), and the vestal virgins, who were all chosen by the *pontifex maximus.* Vacancies in the body of *pontifices* were originally filled by co-optation; but from the second Punic war onwards the *pontifex maximus* was chosen by a peculiar form of popular election, and in the last age of the republic this held good for all the members. They all held office for life.

The immense authority of the *college* centred in the *pontifex maximus,* the other *pontifices* forming his *consilium* or advising body. His functions were partly sacrificial or ritualistic, but these were the least important; the real power lay in the administration of the *jus divinum,* the chief departments of which may briefly be described as follows: (1) the regulation of all expiatory ceremonials needed as the result of pestilence, lightning, etc.; (2) the consecration of all temples and other sacred places and objects dedicated to the gods by the State through its magistrates; (3) the regulation of the calendar both astronomically and in detailed application to the public life of the State; (4) the administration of the law relating to burials and burying-places, and the worship of the Manes, or dead ancestors; (5) the superintendence of all marriages by *confarreatio; i.e.,* originally of all legal patrician marriages; (6) the administration of the law of adoption and of testamentary succession. They had also the care of the State archives, of the lists of magistrates, and kept records of their own decisions (*commentarii*) and of the chief events (*annales*).

It is obvious that a priesthood with such functions and holding office for life, must have been a great power in the State, and for the first three centuries of the republic it is probable that the *pontifex maximus* was in fact its most powerful member. The office might be combined with a magistracy, and, though its powers were declaratory rather than executive, it may be described as quasi-magisterial. Under the later republic it was coveted chiefly for the great dignity of the position; Julius Caesar held it for the last 20 years of his life, and Augustus took it after the death of Lepidus in 12 B.C., after which it became inseparable from the office of the reigning emperor.

See Marquardt, *Staatsverwaltung,* iii. 235 *et seq.;* Wissowa, *Religion u. Kultus der Römer,* 501 *seq.;* Bouché-Leclercq, *Les Pontifes,* passim.

PONTIVY, a town of W. France, in the department of Morbihan. Pop. (1936) 7,109. Pontivy had its origin in a monastery founded in the 7th century by St. Ivy of Lindisfarne. The town, at the confluence of the Blavet with the Nantes-Brest canal, has distinct parts—the old town and that to the south known as Napoléonville and built by Napoleon I as military headquarters for Brittany.

The ancient castle (1485) of the dukes of Rohan, whose capital the town was, is a museum.

PONT-L'ABBÉ, a town of western France in the department of Finistère, 13 mi. S.W. of Quimper by rail. Pop. (1936) 5,578. The town stands on the right bank of the estuary of Pont-l'Abbé, 2 mi. from the sea. Its port carries on fishing, imports timber, coal, etc., and exports mine-props and the cereals and vegetables of the neighbourhood. There is a church of the 14th, 15th and 16th centuries, once attached to a Carmelite convent; an old castle is occupied by the *hôtel de ville.* The local costumes, trimmed with the bright-coloured embroideries for which the town is noted, are among the most striking in Brittany; the *bigouden* or headdress of the women has given its name to the inhabitants.

PONTOISE, a town of northern France, capital of an arrondissement of the department of Seine-et-Oise, 18 mi. N.W. of Paris on the railway to Dieppe. Pop. (1936) 11,959. Pontoise existed in the time of the Gauls as *Briva Isarae* (Bridge of the Oise). It was destroyed by the Normans in the 9th century, united with Normandy in 1032, and acquired by Philip I. in 1064. Capital of the French Vexin, it played a conspicuous part in the wars between the French and the dukes of Normandy and in the Hundred Years' War. The English took it in 1419, and again in 1437. In 1441 Charles VII. took it by storm after a three months' siege. After belonging to the count of Charolais down to the Treaty of Conflans, it was given as a dowry to Jeanne of France when she was divorced by Louis XII. The parlement of Paris several times met in the town; and in 1561 the states-general convoked at Orléans removed thither after the death of Francis II. During the Fronde it offered a refuge to Louis XIV. and Mazarin. Henry III. made it an apanage for his brother the duke of Anjou. Later it passed to the duke of Conti. Down to the Revolution it remained a monastic town.

Two churches alone remain: St. Maclou, a 12th century church, restored in the 15th and 16th centuries, and containing a fine holy sepulchre of the 16th century; and Notre-Dame, of the close of the 16th century, with the tomb of St. Gautier, abbot of Meulan in the 12th century. Trade is in grain and in flour ground by numerous water-mills on the Viosne; a well-known fair is held in November. At Mériel, near Pontoise, there are remains of the 12th century Cistercian abbey of Le Val.

PONTOPPIDAN, ERIK (1698–1764), Danish author, was born at Aarhus on Aug. 24, 1698. He studied divinity at the University of Copenhagen, and for some time acted as a travelling tutor. In 1735 he became one of the chaplains of the king. In 1738 he was made professor extraordinary of theology at Copenhagen, and in 1745 bishop of Bergen. He died on Dec. 20, 1764.

His principal works are: *Theatrum Daniae veteris et modernae* (4to, 1730), a description of the geography, natural history, antiquities, etc., of Denmark; *Gesta et vestigia danorum extra Daniam* (3 vols. 8vo, 1740), a laborious but uncritical work; *Annales ecclesiae danicae* (3 vols., 1741–1747); *Marmora danica selectiora* (2 vols. fol., 1739–41); *Glossarium norvegicum* (1749); *Det förste forsög Norges naturlige historie* (4to, 1752–54); Eng. trans., *Natural History of Norway* (2 vols., 1755), containing curious accounts, often referred to, of the Kraaken, sea-serpent, and the like; *Origines hafnienses* (1760); *Menoza* (3 vols., 1742–43), a religious novel. His *Danske Atlas* (7 vols. 4to), is an historical and topographical account of Denmark.

See S. M. Gjellerup in *Dansk Biografisk Lexikon* (vol. xiii., 1899).

PONTOPPIDAN, HENRIK (1857–1943), Danish author, was born at Fredericia on July 24, 1857. He studied at the university of Copenhagen, and when he was 18 travelled on foot through Germany and Switzerland. His novels show an intimate acquaintance with peasant life and character, the earlier ones showing clear evidence of the influence of Kjelland. An excellent example of his work is the trilogy dealing with the history of Emanuel Hansted, a theorizing radical parson who marries a peasant wife. These three stories, *Muld* ("Soil," 1891), *Det Forjaettede Land* ("The Promised Land," 1892) and *Dommens Dag* (1895) are marked by fine discrimination and great narrative power. Among his other works are *Fra Hytterne* (1887), *Folkelivsskildringer* (2 parts, 1888–90) and *Skyer* (1890). He began in 1898 a new series in *Lykke Per,* the story of a typical Jutlander, completed in 1904. In 1912–16 appeared his trilogy, *De Dodes Rige,* dealing with the first decade of the 20th century. In 1917 he shared with Gjellerup the Nobel prize for literature. He died Aug. 21, 1943, in Charlottenlund, Denmark.

See an article of Niels Möller in *Dansk Biografisk Lexikon* (vol. xiii., 1899); also V. Andersen, *Henrik Pontoppidan* (Copenhagen, 1917).

PONTORMO, JACOPO DA (1494–1556), was one of the leading representatives of the late Florentine school of painting, which, though nearing exhaustion, still reflected the

traditions of the great age. He was born at Pontormo, near Empoli, on May 24, 1494, and was the son of Bartolommeo Carucci, a painter. He was apprenticed to Leonardo da Vinci, and afterwards to Albertinelli and Piero di Cosimo. At the age of 18 he entered the workshop of Andrea del Sarto and was remarked as a young man of exceptional promise. One of his earliest works extant, painted in 1516, is the fresco in the vestibule of S. Annunziata, Florence, representing the "Visitation." Two years later he completed the altarpiece in the church of S. Michele Visdomini. From this early period of the master date three small pictures painted for the mansion of Piero Franceschi Borgherini of Florence. One of these, representing "Joseph and his Kindred in Egypt," is now in the National Gallery, London. It was regarded by Vasari as Pontormo's best picture. The other two panels, also of the story of Joseph, are with Lady Desborough at Panshanger. In 1521 he was employed on decorative work in the Medicean villa at Poggio a Caiano. He was then at the height of his powers, and a fresco painted in a large lunette with mythological figures may be regarded as one of his most successful achievements. He then took to imitating Dürer, whose engravings and woodcuts were circulating in Italy. In 1522 he executed at the Certosa di Val d'Erna a series of frescoes founded on the Passion subjects of the German master. Pontormo's last works were a series of frescoes for the church of S. Lorenzo, Florence. He had then fallen under the dangerous influence of Michelangelo's style. After working on these for 11 years he left them incomplete. He died in Florence on Jan. 2, 1556.

See Vasari, *Vite*, edit. Milanesi.

PONTREMOLI, a town and bishop's see in Tuscany, Italy, in the upper valley of the Magra, 843 ft. above sea-level. Pop. (1936), 3,801 (town); 14,537 (commune). The town has a castle and walls, with the church of the Annunziata and its Augustinian monastery.

PONTRESINA (5,915 ft.), a village of the upper Engadine in the canton of Graubünden (Grisons), Switzerland, a station on the Rhaetic railway which goes over the Bernina pass. It is an important health resort and winter sport centre at the foot of the Bernina alps. Its 984 inhabitants are German-speaking.

PONTUS, a district in the north-east of Asia Minor bordering on the Euxine (Black Sea). About 301 B.C. Mithradates I., *Ktistes*, founded a kingdom beyond the Halys ruled by a succession of kings, mostly bearing the same name, till 64 B.C. As the greater part of this kingdom lay within Cappadocia, which extended from the borders of Cilicia to the Euxine, the kingdom was at first called "Cappadocia towards the Pontos" (*πρὸς τῷ Πόντῳ*), but afterwards simply "Pontus." Under the last king, Mithradates the Great, the realm of Pontus included not only Pontic Cappadocia but also the seaboard from the Bithynian frontier to Colchis, part of inland Paphlagonia, and Lesser Armenia (*see* MITHRADATES). After Pompey's conquest part of the kingdom was annexed to the Roman empire, being united with Bithynia in a double province called "Pontus and Bithynia"; this part included the seaboard between Heracleia (*Eregli*) and Amisus (*Samsun*), the *Ora pontica*. Hereafter the simple name Pontus was employed to denote the half of this dual province.

Its native population was of the same stock as that of Cappadocia, an oriental race called by the Greeks *Leucosyri* or White Syrians, but their precise ethnological relations are uncertain. It is a table-land, forming the north-east corner of the great plateau of Asia Minor, edged on the north by a lofty mountain rim, along the foot of which runs a fringe of coast-land. The table-land consists of a series of fertile plains, drained almost entirely by the river Iris (*Yeshil Irmak*) and its tributaries. Between the Halys and the Iris the mountain rim is comparatively low and broken, but east of the Iris it is a continuous lofty ridge, the rugged northern slopes of which are furrowed by torrent beds. These inaccessible slopes were inhabited in Strabo's time by wild, half-barbarous tribes, of whose ethnical relations we are ignorant—the Chalybes, Tibareni, Mosynoeci, and Macrones, on whose manners and condition some light is thrown by Xenophon (*Anab.* V.). But the fringe of coast-land from Trebizond westward is one of the most beautiful parts of Asia Minor.

The seacoast was studded with Greek colonies founded from the 6th century onwards: Amisus, a colony of Miletus, Cotyora, Cerasus, and Trapezus (*Trebizond*), a famous city from Xenophon's time until the end of the middle ages. The last three were colonies of Sinope, itself a Milesian colony. The chief towns in the interior were Amasia, on the Iris, the birthplace of Strabo, the capital of Mithradates the Great, and the burial place of the earlier kings, whose tombs still exist; Comana, higher up the river, a famous centre of the worship of the goddess Ma (Cybele, *q.v.*); and Zela, a religious centre, refounded by Pompey, now Zīleh.

Christianity was introduced into the province Pontus (the *Ora pontica*) by way of the sea in the 1st century after Christ and was deeply rooted when Pliny governed the province (A.D. 111–113). But the Christianization of the inland Pontic districts began only about the middle of the 3rd century and was largely due to the zeal of Gregory Thaumaturgus, bishop of Neocaesarea.

See Ramsay, *Histor. Geogr. of Asia Minor* (1890); Anderson and Cumont, *Studia pontica* (1903 *et seq.*); Babelon and Reinach, *Recueil des monnaies d'Asie min.*, t.i. (1904); *Cambridge Ancient History*, vol. iii. ch. xxv. (bibliography).

PONTUS DE TYARD (1521?–1605), French poet and member of the Pléiade (*see* DAURAT), was seigneur of Bissy in Burgundy, where he was born in or about 1521. He belonged to the Lyons group of poets and was a friend of Antoine Héroet (*q.v.*) and Maurice Scève. His *Erreurs amoureuses*, originally published in 1549, was augmented with other poems in successive editions till 1573. He translated (1551) the *Dialoghi d'amore* of Léon Hébrieu, the breviary of philosophic lovers of that day. Two of his *Discours philosophiques* (1552) have what may fairly be called parallel statements of the *Défense et illustration de la langue française* of Du Bellay. Pontus was one of the first to write sonnets in French (the actual priority belongs to Melin de St. Gelais). It is also said that he introduced the sestine into France, or rather re-introduced it, for it was originally a Provençal invention. In 1578 he became bishop of Châlons-sur-Saône. He resigned in 1594, and died Sept. 23, 1605.

See the *Pléiade française* (1875) of M. Ch. Marty-Laveaux.

PONTYPOOL, an urban district of Monmouthshire, England, 9¼ mi. N. of Newport, served by the G.W.R. and L.M.S.R. Pop. (est. 1938) 40,200. Area, 24.9 sq.mi. It is at the base of Mynydd Maen on the right bank of the Avon Lewyd, a tributary of the Usk. Its growth is due to its situation on the eastern edge of the great south Wales coalfield. The earliest record of trade in iron is in 1588, but it was developed chiefly in the beginning of the 18th century by the Hanbury family. Tin plate was first made there by Andrew Yarranton in 1670. There are tin and iron works in the neighbourhood. Water communication is with Newport by the Monmouthshire canal. The urban district included after 1935 the former urban districts of Abersychan and Panteg. The rapid growth of the Abersychan population caused the town to expand along the main valley and its tributaries. At Panteg are large steel and galvanized iron works. This whole district suffered greatly in the depression of the 1930s.

PONTYPRIDD, an urban district of Glamorganshire, Wales, situated on the Taff at its junction with the Rhondda, on the G.W.R. and on the Glamorganshire canal, 12 mi. N.W. from Cardiff. Pop. (est. 1938) 38,610. Area, 12.7 sq.mi. It receives its name from a remarkable one-arch bridge spanning the Taff, erected in 1755. It was an insignificant village till the opening of the Taff Vale railway into the town in 1840, and it owes its progress chiefly to the development of the coal areas of the Taff-Rhondda valleys. It also possesses chain and cable works, chemical works, and iron and brass foundries. It became a sort of gathering focus for the coal before being sent to Cardiff and Barry for export. Depression following World War I seriously affected this area, 60.8% of insured men being unemployed in May 1934. A trading estate in the district afforded some relief.

PONY, a horse of a small breed (*see* HORSE).

PONY EXPRESS, THE, an establishment of the United States government to carry mail on horseback from St. Joseph, Mo., to the Pacific before railways or telegraph. It was started in 1860, when an impending crisis made the rapid communication

of news between the older States and far-distant California a national necessity, and it had a brief existence of but 18 months before it was supplanted by a telegraph line. The animals used were, of course, not ponies but fleet American horses. They were stationed at "stages" from 10 to 15 miles apart and each rider rode three animals successively, covering not less than 75 miles before he passed the pouch to his successor. The fastest trip made was in 7 days and 17 hours when Lincoln's first inaugural address was carried, but the schedule was 8 days, about 24 days faster than the schedule of Butterfield's Overland Stage line travelling on the southern route. The maintenance of this schedule in all kinds of weather and in the face of Indian dangers and other hazards won for the service a fame which time has not diminished.

PONZA (anc. *Pontia*), the principal of a small group of islands belonging to Italy. Pop. (1936), 2,787 (town), 6,457 (commune). The group is of volcanic origin, and includes Palmarola (anc. Palmaria), Zannone (Sinonia), Ventotene (Pandateria) and Santo Stefano. It is about 20 mi. S. of Monte Circeo and 70 mi. W. of Naples. There is regular communication with Naples by steamer, and in summer with Gaeta. The islands rise to a height of about 70 ft. above sea-level. Ventotene has a convict prison, and the islands were a place of banishment in ancient times. Under fascism, Ponza became again a place of banishment for Italians opposed to Mussolini, like Gen. Bencivenga and others.

POOD, a Russian weight, equivalent to 40 lb. Russian and about 36 lb. avoirdupois. A little more than 62 poods go to the ton. The word is an adaptation of the Norse *pund*, pound.

POOLE, REGINALD STUART (1832–1895), English archaeologist and orientalist, was born in London on Jan. 27, 1832, the son of Edward Poole and his wife *née* Sophia Lane. Poole acquired his taste for antiquities during a stay (1842–49) with his uncle, R. S. Poole, in Cairo. In 1852 he became an assistant in the British Museum, and was assigned to the department of coins and medals, of which in 1870 he became keeper. In 1882 he helped to found the Egypt Exploration Fund, and in 1884 the Society of English Medallists. He retired in 1893, and died on Feb. 8, 1895.

His elder brother, EDWARD STANLEY POOLE (1830–1867), who was chief clerk in the science and art department at South Kensington, was an Arabic scholar, whose early death cut short a promising career. His two sons, Stanley Lane-Poole (*q.v.*) and Reginald Lane-Poole (b. 1857), keeper of the archives at Oxford (1909–27), lecturer in diplomatic, and author of various historical works, carried on the family tradition of scholarship.

POOLE, WILLIAM FREDERICK (1821–1894), American bibliographer and historian, was born in Salem, Mass., on Dec. 24, 1821. He graduated at Yale college in 1849 and in the previous year had already compiled an *Index to Periodicals,* which was published anew in 1853 and 1882. Later editions were prepared in collaboration and rendered great service to scholars. He was one of the founders of the American Library Association.

His writings include: *The Battle of the Dictionaries* (1856); *Websterian Orthography* (1857); *Cotton Mather and Salem Witchcraft* (1869); *The Popham Colony* (1886); *Anti-Slavery Before 1800* (1887); and *Columbus and the Finding of the New World* (1892).

POOLE, a municipal borough and county, market town and seaport in Dorsetshire, England, 113½ mi. S.W. by W. from London by the S.R. Pop. (1951) 82,958. Area 24.4 sq.mi. Poole is not mentioned till after the Domesday survey. The manor, part of that of Canford, belonged in 1086 to Edward of Salisbury, and passed to William Longespée, earl of Salisbury, thence to Edmund de Lacy, earl of Lincoln, and with his heiress to Thomas, earl of Lancaster, and so to the crown. It is uncertain when the burgesses obtained their town at the fee-farm rent of £8 13*s.* 4*d.* mentioned in 1312. In 1372 they obtained assize of bread and ale, and right to hold the courts of the lord of the manor. Elizabeth incorporated Poole in 1569 and made it a separate county. Poole, as headquarters of the Parliamentary forces in Dorset during the Civil War, escaped the siege that crippled so many of its neighbours. It is on a peninsula between Holes Bay and the shallow irregular inlet of Poole Harbour, one of the best on the south coast, extending inland 6 mi., with a general breadth of 4 mi. The harbour has a narrow entrance, and is studded with low islands, on the largest of which, Brownsea or Branksea, is a castle originally erected as a defense of the harbour in Tudor times, and strengthened by Charles I. A bridge across the harbour entrance, forming a link for road transport to Bournemouth, was opened in 1927. Clay is exported and shipbuilding and the making of ship fittings are carried on.

POOLS, IN INDUSTRY. Rival manufacturers or traders who, while still ostensibly in competition with each other, either allocate among themselves by agreement the amount or proportion of business each shall do, or agree as to who shall put in the lowest tender for a contract, frequently set up, as a part of their agreement machinery, a pooling system. One type is that adopted by those associations of manufacturers in the same industry which allot to each member a percentage of the output of the whole group, and require that each member who exceeds his "quota" shall pay an appropriate sum into a pool and that each member who does not reach his quota shall receive an appropriate sum from it. In associations concerned with work for which tenders are asked, three kinds of pooling are known. In one the tenders prepared by members of the group are confidentially examined by the secretary of the association and a percentage added to each, to be subsequently paid by the successful tenderer into a pool and divided among the rest. In another a uniform tender price is decided upon which all shall quote on the understanding that the firm receiving the contract shall pay an agreed percentage into the pool. In another the tenderers are informed of the order in which the sums quoted run, from highest to lowest, in order that the lowest tenderer may hold out for his price: in which case also the successful tenderer pays an agreed percentage of his contract into a pool. Another arrangement is the profit pooling agreement in which the future profits of two or more businesses are for a specified period paid into a common fund and divided out in agreed proportions. (*See* also COMPETITION IN INDUSTRY; TRADE ORGANIZATION and TRUSTS.) (J. H.)

Finance and Commerce.—A pool on the stock exchange would work in some such way as follows, although the actual details naturally vary:—

(1.) Its members would consist of the holders of a certain share, and while the pool organizers would not attempt to bring in every shareholder, the members of the pool would between them have to hold a substantial block of the total shares issued for the formation of the pool to be worth while.

(2.) The pool members would authorize the pool organizers to sell their shares on their behalf, and would agree not to sell them themselves.

(3.) The pool organizers would agree not to sell these shares at less than a certain price. Thus the first third of the shares in the pool might be sold at a minimum of 21*s.*, the next third at 22*s.*, and the remainder at 23*s.* 6*d.* The proceeds of the sale as effected, less the charge for the pool's expenses, would be paid over to the pool members in proportion to the shares each held.

(4.) After six months from its date of formation, the pool would break up, and any shares still unsold would be re-transferred to the members, to deal with as best they could.

The whole object of a pool is to control and regulate the supply of a certain share to the market. For a pool to be effective, it must have a big holding of the share, or it will be faced with competitive selling from outsiders, and will be unable to obtain its minimum price.

If a new issue meets with an immediately unfavourable reception so that the bulk of it has to be taken up by the underwriters, it often happens that the underwriters form a pool.

A commercial pool in a commodity would work in very much the same way; it might be a buyer's pool—as the American rubber pool—or a seller's pool, such as the Canadian wheat pool, a great non-profit, co-operative marketing association in Canada. In either case, the buying and selling is done by the pool for its members, who agree to operate only through the pool. The object is to obtain by combined effort a reasonable price. (N. E. C.)

United States.—Pools among railway companies became widely prevalent throughout the United States between 1870 and 1887 and aroused so much opposition on the part of the public

that the Interstate Commerce Act was passed in 1887 making them illegal as regards interstate traffic. The act was not altogether successful for division of traffic, especially in the shipping of cotton, fruit and grain, persisted without the usual pooling machinery being in evidence. Such agreements, however, being non-enforceable, were seldom of long duration. The wisdom of the Interstate Commerce Act has been often called into question, and recommendations favouring legalization under government supervision have been made both in presidential messages and in the reports of the interstate commerce commission itself. A decision of the Supreme Court in 1911 making contracts not illegal unless in "unreasonable restraint of trade" eased the situation somewhat, while the modern tendency toward combination also tends to eliminate the conditions which cause pooling arrangements to be made.

POONA, a city and district of British India, in the Central division of Bombay. The city is at the confluence of the Mutha and Mula rivers, 1,850 ft. above sea-level and 119 mi. S.E. from Bombay on the Great Indian Peninsula railway. Pop. (1941), 258,197. It is pleasantly situated amid extensive gardens, with a large number of modern public buildings, and also temples and palaces dating from the 16th to the 19th century. The palace of the peshwas is a ruin, having been destroyed by fire in 1827. From its healthful situation Poona has been chosen not only as the headquarters of the Southern Command, but also as the residence of the governor of Bombay during the rainy season, from June to September. The cantonment is at Kirkee, 4 mi. N.W. (pop. [1931] 16,302), where there is also a large ammunition factory. The waterworks were constructed mainly by the munificence of Sir Jamsetjee Jeejeebhoy. There are cotton, paper, rice and sugar mills, ice and iron works, distilleries and a tannery. It was proposed in 1927 to bring electric power to the city from the Tata power company's installation at Nila-Mula. Educational institutions include the government Deccan college; Fergusson college; the government colleges of science, engineering and agriculture; training schools for masters and mistresses; medical school; and municipal technical school.

The District of Poona has an area of 5,347 sq.mi. Population (1941) 1,359,408. Towards the west the country is undulating, and numerous spurs from the Western Ghats enter the district; to the east it opens out into plains. The district is liable to drought. The two most important irrigation works are the Mutha canal, with which the Poona waterworks are connected, and the Nira canal. The district is traversed by the Great Indian Peninsula railway, and also by the Madras and Southern Mahratta line, which starts from Poona city towards Satara.

In the 17th century the district formed part of the Mohammedan kingdom of Ahmadnagar, and was the early centre of the Mahratta power and the seat of government.

POORE (or Poor), **RICHARD** (d. 1237), English bishop, was a son of Richard of Ilchester, bishop of Winchester. About 1197 he was chosen dean of Sarum and, after being an unsuccessful candidate for the bishoprics of Winchester and of Durham, he became bishop of Chichester in 1214. In 1217 he was translated to Salisbury, where he succeeded his elder brother, Herbert Poore, and in 1228 to Durham. He died at Tarrant Monkton, Dorset, said by some to be his birthplace, on April 15, 1237. Poore took some part in public affairs, under Henry III., but the great work of his life was done at Salisbury. Having in 1219 removed his see from Old to New Sarum, or Salisbury, he began the building of the magnificent cathedral there. He laid the foundation stone in April 1220, and during his episcopate he found money and forwarded the work in other ways. For the city the bishop secured a charter from Henry III. and he was responsible for the plan on which it was built.

POOR LAW. The term "poor law" in British usage denotes a peculiar system of giving public relief to the destitute. (*See* Pauper.) The principles are laid down in statutes and worked out in detail in "orders" and "circulars" of a central department of State, the Ministry of Health or the Scottish Board of Health. The administration is in the hands of a special local authority, known as the board of guardians in England and Wales, and the parish council in Scotland. The modern system began in 1834, when the "New Poor Law" replaced the "Old Poor Law" which after nearly two and a half centuries of existence had become an intolerable scandal. The machinery set up then has not undergone much change, nor, in theory at least, have the methods of relief, though there have been considerable modifications in practice, which will be referred to presently. The whole of the Statute law was consolidated in the Poor Law Act, 1927, which together with the Poor Law Institutions Order, 1913, and the Relief Regulation Order, 1911, contains a full outline of the system.

Central Authority.—The Ministry of Health took over the functions of the Local Government Board in 1919. (The first central authority was the Poor Law Commissioners of 1834. These were replaced in 1847 by the Poor Law Board, which in turn was abolished on the creation of the Local Government Board in 1871.) The Ministry of Health exercises a close control over the local authorities, through its poor law "orders," which they must obey, its inspectors, its systematic audit of local accounts, and its power of sanctioning loans. And, by the Boards of Guardians (Default) Act, 1926, the minister has power to supersede any board of guardians, which he considers unable to discharge its functions properly, by persons appointed by himself.

Local Authorities.—The board of guardians is a popularly elected body in each of the 600 odd Poor Law Unions in England and Wales, whose members hold office for three years. It has a limited power of co-opting. The board acts, like other local authorities, through committees dealing with separate departments of its work, and through its permanent officials. The most important of these are the clerk, the master and the matron of the workhouse, the relieving officer and the medical officers. In addition there are officials in charge of various institutions, such as children's homes and schools and casual wards, as well as teachers, infirmary nurses, etc. The guardians' expenses are met mainly out of the local rates, by precepting on the rating authority, the town or district council. But they also receive considerable grants-in-aid from the national exchequer. In London the expenditure of the boards of guardians is largely equalized through a pool system known as the Metropolitan Common Poor Fund, into which the richer Unions pay, and out of which the poorer Unions receive, large sums. Thus in 1925–6 Bermondsey drew £248,469 from the fund, Stepney £308,386, and Poplar £520,095.

Powers and Duties.—The principal duty of the board of guardians is the relief of destitution. It has besides one or two minor functions; *e.g.*, it enforces the vaccination acts and appoints registrars of births and deaths. The relief to the destitute may be either "indoor" or "outdoor." Indoor relief is closely regulated by the Poor Law Institutions Order, 1913, and is given in workhouses, infirmaries and other institutions such as casual wards, district sick asylums, poor law schools, training-ships, "cottage" and other homes for children, homes for the aged, county and county borough asylums, licensed houses for lunatics, schools for the blind, deaf and dumb. Outdoor relief includes allowances in money or kind, medical attendance and drugs, the payment of funeral expenses, and the provision of work for able-bodied men. Outdoor relief is not normally given to the able-bodied; but the Relief Regulation Order, 1911, permits the guardians to depart from the rule when they consider that special circumstances warrant it, and report to, and get the sanction of, the Ministry. For the administration of medical out-relief the whole country is divided into districts more or less equal in area and population, for each of which a medical officer is appointed. Relief may, if the guardians choose, be given on loan, and the cost is then recoverable in a county court. The guardians also have power to recover the cost of relief either wholly or in part from certain persons who are legally liable for the maintenance of relatives. Thus a husband is bound to maintain his wife. Parents are bound to maintain their children under 16 (or over 16 if unable to support themselves), and grandparents their grandchildren under 16. Legitimate children are bound to maintain parents who are unable to support themselves. A married woman

having a separate estate is bound to maintain her husband, her children under 16 and her parents. A single woman is bound to maintain her illegitimate children under 16.

Except in the case of vagrants, relief is normally given to a person only in his own parish, *i.e.*, the parish in which he is legally "settled." Settlement is acquired by birth, marriage, ownership or occupation of property, apprenticeship, or residence. Residence for three years constitutes a full settlement; but one year's residence gives a status of "irremovability." The harsh settlement laws that caused so much mischief in the old days have been very greatly modified; but paupers can be, and still are, removed from one Union to another. Removal orders must be signed by two justices of the peace. Of course relief is not withheld because of a doubt or dispute about a person's settlement. It is given, and the questions of chargeability and removal are decided subsequently between the Unions concerned.

Vagrancy.—The treatment of vagrancy has certain peculiarities. The casual ward is subject to the strict regulations of the central authority in respect of tasks, dietary, sleeping accommodation, bathing and conditions of admission and discharge. Normally the casual cannot leave before the morning of the second day following his admission, nor till he has finished the task which is the price of his food and lodging. But if he satisfies the superintendent that he is definitely seeking work, he may be discharged after one night. The casual's task may be stone-breaking, digging, pumping, wood-cutting or grinding, and for women, washing, scrubbing, or cleaning. Oakum-picking was abolished in 1925. Since the report of the royal commission in 1909, some reforms have been introduced in the administration. In the provinces there are county vagrancy committees, representing the boards of guardians within the county, or sometimes a larger area. Through these committees a more or less uniform treatment is secured, the cost of relief of the casual paupers is pooled, and arrangements are made for mid-day meals and other forms of assistance to men on the tramp for work. Boards of guardians are not compelled to come into these combinations, and many refuse to. Some of the independent casual wards are very unsatisfactory. The majority of the boards, however, have come in, and in 1927 the vagrancy committees represented 480 Unions. In London all the casual wards have been managed since 1912 by one central body, the Metropolitan Asylums Board. The majority of the members of the M.A.B. are representatives of the 25 London boards of guardians, the rest are nominated by the Ministry of Health. Besides the management of the casual wards it has a number of other duties; *e.g.*, it maintains isolation hospitals (for non-pauper as well as pauper cases), asylums for the mentally defective, a colony for sane epileptics, and the *Exmouth* training-ship for poor-law boys.

Scotland.—The Scottish system closely resembles the English. It begins with an Act of 1579, entitled "For Punishment of the Strong and Idle Beggars, and Relief of the Poor and Impotent," which corresponds to the English act of 1601. The Poor Law Amendment (Scotland) Act, 1845, corresponding to the English act of 1834, established poorhouses and local authorities known as parochial boards. These were replaced in 1894 by parish councils, whose duties in regard to the relief of destitution are very much the same as those of the boards of guardians, and which are under the supervision of the Scottish Board of Health. One peculiar feature of the Scottish poor law may be noted, however; an able-bodied person, until 1921, had no legal right to relief of any kind. An act of that year, the Poor Law Emergency Provisions (Scotland) Act, supplemented by another in 1927, gave the right, but only for a limited period (till the end of 1928).

The Old Poor Law.—The Old Poor Law was the creation of Tudor statesmen, and was forced upon them by the necessities of their age. After the Reformation the Church was no longer equal to the task of relieving the needs of the poor, and the social and economic changes of the 15th and 16th centuries had multiplied the numbers of the vagrants and the "idle and disorderly." Various measures were passed for dealing with the mischief, and these were eventually codified in the famous statute of the 43rd year of Elizabeth (1601). Every parish was required to appoint overseers, whose duty it was to levy rates for the relief of the poor. The rates were to be expended for the apprenticeship of children whose parents could not maintain them; for providing work for the able-bodied unemployed; and for assisting those who were unable to work owing to sickness, age or other infirmity. The Elizabethan system was fairly successful for a generation or so, but with the Civil War decay set in. After 1662 the difficulties were aggravated by the law of settlement (under which any person who came to live in a parish not his own might, if he seemed likely to become a charge on the rates, be turned out, and sent back to the place where he "belonged") and abuses rapidly increased. Experiments in reform were tried at intervals throughout the 18th century—workhouses, the farming-out of the poor to contractors, and various forms of outdoor relief, ranging from the payment of unconditional doles to the hiring of paupers to farmers at nominal wages which were supplemented out of the rates. Finally the "Speenhamland system" spread far and wide. This developed out of a rule made in 1795 by the Berkshire magistrates, meeting at the Pelican inn, Speenhamland, that allowances of money should be given on a sliding scale regulated by the price of bread. In the early part of the 19th century pauperism was a canker in the body politic, and its cost a crippling burden. In 1818 poor law expenditure reached the figure of nearly £8,000,000, or 13/3d. per head of the population, and though it fell a little in the following years, it stood at £7,000,000, or 10/– per head of the population, in 1832. In that year a royal commission was appointed to enquire into the whole system, and its recommendations were the basis of the reforms which were embodied in the Poor Law Amendment Act of 1834.

The New Poor Law.—The New Poor Law made a clean sweep of the old practice of unrestricted out-relief. It grouped hitherto independent parishes into Unions, each under an elected board of guardians, with a strong central authority to enforce a uniform policy. And it laid down the cardinal principle that relief should only be given to the able-bodied poor and their dependants in a well-regulated workhouse under conditions inferior to those of the humblest labourer outside. This drastic measure of deterrence naturally provoked widespread popular discontent, and was indeed one of the grievances which played a part in the Chartist agitation. But it went far to reduce the volume and the cost of pauperism. As time wore on, however, its strict application became more and more difficult. The development of democracy, the growth of humanitarian feeling, and the discovery of more scientific methods of dealing with destitution, all helped to mitigate the harshness of poor law administration. There were improvements in the treatment of different classes of paupers, and many boards of guardians adopted a more generous—or, as their critics said, a more lax—policy both in the granting of outdoor relief and in the management of the workhouse. But no one who looked below the surface could be satisfied with the poor law at the beginning of this century. Its abuses were not those of a hundred years earlier, but they were serious enough to call for public investigation. A royal commission "on the poor laws and the relief of distress" was appointed in 1905, and its reports, issued in 1909, exposed the whole system to a searching criticism. The failure of the poor law was seen in almost every department. "Well-regulated workhouses" were the exception rather than the rule. Here and there the deterrent principle was maintained, and "able-bodied tests" were applied in the shape of stone-breaking or other tasks set to the unemployed workman, which were not only brutal but uneconomic. More often, however, the workhouse had an able-bodied ward, in which all and sundry were left to twiddle their thumbs in a demoralizing idleness. For the tramps there were casual wards run on methods that were cruel to the honest work-seeker, and utterly useless from the point of view of reforming the "work-shy." Nor was the condition of the non-able-bodied less deplorable. The general workhouses contained a great host of children, in constant contact with the adult paupers, often ill-tended and improperly educated. The treatment of the patients in many of the infirmaries and sick-wards, and of the idiots, imbeciles and lunatics, was a scandal. In the granting of outdoor relief there was no uniformity at all. In some Unions the allowances were

fairly generous, in others they were utterly inadequate. There were boards of guardians which gave a widow 1s. or 1/6d. a week for her child, with nothing for herself. And despite the strenuous efforts of many of the guardians to humanize the administration and of others to keep down the cost of pauperism, the poor law was detested by the poor and a growing burden on the rates.

Reports of Royal Commission, 1909.—The royal commission demanded drastic reforms. The majority recommended that the boards of guardians should be replaced by statutory committees of the county and county borough councils, to be known as "public assistance authorities," with a number of minor bodies (public assistance committees) working under them in sub-areas. The general workhouses should be abolished, and different classes of the destitute relieved in properly specialized institutions. The able-bodied should as far as possible be provided for by other methods. Outdoor relief, or "home assistance," should be adequate, but should be given only after strict inquiry, under supervision, and on a uniform basis. The minority were not content with this; they proposed the complete abolition of the poor law—the thing as well as the name. They argued that the system was fundamentally bad. It was the business of the community to try to prevent destitution, and not merely to palliate it when it occurred. This had long been recognized in the case of other public authorities which had to deal with different classes of the poor—the aged, the children, the sick and the feeble-minded. And these authorities, it was pointed out, were not only working on the right principle; they were better equipped than were the guardians for giving the appropriate treatment in each case, they were free of the "stigma of the poor law," and parliament was steadily extending their functions. But, while this was satisfactory in itself, it involved in practically every department a deplorable amount of administrative disorder, overlapping, duplication of machinery and waste. In the case of each class of the poor, infants, children of school age, the sick, the feeble-minded, the aged, the able-bodied, there was at least one, and often more than one, other authority set up as a rival to the board of guardians. On administrative as well as humanitarian grounds, therefore, the minority report recommended the break-up of the poor law, and the distribution of the functions of the guardians (or the parish councils in Scotland) among the appropriate local authorities, save in the case of the able-bodied, who it was proposed should be made the charge of a national unemployment authority.

This policy received strong support throughout the country and there was an active agitation for poor law reform during the next two or three years. The Government, however, was not disposed to introduce the necessary legislation, and John Burns, the president of the Local Government Board, undertook what he called "revolution by administration." All that he did in fact, was to abate certain of the most crying scandals; in essentials the poor law was left intact. When the war broke out in 1914, the problem was naturally shelved; the volume of pauperism rapidly diminished, and in any case no large reform was possible under war-time conditions. In 1917, however, the whole question was re-examined by a committee appointed by the Ministry of Reconstruction, and presided over by Sir Donald Maclean, M.P.

The Maclean Report.—The Maclean committee was important, because it included representatives of both the majority and the minority of the old royal commission, and it produced a unanimous report which reconciled their differences. The report in fact confirmed the sentence of death passed on the guardians eight years before, and made detailed recommendations for the break-up of the poor law. Its main proposals were:—

1. The transfer of all the functions of the boards of guardians to the councils of counties, county boroughs, and boroughs or urban districts with populations exceeding 50,000.

2. Provision for all the sick and infirm (including the aged requiring institutional care, and maternity cases and infants) should be made by these authorities under the Public Health Acts, suitably extended.

3. The Ministry of Health should have power to put any borough with a population over 10,000, or any urban district with over 20,000, in the position of an autonomous health authority, with such reservations as might be desirable.

4. The children should be dealt with by the local education authorities, the mentally deficient by the local lunacy authorities.

5. Every county or county borough (or borough or urban district council with a population over 50,000) should set up: (1) a prevention of unemployment and training committee (on the lines of the education committee, and including representatives of employers and trade unions); (2) a home assistance committee (on the lines of the education committee) to enquire into the economic circumstances of all applicants for public assistance, to supervise them, to administer all relief given in the home, to recover expenses of maintenance, treatment, etc., and to keep a private register of all such applicants and their families and of the assistance given.

6. County councils should appoint committees for districts or combinations of districts, to which various functions of the home assistance committee and the prevention of unemployment committee would be delegated. Such district committees would consist of: (a) members of the county council; (b) borough or district councillors; (c) persons experienced in the work to be done.

7. London should have a special scheme, in which the functions would be divided between the L.C.C. and the metropolitan borough councils. The borough councils would appoint home assistance committees, and would also be responsible for vaccination and registration of births and deaths. The L.C.C. would, through its appropriate committees, exercise the rest of the functions transferred. It would also appoint a central assistance committee, which would lay down a policy and rules of local administration for the home assistance committees in the metropolitan boroughs.

8. Poor law officials should be transferred to the local authorities (provided both they and the local authorities agreed), and compensated for any pecuniary loss incurred by the change.

9. The cost of all functions transferred should fall on the new authority (the county, county borough, borough or urban district, and in London mainly on the county, but partly on the metropolitan borough).

Scotland was outside the committee's terms of reference. But the matter was referred for consideration to the Scottish consultative council on local health administration. The council issued majority and minority reports, the majority declaring in favour of a Scottish scheme on the general lines of the Maclean report. This scheme was approved by the government of the day, and pledges were given that a bill to reform the poor law would be introduced as soon as opportunity offered. Nothing was done, however, either by that government or by its successors, until Neville Chamberlain, the Conservative minister of health, began to move in the matter in 1925.

In the meantime the poor law entered on a new and alarming phase. The industrial depression, which began in 1920, resulted in a rapid and unprecedented increase of unemployment. Trade union funds and such private savings as the workpeople had were soon exhausted, and the Unemployment Insurance Act and relief works were inadequate to meet the widespread distress. Unless the government was prepared with some heroic policy, it was evident that nothing remained save the poor law. The government refused to be heroic; it actually encouraged recourse to the poor law, in order, as its critics said, to shift as much of the cost as possible from the taxes to the rates. Before long the boards of guardians in all the most heavily stricken areas were flooded with applicants. At the end of 1920 there were just over half a million persons in receipt of poor relief in England and Wales. By the following October the figure was nearly a million and a half, and in the middle of June, 1922, it reached the record of 1,837,980, or 1 in 21 of the whole population. In certain districts the position was even worse than this. No less than thirty Unions had 1 in 10, and several had 1 in 5, of their inhabitants registered as paupers. There was presently a gradual decrease, but the total in June, 1923, was still 1,270,000. In Dec., 1925, it rose again to 1,324,000, and in Aug., 1926, as a result of the great coal dispute, to over 2,250,000. In this month there were eight Unions with a third, and

fourteen others with a quarter of their population in receipt of relief. In two Unions in particular weeks more than 50% of the population were paupers. The vast majority of those relieved in the mining areas were the wives and children of the miners, since the "Merthyr judgment" forbade relief to the men themselves. (In the case of *Attorney-General* v. *Merthyr Tydfil Union* [1900, 1 Ch. 516], the court of Appeal decided that poor relief may not legally be given to an able-bodied person who, by reason of a strike or otherwise, refuses work which is available for him, unless he is so reduced by privation as to be physically incapable of work; but that it may be given to his dependants.) In 78 Unions (covering 85% of the mining population of the country) there were approximately 1,507,600 persons receiving out-relief on Oct. 30, 1926—or about three-fifths of the whole number of miners' dependants in those areas. And for the period of the general strike and the coal dispute, *i.e.*, from May 1 to Nov. 27, these 78 boards of guardians spent some £6½ million more than they would have done if the April rate of expenditure had continued. Scotland had much the same experience. The total number of poor of all classes relieved by the Scottish parish councils was 138,071 on September 15, 1921, and 261,408 a year later. The peak figure of 382,970 was reached on Sept. 15, 1926.

All this, of course, meant an appalling rise of the rates in the crowded industrial districts, which were hit by the trade slump in the earlier part of the period, and hit again by the general strike and the coal stoppage. On Tyneside in 1926–27 the rates were 17/5 in the £ in Wallsend, 17/6 in Tynemouth, 19/11 in Jarrow, 23/9 in Gateshead, 24/8 in Felling, 27/8 in Blaydon. The poor rate formed a large proportion of all these: in Gateshead it was 11/–, which represented an increase of over 600% over the poor rate of 1913–14. Among the metropolitan boroughs Bermondsey had a rate of 18/7, Stepney 19/–, Bethnal Green 22/–, and Poplar 25/–. Other highly rated places were Sheffield (18/2), Middlesbrough (19/8), West Ham (24/6), Pontypridd (20/8), Merthyr Tydfil (24/4). In some cases the ratepayers were unable to meet the strain. The guardians were compelled to borrow and thus saddle the rates with a heavy burden for the future. In 1923 the actual total indebtedness of the Unions that had raised loans was about £5¼ millions. By March, 1926, it stood at over £7 millions, and in March, 1927, at nearly £12¾ millions. The bulk of the new borrowing in this last year was in the mining districts.

Breakdown of "Principles of 1834."—The task thus thrust on the poor law was clearly one for which it was neither intended nor equipped. And the inevitable result was confusion worse confounded, and a widespread abandonment of what was left of the principles of 1834. The prohibition of outdoor relief to the able-bodied unemployed, save with the express sanction of the Minister of Health in particular cases, still remained on paper. But it became virtually a dead letter in Unions where there was serious unemployment. Outdoor relief was given wholesale, and as a matter of course, to able-bodied men simply because they were out of work, and often not even the names of the recipients, but only the number of cases, were reported to the Ministry for its formal approval. The guardians of course could not fairly be blamed for this; in the circumstances there was nothing else they could do. And the central authority was equally helpless; it could not adhere to the letter of the law without provoking a general upheaval. It could, and indeed did, grumble and remonstrate, but in the last resort it was bound to sanction departure from the regulations. And it could not prevent the use of "scales" of relief adopted by boards of guardians and applied mechanically or in a slipshod fashion. It strove to keep the amount given in outdoor relief below the level of the wage earned by regular full-time employment, but even in this it was only partially successful. In the annual report of the Ministry of Health for 1923–24, the complaint is made that "it is still the fact that the scale on which relief is given is such as, in a number of Unions, to make the income of the person relieved compare very favourably with the wages of an employed person." And again in the 1926 report the warning is repeated that a scale of relief "should not be such as to challenge comparison with the earnings of the workers who are called upon, directly or indirectly, to contribute to the relief so granted." A common scale at this period was 36/– a week for a man, wife and four children. There were maximum scales in 1924–25 of 44/– in Cardiff, 45/6 in Burnley, 46/– in Leeds, 51/– in Poplar, 55/– in West Ham. In Scotland the Board of Health was a little more successful in its attempts to keep down the relief to the unemployed. In view of the critical financial position in 1926 it recommended a maximum scale (23/– a week for man and wife; 2/– for a child under 16; 7/6d. for an adult son or daughter living in the family; 15/– for a single man or woman; and all household income to be deducted), and it refused to sanction loans or overdrafts to parish councils which did not keep within the scale. This had the effect generally of stopping poor law relief in supplement of unemployment benefit, which had become a common practice. Nevertheless the burden was immense. In two big parishes, Glasgow and Govan, the 1926 expenditure was double that of the previous year, and in some smaller parishes it rose by over 300%.

"Poplarism."—To return to England, however—what appeared serious in this development was that it was not merely the result of carelessness or fluster in the guardians. On the contrary, certain boards quite deliberately adopted the policy of giving out-relief on such a generous scale that there could be no pretence of making the lot of the pauper less desirable than that of the independent labourer. This policy was not entirely new; the Poplar board, dominated by a Socialist majority, had long favoured the giving of what it regarded as adequate, and its critics as extravagant, relief. But with the increase of distress that was now facing many of the poor law authorities the burden on the ratepayers became formidable, and a struggle presently began over what was known as "Poplarism." Efforts were at first made to get the Ministry of Health to devise means for alleviating this burden in the poorer districts, but in vain. The Poplar borough council (which also had a Socialist majority) then took the desperate course of refusing to collect the rates for the London county council and certain other central bodies. Legal proceedings were taken, and the high court ordered the collection of the rates. The borough council ignored the order and 29 of its members were imprisoned for contempt of court. Their imprisonment put the Government in an uncomfortable position, and forced it to concede the legislation which Poplar had been demanding. The Local Authorities (Financial Provisions) Act, 1921, provided for a large measure of equalisation of poor rates in London; in particular it laid down that the cost of outdoor relief should be borne by the Metropolitan common poor fund within the limits of a scale to be fixed by the minister of health.

The minister, Sir Alfred Mond, issued his scale in Jan. 1922. It did not satisfy the Poplar guardians, who now pressed for a loan to tide them over their immediate difficulties. A special inquiry was then instituted by the minister into the circumstances of Poplar. The report was unfavourable to the guardians, and declared that by more economical methods they could save £100,000 a year. This they hotly denied; they still demanded their loan, and insisted on their right to administer relief at their discretion. The minister thereupon played his trump card. He issued a "peremptory order," applicable to the Poplar Union alone, providing that no relief in excess of the "Mond scale" to an able-bodied person or any member of his family should be legal, unless specially sanctioned by the minister. The guardians, however, persisted in defying this order, and so laid themselves open to surcharge. After a few months a curious complication was introduced by the Local Authorities (Emergency Provisions) Act, 1923, which apparently revoked automatically the "Mond scale," but left the Poplar order intact, though the two had been closely bound up together. This anomaly lasted till Feb. 1924. The guardians meanwhile were regularly surcharged by the auditor, but successive ministers of health shut their eyes to the matter, until at length John Wheatley in 1924 rescinded the order, and announced that no action would be taken to enforce surcharges in respect of the "illegal relief" given before its rescission. That was the end of this particular battle, though it was not the end of high relief scales. Other boards of guardians continued to favour "Poplarism" and pursued a guerrilla warfare with the Ministry of Health.

There was, of course, a division of opinion over "Poplarism." The one side insisted that it was not only the right, but the duty of the guardians to give adequate relief; the other retorted that the Poplar conception of adequacy was preposterous. But the division was not, as is sometimes supposed, simply one between Socialists and anti-Socialists. The critics included many supporters of the Labour party who not only looked askance at law-breaking tactics, but foresaw disastrous results if the policy of lavish and unconditional relief were to become general. At the same time they appreciated the difficulties of Poplar and similarly placed unions, and argued that the mischief could only be remedied by the reform or the abolition of the poor law. In this view the "Poplarists" themselves concurred, and, indeed, it was realised on all sides that the poor law guardians were not and could never be a satisfactory unemployment authority. But nothing was done to relieve them of their burden, and fresh trouble soon developed.

The Battle of West Ham.—The West Ham board of guardians had for some time been paying out in poor relief a sum far exceeding what could normally be raised by way of rates, and were in fact financed by loans advanced by the Ministry of Health on the recommendation of a Treasury committee. By the autumn of 1925 the outstanding balance of these loans had reached nearly £2,000,000, or 57% of the rateable value of the Union, and the guardians were asking for another £350,000 in respect of current expenditure. The Treasury and the Ministry of Health made a stand at this point and insisted on certain restrictions of expenditure as a condition of the loan. The guardians refused to accept the conditions, and so found themselves with no funds out of which to pay their outdoor relief, their officers' salaries or the other expenses of the Union. The minister thereupon took the unprecedented step of guaranteeing payment of tradesmen's bills for outdoor relief supplied in kind on orders made by the guardians and marked with a special stamp. The amount of the relief was not, however, to exceed three-quarters of the amount which would have been granted under the guardians' scale. This plan worked for four weeks, and then, as the guardians were still obstinate, the minister threatened that he himself would take over the whole business of administration in the West Ham Union. He had (at that date) no legal power to do this, but he would, of course, have got an indemnity from parliament. The threat brought the guardians to heel; they accepted the conditions and got their loan. But this was only the first round. In the summer of 1926 there was a renewal of the contest. At the beginning of May some 70,000 persons in the Union were in receipt of relief; by the middle of the month the general strike had brought the number up to 165,000, or 21% of the population. The board of guardians now applied for another loan of £425,000. The minister pointed out that the district auditor had held their expenditure to be in many cases entirely unjustifiable, and certain members of the board agreed with this view. Their scale of weekly relief was 24/– for a man and wife, and 4/– for each child, up to a maximum of 49/–, plus 1/6d. for coal. He once more insisted upon drastic economies, as a condition of the loan; but the guardians refused to amend their scale, and he administered a knockout blow. Under the bill that was passed into law as the Boards of Guardians (Default) Act, 1926, he superseded the West Ham guardians and handed over their functions on July 20 to three paid administrators, two civil servants and one ex-civil servant, nominated by himself. Under the new régime the number of outdoor paupers rapidly fell (it was 60,000 on July 17, 1926, and 41,000 on March 26, 1927), and the expenditure was substantially reduced.

The Guardians (Default) Act.—But West Ham was not the only Union in which the act was applied. In August the Chester-le-Street, and in the following February the Bedwellty, guardians were removed. In both cases an acute crisis had developed during the coal stoppage. Liberal relief was being given, and it was being given to unmarried miners, which was contrary to the law as laid down by the judges in the Merthyr Tydfil case. In Chester-le-Street the total of outdoor paupers rose from 10,547 on March 27, 1926, to 37,643 on August 28, and in Bedwellty from 15,293 on March 27 to 59,565 on July 17. The minister admitted that the guardians were in an exceedingly difficult position; but he declined to sanction further loans, and put in his appointed guardians. They at once revolutionised the administration by cutting down the relief scales, by refusing to supplement unemployment benefit except by medical extras, and by discontinuing all subsidies to wage-earners, and so effected a reduction of rates, if not of distress.

The passage and the application of the Default Act naturally caused much heartburning. Nor did the criticism come only from whole-hearted champions of "Poplarism." Many who deprecated the policy pursued in these three Unions held that the act was a dangerous infringement of the principles of local government. It put excessive power in the hands of a central department, which might be used quite arbitrarily to undermine democracy up and down the land. Even if Neville Chamberlain could be acquitted of any such intention, there was no guarantee that others would not cherish it, and there were actually, it was pointed out, influential persons in his party who were clamorous for tightening the grip of parliament and Whitehall on the local authorities throughout the country. On the other hand it was contended that the true interests of democracy were not served by letting it run into excesses; the example of West Ham and Chester-le-Street and Bedwellty, if it were generally imitated, would mean an immense demoralisation and in the end violent reaction. Both sides undoubtedly had a case in this controversy, though it was often exaggerated or obscured by party bias. But the real moral of the whole episode was not the danger of "Socialism" or of "Fascism." It was the folly of putting new wine into old bottles.

The Guardians and Unemployment.—Neither the Elizabethan nor the 19th century poor law was framed to deal with unemployment in its modern form. It is true that the duty of "setting to work all such persons having no means to maintain them" was laid upon the overseers in 1601, and the duty of "offering the workhouse" upon the guardians in 1834. But the prime objects of both the Old and the New poor law were the repression of the idle who could work and the succouring of the sick and the aged and the young, who could not work. Relief to an able-bodied adult was to be regarded as exceptional (in Scotland it was not allowed at all until 1921), and under the New poor law, at least, was given on repellent terms. How could the ancient machinery of the poor law be expected to adapt itself to the very different conditions and mind of the 20th century? Boards of guardians cannot set to work a million men of all sorts, nor can they "test" them, even if they wished to. Some, perhaps most, do not wish to "test" the unemployed workman who has lost his job through no fault of his own and is unable, either privately or through the employment exchange, to find another. That feeling of compunction, as has already been mentioned, was growing fast in the early years of this century. It was expressed in legislation for making provision for the unemployed otherwise than through the poor law; it was expressed by poor law administrators themselves in the relaxing of restrictions on relief to the able-bodied. After the war the idea of the "test" became still more unpopular, and finally the flood of unemployment made the "offer of the house" an impossibility in the most seriously affected areas. And thus it was that the poor law reverted to a condition very like that of a hundred years earlier, save that then the bulk of the pauperism had been rural, and now it was urban. The minister of health in his 1927 report mentions one remarkable similarity. "During the past six years," he says, "numbers of young men, without employment and maintained on poor law relief, have married, securing thereby an increase in their income from relief, and have had families, each addition to the family bringing its addition to the family income. In this respect it may be doubted whether the present position can be paralleled since 1834." It was inevitable that such abuses should occur. The guardians were compelled to be a dole disbursing agency, filling the "gaps" of the Unemployment Insurance Act, supplementing its benefits, or feeding those who fell outside its provisions. They had not then, and never had, the power to deal with unemployment as a whole, or to organise any proper palliative, let alone preventive, measures. In all the circumstances it is not surprising that there were muddles, fraud and extravagance, involuntary or deliberate, or that when a whole population was workless and political passions were run-

ning high, the law was defied. There might easily have been a hundred West Hams and Chester-le-Streets. As it was, there were only three; and the guardians and their officials, as a whole, might fairly claim to have struggled honestly and courageously with their herculean task.

But if the poor law managed somehow to weather the worst of the storm, that does not prove that the ship was, or can ever be made, seaworthy. What was done in the years of distress from 1921 onwards was done at a fearful cost, financial and moral. The burden of the rates lay heaviest where it could least be borne—on struggling industries and small householders and shopkeepers, in districts whose rateable value was low and in which public expenditure was bound to be high. The guardians could only ease its present weight by borrowings which spread it over the future. And the distribution of these vast sums was, and could only be, for the most part a dangerous form of charitable relief. Such a system might be justified as a temporary necessity in an emergency like that of the mining dispute of 1926. But as a settled policy it must lead to a pauperisation which would be none the less deplorable because the old "pauper stigma" was not attached to it. The experience of these "seven lean years," in short, confirmed only too plainly the conclusions of those who had insisted, before the war and after it, that local boards of guardians could not do the work of a national unemployment authority. And the vast majority of the guardians themselves, however much they might object to other proposed reforms of the poor law, were converted at least to this.

The Poor Law in 1927–28.—The following figures give some indication of the effect of the "seven lean years" on the extent and the cost of pauperism.

(A) Total number of persons in receipt of poor relief in England and Wales on January 1, and in Scotland on January 15, 1928, 1920 and 1914.

	England & Wales	Scotland
1928	1,236,000	240,580
1920	576,418	85,678
1914	761,578	105,245

(B) Total numbers in receipt of indoor and outdoor relief in 31 chief urban areas of Great Britain in Jan., 1928. (From *Ministry of Labour Gazette.*)

Area	No. in receipt of relief			Rate per 10,000 of estimated population
	Indoor	Outdoor	Total	
England and Wales:				
Metropolis:—				
West District	9,498	7,317	16,815	202
North District	10,873	18,580	29,453	286
Central District	2,399	2,578	4,977	371
East District	10,097	59,834	69,931	1,072
South District	19,647	71,936	91,583	466
Total Metropolis	52,514	160,245	212,759	461
West Ham	4,603	27,559	32,162	425
Other Districts:—				
Newcastle District	2,898	27,415	30,313	597
Stockton-on-Tees District	1,432	14,656	16,088	583
Bolton, Oldham, etc.	4,319	8,207	12,526	160
Wigan District	1,883	14,850	16,733	368
Manchester District	9,892	34,336	44,228	422
Liverpool District	10,159	65,088	75,247	593
Bradford District	1,826	6,913	8,739	237
Halifax and Huddersfield	1,562	3,349	4,911	131
Leeds	2,907	10,888	13,795	289
Barnsley District	1,007	10,509	11,516	343
Sheffield	2,655	23,694	26,349	512
Hull District	1,876	16,061	17,937	560
North Staffordshire	2,524	8,951	11,475	276
Other Districts:—Cont.				
Nottingham District	2,315	12,669	14,984	319
Leicester	1,208	4,147	5,355	222
Wolverhampton District	3,642	15,939	19,581	260
Birmingham	7,676	18,584	26,260	281
Bristol District	2,628	14,732	17,360	420
Cardiff and Swansea	2,645	20,039	22,684	469
Total, "Other Districts"	65,054	331,027	396,081	379
Total, Districts in England and Wales	122,171	518,831	641,002	405
Scotland:				
Glasgow District	6,121	78,963	85,084	885
Paisley and Greenock District	903	13,336	14,239	737
Edinburgh	1,794	18,742	20,536	484
Dundee and Dunfermline	877	4,802	5,679	263
Aberdeen	538	4,809	5,347	339
Coatbridge and Airdrie	380	5,529	5,909	581
Total for the above Scottish Districts	10,613	126,181	136,794	666
Total for above 31 Districts in Jan., 1928	132,784	645,012	777,796	435

(C) Unemployed persons (excluding the sick) who were in receipt of outdoor relief in England and Wales, June, 1927. (These figures are based on a return of the Ministry of Health [Cmd. 3006].)

	Men having no wife or child dependent	Men having wife or child dependent	Women	Total
Number of persons in each class who had been in receipt of poor-law relief in the same union continuously for—				
Less than one year	12,069	43,051	1,962	57,082
One year, but less than three years	9,900	27,356	1,712	38,968
Three years, but less than four years	1,934	6,795	536	9,265
Four years or more	1,963	8,528	536	11,027
Total number of persons in each class included in the returns	25,866	85,730	4,746	116,342

Of the total 82% were in 50 large unions, which contain 35% of the population of England and Wales. Over 44% of the men, and over 32% of the women were aged between 30 and 50. 2½% of the men and 15½% of the women were under 21. About 5% of both sexes were over 65.

(D) This table shows the total number of vagrants who were relieved in the casual wards (average on Friday nights throughout the year).

1910–11	11,801	1923–24	8,505
1913–14	7,794	1924–25	7,915
1919–20	1,870	1925–26	8,475

(E) Numbers on outdoor relief in certain London Unions in September, 1927.

Poplar	22,906	Greenwich	11,147
Bermondsey	13,206	Bethnal Green	10,851
Stepney	13,769		

(F) Proportionate increase of outdoor relief in certain London Unions (March 26, 1927, compared with December 25, 1920).

Union	Increase per cent.
Paddington, Hammersmith, St. Pancras, Hackney, Southwark, Lewisham	over 200
Poplar	„ 300
Greenwich	„ 500
St. Marylebone	„ 600
Stepney, Bermondsey, Woolwich	„ 700
Bethnal Green	„ 4,000

(G) Total poor law expenditure* (in round figures).

Year	England & Wales	Scotland
1926–27	£49,500,000	£5,171,000
1925–26	40,000,000	4,400,000
1919–20	23,500,000	2,100,000
1913–14	15,000,000	1,600,000

(H) Total cost of outdoor relief* (in round figures).

Year	England & Wales	Scotland
1926–27	£23,600,000	£3,947,000
1925–26	15,300,000	2,800,000
1919–20	4,109,000	963,000
1913–14	2,215,000	594,000

(*N.B. In making comparisons between the figures for different years, regard should be had to changes in the value of money. £1 in 1913–14 was equal roughly to 9/– in 1919–20, and 11/8 in 1926–27.)

(I) Cost of outdoor relief, per head of "ordinary outdoor poor," in 1926–27.

	Per week
England & Wales (average)	6/7¾d.
Bishopsthorpe	9/–
Berwick-on-Tweed	9/9d.
London (average)	7/4d.
Bethnal Green	8/3d.
Poplar	9/6d.
Scotland (average) (1925–26):	
Other than able-bodied	6/10¾d.
Able-bodied unemployed	4/6½d.

(J) Cost of indoor relief per head in 1925–26.

England & Wales (average).

(a) Provinces:

	Per week
In workhouse	from 8/11¾d. to 10/11¾d.
„ hospitals and asylums	„ 9/11½d. to 16/8½d.
„ separate institutions for children	„ 7/10¾d. to 9/0¼d.

(b) London:

	Per week
In workhouse	9/4d.
„ hospitals and asylums	15/4¾d.
„ separate institutions for children	9/7¾d.

Scotland.

"Sane indoor poor"	19/2¼d.

Neville Chamberlain began to move in the matter of poor law reform soon after he took office as minister of health in 1925. He carried through a measure which, though its prime object was to amend the rating system, was an important preliminary step towards the abolition of the guardians. Under the Rating and Valuation Act, 1925, the parish disappears as the valuation area, the board of guardians no longer appoints the assessment committee, and all the rating functions of the overseers of the poor are transferred to the town and district councils. The Rating (Scotland) Act, 1926, was framed on similar lines; the parish councils are replaced as rating authorities by the town and county councils, and the poor rates are raised by requisition on these. This legislation was followed towards the end of 1925 by detailed plans for the break up of the poor law. The main points were:—

(1) Boards of guardians to be abolished.

(2) Registration of births, deaths and marriages to be transferred to electoral registration officers acting for counties and county boroughs.

(3) The rest of their functions, and their property (including institutions), liabilities and staffs to be transferred to the county and county borough councils.

(4) County borough councils to provide at their own discretion for the carrying out of the transferred duties.

(5) The county council to be the supervising and controlling authority for all health purposes and to have complete responsibility for "home assistance" throughout the administrative county. The transferred duties to be carried out "through existing or new committees of the council, assisted where necessary by local sub-committees consisting of county councillors, or partly of county councillors and partly of representatives of the borough and district councils of the localities" (or of the metropolitan borough councils in London). But delegation to be allowed to borough and district councils (or metropolitan borough councils in London) of "any transferred service identical in kind with a service already administered by the borough or district council" (*e.g.*, care of infancy and expectant or nursing mothers).

(6) Relief to able-bodied persons to be limited and correlated with unemployment insurance.

(7) The assigned revenue system to be abolished. Block grants, fixed for a term of years, to be paid in aid of transferred and existing health services and distributed to county borough councils on a basis of population qualified by a factor representing low ability to pay. The cost of delegated services to be borne by the borough or district councils to which they are delegated.

This scheme, it will be seen, was based in principle on the Maclean report. But it had certain differences of detail, some of them important. In particular, it gave greater power to the counties, allowing no such autonomy as the Maclean report recommended to the larger non-county boroughs and urban districts. It also contemplated some special system of dealing with the able-bodied unemployed, though what that system was could not be discovered from the brief and obscure statement (*see* point [6] above) in which it was adumbrated. The whole scheme, however, was, Chamberlain said, provisional; it was issued primarily for consideration and criticism by the local authorities and others concerned. It had a mixed reception. Root and branch reformers welcomed it, though they were critical of certain details. The county and borough and district councils raised various technical objections. The guardians, who did not want to be done away with, and their friends, who carried weight with the Conservative Government, denounced it. In these circumstances it was evident that the proposals would have to be considerably modified before they could be made the basis of a Government bill. A new scheme emerged from the melting pot in the summer of 1927. It was largely an attempt to meet the criticisms of the Conservatives in the rural areas, and it represented a dubious compromise between the demand for reform and the claims of vested interests. Its principal features are:—

(1) The administration of the poor law is to be transferred from the existing boards of guardians to (a) the councils of the county boroughs, and (b) the councils of the non-county boroughs and the districts.

(2) The area of each county borough will be a single Union and the council will exercise all the poor law functions within its area.

(3) Elsewhere there is to be a division of powers. The town or district council will become the board of guardians for its area and will have the same powers and duties as the former guardians in regard to domiciliary relief.

(4) The provision of institutional relief will be the business of the county council, and all poor law institutions—workhouses, hospitals, casual wards, etc.—will be transferred to it. The new boards of guardians (save, as stated above, in the county boroughs) will not be allowed to own or lease any institution or building, except their own offices.

(5) Schemes for the reorganisation and administration of the institutions are to be prepared by the counties and county boroughs for the approval of the Ministry of Health. And these schemes are to include proposals not merely for the institutional treatment of paupers, but for the co-ordination of the public health service generally.

(6) The expenses of running the institutions will fall on the county or county borough, but the county council may recover from each board of guardians the cost of maintenance of its cases in an institution (except vagrants, who will be wholly a county charge).

There was little public discussion of the scheme, however, and in 1928 the Government abandoned it and reverted to the original plan.

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(C. M. L.)

The Local Government Act, 1929.—The whole machinery of Poor Law administration was changed by this Act which replaced the Boards of Guardians by Public Assistance Committees acting under the Ministry of Health. Two-thirds of the members of these Committees are required to be members of a County or County Borough Council. This law, together with previous legislation, was consolidated in the Poor Law Act, 1930.

UNITED STATES

Any discussion of the laws which relate to the relief of the poor in the United States is much complicated by the wide variety of law and practice among the 48 States, the many laws within States covering the different types of public assistance, and the present involvement of the three levels of government—Federal, State, and local. Prior to 1933, there was no Federal agency where comprehensive data could be secured covering State relief laws, their administration, or relief expenditures and the number of persons assisted. Since 1933, progress has been made in the collection of data covering the country generally on various types of outdoor relief. In addition, there have been many important special studies on phases of public welfare made by various Federal agencies.

I. HISTORY PRIOR TO 1930

State Laws.—Few States had a "Poor Law" in the sense of a comprehensive statute regulating relief to the poor and its administration. In many States the subject was dealt with briefly and fragmentarily in sections scattered through the general statutes. In some States, local provisions so modified State law that it was difficult to know what the law really was.

State laws were based largely on the early English Poor Law. They had been only slightly altered since enactment, with no reflection of changing social conditions and increasing understanding of social problems. The most important changes had been effected by taking away certain functions from poor relief officials, and not by reorganizing and improving the poor relief system. Under laws largely concerned with the control of vagrancy and able-bodied pauperism, officials attempted to care for the sick, aged, infirm, dependent children, destitute families, and in some cases the insane and mental defectives.

Responsibility for Care of the Poor.—The principle of responsibility for the care of the poor by some governmental unit was found in the laws of all States. The legislation tended to be permissive, leaving to the responsible authorities the decision as to whether almshouses should be erected and whether outdoor relief should be granted.

Administrative Systems.—In the New England States the townships, through their selectmen, cared for the poor. Later, when the duties became heavier, a special poor relief official, the overseer of the poor, was substituted for the selectman. Cities usually had the same responsibilities as the towns. In Southern States, the county was the governmental unit and poor relief was on a county basis, with the governing board of the county as the administrative authority. These two systems, or some combination of them, formed the basis for the administrative systems of all the States, the governmental form adopted in the States depending largely on the system in vogue in the State from which most of the settlers came. In about half of the States all poor relief was administered on a county basis. In States having a mixed administrative system, the relation of the city and town to the county was complicated and varied greatly from State to State. City charters usually placed the responsibility for the care of the poor on a special official or board, either elected or appointed.

Authorized Relief.—The laws of every State except New Mexico authorized the establishment of almshouses by some governmental unit, either the town, city, or county. The law, with the exception of two States, was permissive. Outdoor relief was authorized at the discretion of the poor law authorities, either by specific statement or by implication. As a rule, the laws dealt briefly with outdoor relief, regarding it as a temporary expedient, and tended to place greater emphasis on almshouse care. Medical care was authorized at the discretion of the poor law officials as a form of poor relief.

Eligibility for Relief.—Practically all laws had some definition of what sort of persons were to be cared for by public relief. In about three-quarters of the States, care was to be given to "persons unable to support themselves" or "all poor, indigent, and incapacitated persons." The laws of most of the States established the liability of the community for support of a needy person on the basis of "settlement,"—a required length of residence in the community. As a rule, legal settlement was acquired by a residence for a stated time in the particular governmental unit without receipt of relief. The usual requirement was for residence of one year, though some States required as much as five or seven years. Settlement was generally considered to have been lost in a State by absence for one year from that State.

Liability of Relatives.—The laws of most of the States were based on the principle that relief should be given only when there were no close relatives liable and able to support their dependents. Occasionally the grandparents and grandchildren were made liable, but usually only parents and children.

State Supervision.—While 43 States had some central board or department with some degree of administrative or supervisory responsibility relating to some phases of the care of the dependent classes, comparatively few such State bodies had definite responsibilities in regard to the supervision of poor relief. In about one-quarter of the States, State authorities inspected almshouses, received financial reports, and made recommendations to local authorities. The recommendations, however, could seldom be enforced. There was even less supervision of outdoor relief, and comparatively few States had accurate figures as to the amount expended for this purpose by local authorities.

Development of Poor Relief.—At first, the poor were cared for by outdoor relief, by indenture of adults or children, or by boarding out. As the number of poor increased, the practice grew of auctioning the care of the poor as individuals or as a group. The first almshouse was established in Massachusetts in 1660, but it was not until after 1700 that any great number were established. During the 18th century and the first half of the 19th century the almshouse came to be looked upon as the best method of correcting the abuses inherent in the earlier systems of aiding the poor at home. It soon became a catch-all for all types of people for whom no other care was available, such as the sick, the aged, infirm, children, insane, feeble-minded, vagrants, etc. The period from 1870 was characterized by a growing realization of the

failure of the almshouse to care adequately for its varied type of inmates. By steady effort, specialized care was secured for many of these cases. In particular, laws were enacted forbidding the care of children in almshouses and requiring the removal of the insane and feeble-minded.

A report of the United States census on Jan. 1, 1923, showed that there were 78,090 inmates in almshouses, showing a decrease since 1910 when there had been 84,198 inmates. In 1923, 47 States had 2,183 publicly owned almshouses, representing an investment of $150,485,230. The annual maintenance cost of the publicly owned institutions was $28,740,523. About 88% of the publicly owned almshouses were directly operated by public officials. The other 12% operated under a contract system whereby the public institution and care of the inmates was given to a private individual on various terms. As to public outdoor relief, very little was known prior to 1930, since no general study had ever been made and few States had even accurate information as to the amount expended by local officials for this purpose. From figures available from a few States, it was evident that many more people were being aided by outdoor relief than through almshouse care. The administration of outdoor relief was subject to great criticism which certain special studies justified.

Children.—Poor relief officials were originally responsible for all public care given to dependent children, but this function was taken away from them in all but a few States, chiefly during the years following 1900. The inefficiency of almshouse care and the inadequate care given by poor law officials to children, resulted in the establishment of new agencies for the care of dependent children, such as county boards of child welfare, boards of children's guardians, county children's courts, county children's homes, or a State institution. In all except a few States, the poor relief officials came to have practically no responsibility for children cared for away from their families.

Special Types of Assistance.—The inadequacies of the poor relief system also gave rise to statutory provision for special types of assistance, now commonly called categorical assistance, usually administered by other than poor law officials. These types included assistance to veterans, widows' pensions or mother's aid, and assistance to the blind and the aged. Relief to war veterans was the earliest type of special assistance. The first State statute providing mother's aid, now known as aid to dependent children, was passed in 1911. Major development in the field of assistance to the blind began in 1910. A law providing for old age assistance was passed in 1914, but was declared unconstitutional; the next such statute was enacted in 1923. By 1930, there had been substantial growth in all of the special types of assistance.

Poor Law Administration.—Faulty administration was undoubtedly the chief weakness of the poor relief system in every State. In only a few States was there any evidence of public interest in poor law reform. Instead, the tendency had been to transfer poor relief functions to agencies caring for special groups of dependents. Some changes made in State laws were in the direction of establishing the county as the unit of administration, as for example, the new poor law passed in Pennsylvania in 1925 and the public welfare law passed in New York State in 1929. The New York public welfare law, replacing a statute which had not been significantly changed for a hundred years, embodied the modern philosophy which was to mark later legislation in the relief field.

II. HISTORY SINCE 1930

Great changes in the relief structure of the United States occurred in the decade following 1930. The depression beginning in 1929, and the ensuing unemployment, brought on a volume of relief need with which existing poor law systems were utterly unable to cope. Not only was this magnitude of need entirely beyond the possibility of local units of Government to finance, the nature of the problem itself had significantly changed. Previously the group aided by poor officials comprised mainly the unemployable; the new group, on the other hand, was constituted principally of people out of work who were able and wanted to work. New administrative systems and procedures had to be established, and the deterrent philosophy underlying the poor law had to give way to a more constructive method of public assistance. This is strikingly apparent in the relief field, but other forms of care such as almshouse care and care of children away from their own homes have continued with relatively little change during this period.

Emergency Unemployment Relief and Federal Participation in Relief.—Beginning in 1931, States enacted emergency unemployment relief laws usually with the purpose of providing State funds for relief. In general, these laws supplemented and broadened poor laws, or temporarily superseded them. In some States, the emergency unemployment relief program was separate from the established outdoor relief system; in other States, the two programs were integrated from the outset. By 1933, legislation had been enacted in nearly three-quarters of the States which provided some system for emergency unemployment relief. In many States the systems included a program of work relief whereby needy persons were provided for by wages earned on relief projects.

A major step in the public welfare history of the country was taken with the entrance of the Federal Government as a participant in the relief problem. This occurred first in 1932, when funds were loaned to States and local governmental units for the relief of the unemployed. It continued, more significantly and on a wider scale, with the establishment of the Federal Emergency Relief Administration in 1933, authorized to make outright grants to States for relief purposes. Work programs financed by Federal, State, and local funds came to play a large part in the general relief program, and it was roughly calculated that about 50% of persons in need were cared for through work relief. Relief standards were quite generally raised through financial participation of the Federal Government and some degree of Federal supervision or control.

The FERA was discontinued in 1935, with the Federal Government then embarking on what it regarded as a sounder method of assisting in the emergency relief problem. It established a federally administered and financed work program, the Works Progress Administration. At the same time, under the Social Security Act, it provided grants in aid to States for the care of the aged, blind, and children at home. The cessation of Federal grants to States for direct unemployment relief had an adverse effect particularly serious in poorer States. In some States, though some meagre provision for assistance was available, no relief was provided to employables for whom there was no place on WPA.

Special Types of Assistance.—The Social Security Act established the principle of Federal assistance to States in special forms of relief. It provides grants-in-aid to States for old age assistance, aid to the blind and aid to dependent children, with requirements for State financial participation and certain standards in State plans as a condition for receiving Federal grants. Prior to the Social Security Act, there had been considerable development of these special forms of relief. In 1934, all except three States had mother's aid laws; 28 States had laws providing assistance for the aged; and in 1935, 26 States had laws providing assistance to the blind. The Federal act stimulated greatly the enactment of more such laws, and revision of existing laws. In 1939 all but a very few States had legislative provision for all of these types of assistance.

Provisions for Care and Eligibility.—Persons in need are cared for chiefly in three ways: general home relief, special types of assistance, work relief. General home relief cares for those not eligible for the special types of assistance or for WPA, and for those eligible for but not receiving these forms of aid. Established need and settlement are the usual prerequisites for receiving general home relief. Certain additional qualifications are necessary for the special types of assistance. WPA takes care of the major number of employable unemployed who are certified as to need by relief agencies in the majority of States, but occasionally by WPA itself. In addition, hospital care, institutional care and care of children away from their own homes are provided, though these types of care are overshadowed by the magnitude of the outdoor relief programs.

Administration of Outdoor Relief.—The Federal Government directly administers WPA and establishes the standards for the special types of assistance which States must meet to receive Federal aid. The State governments either administer or supervise the local administration of the special types of assistance. About two-thirds of the States also have either administrative or supervisory responsibility for general home relief. The local governments in many States directly administer the special types of assistance, and in all except ten States are administratively responsible for general home relief. There has been a trend toward integration of State supervisory or administra-

tive departments to cover the different types of assistance. In 1939, 45 States had State agencies administering or supervising at least three types of assistance, 22 of them administering or supervising five types of assistance. Several State agencies administered or supervised a completely integrated program. It may be said in general that the administration of special types of assistance is more controlled and on a more permanent basis than the administration of general home relief which remains quite largely the responsibility of local governmental units. Extremely significant changes, however, have occurred or are occurring, as follows: (1) a decided increase in the strengthening of State supervision of local administration; (2) an assumption by the State of direct administrative responsibility; and (3) a tendency toward integration in one central State body of supervisory or administrative responsibility. The degree to which these changes have occurred vary, of course, from State to State.

Financing of Relief.—Prior to 1930, the cost of relief with minor exceptions was borne by local units of government. This applied in the majority of instances to the special types of assistance as well as to general home relief. Beginning in 1931, there was an increase in State financial participation in general home relief; and after 1935, a similar increase for the special types of assistance. In 1939, some State funds for general home relief were provided in two-thirds of the States; all States provided funds for old age assistance; all but two States provided funds for blind assistance; and all but four States provided funds for aid to dependent children. Usually when financial responsibility is divided between States and local units, the amounts to be contributed by each are determined by a fixed percentage of the total. Some States allow administrative discretion for the distribution of State funds, with various criteria used for such distribution. The trend in the financing of relief generally parallels the trends in relief administration and supervision, with more and more responsibilities assumed by the States. For general home relief, the major financial responsibility, if not the exclusive responsibility, remains with the local units of government in most States.

Statistics on Expenditures and Caseloads.—Before 1933 there were no figures on relief expenditures for recipients even approximately complete, though special studies had shown a slight but steady trend upward before 1929, and a sharp upward trend after that year. The Social Security board has collected figures on outdoor relief with relative completeness covering the period from 1933, though the general relief figures rely partially on estimates. These figures show an increase in expenditures for all forms of outdoor relief from $1,358,159,000 in 1933 to $3,485,757,000 in 1938. Monthly expenditures in the early months of 1939 amounted to more than $300,000,000. As of 1938, WPA accounted for about 50% of the expenditures, the special types of assistance about 15%, general relief about 14%, and miscellaneous programs about 21%. It was estimated that in December of 1938, 6,500,000 households representing 20,900,000 persons, or between one-sixth and one-seventh of the total population, received some sort of assistance during the month.

Status of Relief Legislation.—Legislation in the relief field is in a transitional stage. Beginning with the enactment of emergency unemployment relief laws and later with the increase in laws covering special types of assistance, the past decade has been particularly marked by the diminishing importance of the old "poor laws" which now play a relatively small part in the total public welfare structure. The status of relief legislation varies greatly from State to State. Some States have passed unified statutes covering all types of relief; other States still operate under a combination of poor laws, laws covering special types of assistance, and emergency unemployment relief laws. The trend is toward unification, with the elimination of the poor laws and emergency laws and the enactment of comprehensive public welfare laws covering all forms of public assistance. In States where this has occurred, the new laws show marked improvement both in substance and spirit over the old laws, even though they embody some of the characteristics of the poor laws, particularly the requirements of settlement and responsibility of legally liable relatives to support dependents. In general, there has been astonishing progress made in the decade since 1930, and the coming years should show further progress toward a sound public welfare structure.

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POOR PERSONS: *see* PRACTICE AND PROCEDURE.

POOR-WILL, the name (from its cry) of a North American bird (*Phalaenoptilus nuttalli*), allied to the whip-poor-will, nightjar and nighthawk (*qq.v.*), which it resembles in habits. It is about 8 in. long, the smallest of the family; the primaries are rusty, barred with black. It breeds west of the Mississippi north to British Columbia, and south to southern California. There are two subspecies, the frosted poor-will (*P. n. nitidus*) in Texas and Arizona, and the California poor-will (*P. n. Californicus*) in the coast region of California.

POPAYÁN, a city of Colombia, capital of the department of Cauca, about 240 mi. S.W. of Bogotá, on the old trade route between that city and Quito, in 2° 26′ N., 76° 49′ W. Pop. (1947) 35,960. Popayán is built on a great plain sloping northwest from the foot of the volcano Puracé, near the source of the Cauca and on one of its small tributaries, 5,712 ft. above the sea. Its situation is singularly picturesque, the Puracé rising to an elevation of 15,420 ft. about 20 mi. S.E. of the city, the Sotara volcano to approximately the same height about the same distance south by east; behind these at a greater distance is the Pan de Azúcar, 15,978 ft. high. It has rail connection with Cali. Earthquakes caused much damage to Popayán, especially those of 1827 and 1834.

Popayán was founded by Sebastián Benalcázar in 1538 on the site of an Indian settlement, whose chief, Payán, had the unusual honour of having his name given to the usurping town. It is noted as the birthplace of Caldas, the Colombian naturalist, and of Mosquera, the geographer.

POPE, an ecclesiastical title now used in the West exclusively to designate the head of the Roman Catholic Church. In the 4th and 5th centuries it was frequently used by any bishop (Du Cange, *s.v.*); but it gradually came to be reserved to the bishop of Rome, becoming official. In the East, the title became restricted to the patriarchs of Alexandria, Antioch, Jerusalem and Constantinople, but is still given by popular usage to priests. Even in the case of the sovereign pontiff the word pope is officially only used as a less solemn style: though the ordinary signature and heading of briefs is, *e.g.*, "Pius P.P.X.," the signature of bulls is *Pius episcopus ecclesiae catholicae,* and the heading, *Pius episcopus, servus servorum Dei,* this latter formula going back to the time of St. Gregory the Great. Other styles met with in official documents are *Pontifex, Summus pontifex, Romanus pontifex, Sanctissimus, Sanctissimus pater, Sanctissimus dominus noster, Sanctitas sua, Beatissimus pater, Beatitudo sua;* while the pope is addressed in speaking as *"Sanctitas vestra,"* or *"Beatissime pater."*

Jurisdiction.—The pope is pre-eminently, as successor of St. Peter, bishop of Rome. Writers are fond of viewing him as representing all the degrees of the ecclesiastical hierarchy; they say that he is bishop of Rome, metropolitan of the Roman province, primate of Italy, patriarch of the Western Church and head of the universal Church. This is strictly correct, but, with the exception of the first and last, these titles are seldom to be found in documents. And if these terms were intended to indicate so many degrees in the exercise of jurisdiction they would not be correct. As a matter of fact, from the earliest centuries (*cf.* can. 6 of Nicaea, in 325), we see that the popes exercised a special metropolitan jurisdiction not only over the bishops nearest to Rome, the future cardinal bishops, but also over all those of central and southern Italy, including Sicily (*cf.* Duchesne, *Origines du culte,* ch. 1), all of whom received their ordination at his hands. Northern Italy and the rest of the western Church, still more the eastern Church, did not depend upon him so closely for their administration. His influence was exercised, however, not only in dogmatic questions but in matters of discipline, by means of appeals, petitions and consultations, not forgetting to mention spontaneous intervention.

Primacy.—The primacy of the pope, a primacy of honour and jurisdiction, involving the plenitude of power over the teaching, the worship, the discipline and administration of the Church, is received by the pope as part of the succession of St. Peter, together with the episcopate of Rome. The whole episcopal body, with the pope at its head, should be considered as succeeding to the apostolic college, presided over by St. Peter; and the head of it, now as then, as personally invested with all the powers enjoyed by the whole body, including the head. Hence the pope, as supreme in matters of doctrine, possesses the same authority and the same infallibility as the whole Church; as legislator and

judge he possesses the same power as the episcopal body gathered around and with him in oecumenical council. Such are the two essential prerogatives of the papal primacy: infallibility in his supreme pronouncements in matters of doctrine (*see* INFALLIBILITY); and immediate and sovereign jurisdiction, under all its aspects, over all the pastors and the faithful. These two privileges, having been claimed and enjoyed by the popes in the course of centuries, were solemnly defined at the Vatican Council by the constitution *Pastor aeternus* of the 18th of July 1870. For the history of the papacy, and associated questions *see* PAPACY, CONCLAVE, CURIA ROMANA, CARDINAL, VESTMENTS. For restoration of the temporal power, *see* VATICAN. For particulars regarding the lives of the different popes, *see* the separate articles.

POPE, ALEXANDER (1688–1744), English poet, was born in Lombard street, London, on May 21, 1688. His father, Alexander Pope, a Roman Catholic, was a linen-draper who afterwards retired from business with a small fortune and fixed his residence about 1700 at Binfield in Windsor forest. Pope's education was desultory. Before he was 12 he had obtained a smattering of Latin and Greek from various masters; by his 17th year excessive study had undermined his health and he had developed the personal deformity which later on largely distorted his view of life. Under the treatment, however, of the famous physician John Radcliffe, he recovered his health and continued his studies.

Pope was early an eager aspirant to the highest honours in poetry, and his connections with neighbouring Roman Catholic families of influence in the literary world gave direction to his ambitions. Pope was thus brought under the notice of Sir William Trumbull, a retired diplomatist, living at Easthampstead. Thomas Dancastle, lord of the manor of Binfield, took an active interest in his writings, and at Whiteknights, near Reading, lived another Roman Catholic, Anthony Englefield, "a great lover of poets and poetry." Through him Pope made the acquaintance of Wycherley and of Henry Cromwell, the former introducing him to William Walsh, then of great renown as a critic. Before the poet was 17 he was admitted in this way to the society of London "wits" and men of fashion, and was cordially encouraged as a prodigy.

Pope recognized soon that a long course of preparation was needed for the translation of *Homer* into English verse, on which he had decided. He learnt most, as he acknowledged, from Dryden, but the harmony of his verse also owed something to an earlier writer, George Sandys, the translator of Ovid. At the beginning of the 18th century Dryden's success had given great vogue to translations and modernizations. Dryden had rewritten three of the *Canterbury Tales;* Pope tried his hand at the *Merchant's Tale, Prologue to the Wife of Bath's Tale,* the *House of Fame,* and further experimented with translations from some Latin authors and the *Odyssey.*

Precocious Pope was, but he was also industrious; and he spent nine years in arduous discipline, before anything of his appeared in print. His first publication was his "Pastorals"; they appeared in May 1709 at the end of the sixth volume of Tonson's *Poetical Miscellanies,* containing contributions from Ambrose Philips, Sheffield, Garth and Rowe, with "January and May," Pope's version of Chaucer's "Merchant's Tale."

Pope's next publication was the *Essay on Criticism* (1711), written two years earlier, and printed without the author's name. The sales were slow until Pope caused copies to be sent to Lord Lansdowne and others, but its success was none the less brilliant for the delay. The town was fairly dazzled by the young poet's learning, judgment, and felicity of expressions, and Pope gained credit for much that might have been found where he found it, in the *Institutes* of Quintilian, in the numerous critical writings of René Rapin, and in René le Bossu's treatise on epic poetry. Addison has been made responsible for the exaggerated value once set on the essay, but Addison's paper (*Spectator,* No. 253) was not unmixed praise. He and Pope became acquainted and Pope's sacred eclogue, "Messiah," was printed as No. 378 of the *Spectator.* In the *Essay on Criticism* Pope provoked one bitter personal enemy in John Dennis, the critic, by describing him as Appius, who "stares, tremendous, with a threat'ning eye." Dennis retorted in *Reflections . . . upon a late Rhapsody . . .* (1711), abusing Pope among other things for his personal deformity; and Pope never forgot this brutal attack.

The *Rape of the Lock,* in its first form, appeared in 1712 in *Lintot's Miscellanies;* the "machinery" of sylphs and gnomes was an afterthought, and the poem was republished as we now have it early in 1714. William, 4th Baron Petre, had surreptitiously cut off a lock of Miss Arabella Fermor's hair, and the liberty had been resented; Pope hearing of this, caught at the hint, and treated the subject in mock heroic vein—the result being a poem which is generally admitted to be a masterpiece of airiness, ingenuity, and exquisite finish. It was followed by the publication in March, 1713, of *Windsor Forest,* which was begun, according to Pope, when he was 16 or 17. Hitherto, Pope had avoided politics, but this work appeared with a flattering dedication to the secretary for war, George Granville, Lord Lansdowne, and an opportune allusion to the Treaty of Utrecht. When the poem appeared, it was made the subject of an insidious attack by the Addison coterie, who about this time became estranged from Pope. Addison disavowed connivance of this coarse attack, but a coolness between the two friends ensued.

The attacks upon *Windsor Forest* appeared in a series of papers on "Pastorals" which were published in the *Guardian* (Nos. 22, 23, 28, 30 and 32). No mention was made of the poem, but everyone knew to whom the general principles referred. In the articles the introduction of Greek names, customs and deities was ridiculed and as *Windsor Forest* was fairly open to criticism on this ground, the real subject of the papers was manifest. The real sting of the criticisms, however, lay in their extravagant praise of the second-rate poet Ambrose Philips and the implied comparison with Pope. The latter characteristically succeeded in revenging himself. He secured the publication in the *Guardian* of an anonymous article which ostensibly attacked his own poems, but which actually, by quotation, disposed of the pretensions of Ambrose Philips, and ridiculed the *Guardian's* principles.

The links that attached Pope to the Tory party were strengthened by a new friendship. His first letter to Swift, who became warmly attached to him, is dated Dec. 8, 1713. Swift had been a leading member of the Brothers' Club, from which the famous Scriblerus Club seems to have been an offshoot. The leading members of this informal literary society were Swift, Arbuthnot, Congreve, Bishop Atterbury, Pope, Gay and Thomas Parnell. Their chief object was a general war against the dunces, waged with great spirit by Arbuthnot, Swift and Pope.

The estrangement from Addison was completed in connection with Pope's translation of Homer, which was definitely undertaken in 1713, and was published by subscription. Men of all parties subscribed, their unanimity being a striking proof of the position Pope had attained at the age of 25. But the unanimity was broken by a discordant note. A member of the Addison clique, Tickell, attempted to run a rival version. Pope suspected Addison's instigation; Tickell had at least Addison's encouragement. Pope's famous character of Addison as "Atticus" in the *Epistle to Dr. Arbuthnot* (ii. 193–215) was, however, inspired by resentment at insults that existed chiefly in his own imagination.

The translation of Homer was Pope's chief employment for 12 years. The new pieces in the miscellanies published in 1717, his "Elegy on an Unfortunate Lady," and his "Eloisa to Abelard," were probably written some years before their publication. The *Iliad* was delivered to the subscribers in instalments in 1715, 1717, 1718 and 1720. Pope's own defective scholarship made help necessary. William Broome and John Jortin supplied the bulk of the notes, and Thomas Parnell the preface. For the translation of the *Odyssey* he took Elijah Fenton and Broome as coadjutors, who between them translated 12 out of the 24 books. (1, 4, 19 and 20 are by Fenton; 2, 6, 8, 11, 12, 16, 18, 23, with notes to all the books, by Broome.) It was completed in 1725. Opinions have varied on the purely literary merits of the poem, but with regard to it as a translation few have differed from Bentley's criticism, "A fine poem, Mr. Pope, but you must not call it Homer." In 1722 he edited the poems of Thomas Parnell, and in 1725 made a considerable sum by an unsatisfactory edition of Shakespeare, in which he had the assistance of Fenton and Gay.

Pope, who cleared £8,000 by the two translations, was thus rendered independent and enabled to live near London. The estate at Binfield was sold, and he removed with his parents to Mawson's buildings, Chiswick, in 1716, and in 1719 to Twickenham, to the house with which his name is associated. Here he practised elaborate gardening on a small scale, and built his famous grotto, which was really a tunnel under the road connecting the garden with the lawn on the Thames. He was constantly visited at Twickenham by his intimates, Dr. John Arbuthnot, John Gay, Bolingbroke (after his return in 1723), and Swift (during his brief visits to England in 1726 and 1727), and by many other friends of the Tory party. With Atterbury, bishop of Rochester, he was on terms of affectionate intimacy, but he blundered in his evidence when he was called as a witness on his behalf in 1723.

In 1717 his father died, and he appears to have turned to the Blounts for sympathy in what was to him a very serious bereavement. He had early made the acquaintance of Martha and Teresa Blount, having probably met them first at the house of his neighbour, Englefield of Whiteknights, who was their grandfather. Their home was at Mapledurham, near Reading. He began to correspond with Martha Blount in 1712, and after 1717, the letters are much more serious in tone. He quarrelled with Teresa, who had apparently injured or prevented his suit to her sister, but his friendship with Martha lasted all his life. So long as his mother lived he was unwearying in his attendance on her, but after her death in 1733 his association with Martha Blount was more constant. His earlier attachment to Lady Mary Wortley Montague was apparently a literary passion, which perished under Lady Mary's ridicule.

The year 1725 may be taken as the beginning of the third period of Pope's career, when he made his fame as a moralist and a satirist. Edward Young's satire, *The Universal Passion,* had just appeared, and been received with more enthusiasm than any thing published since Pope's own early successes. Swift was finishing Gulliver's *Travels,* and the survivors of the Scriblerus Club resumed their old amusement of parodying and otherwise ridiculing bad writers, especially bad writers in the Whig interest; four volumes of their *Miscellanies in Prose and Verse* were published from 1727 to 1732. According to Pope's own history of the *Dunciad, an Heroic Poem in Three Books,* which first appeared on May 28, 1728, the idea of it grew out of this. Among the Miscellanies was a "Treatise of the Bathos or the Art of Sinking in Poetry," which gave rise to a torrent of abusive falsehoods and scurrilities from those who thought themselves injured by it.

The *Dunciad* was Pope's answer to them, and among the most prominent objects of his satire were Lewis Theobald, Colley Cibber, John Dennis, Richard Bentley, Aaron Hill and Bernard Lintot, who, in spite of his former relations with Pope, was now classed with the piratical Edmund Curll. The book was published anonymously with the greatest precautions. When the success of the poem was assured, it was republished in 1729, and a copy was presented to the king by Sir Robert Walpole. Names took the place of initials, and a defence of the satire, written by Pope himself, but signed by his friend William Cleland, was printed as "A letter to the Publisher." Various indexes, notes and particulars of the attacks on Pope made by the different authors satirized were added. To avoid any danger of prosecution, the copyright was assigned to Lord Oxford, Lord Bathurst and Lord Burlington, whose position made them practically unassailable. The most unprovoked assault was on Richard Bentley, whom he satirized in the reconstruction and enlargement of the *Dunciad* made in the last years of his life at the instigation, it is said, of William Warburton. In the earlier editions the place of hero had been occupied by Lewis Theobald, who had ventured to criticize Pope's *Shakespeare.* In the edition which appeared in Pope's *Works* (1742), he was dethroned in favour of Colley Cibber; Warburton's name is attached to many new notes, and one of the preliminary dissertations by Ricardus Aristarchus on the hero of the poem seems to be by him.

The four epistles of the *Essay on Man* (1733) were also intimately connected with passing controversies. The subject was suggested to him by Henry St. John, Lord Bolingbroke, who had returned from exile in 1723 and was a fellow-member of the Scriblerus Club. Bolingbroke is said—and the statement is supported by the contents of his posthumous works—to have furnished most of the arguments. In this didactic work, as in his *Essay on Criticism,* Pope put together on a sufficiently simple plan a series of happy sayings, separately elaborated, picking up the thoughts as he found them in miscellaneous reading and conversation and trying only to fit them with perfect expression. His readers were too dazzled by the verse to be severely critical of the sense. Pope himself had not comprehended the drift of the arguments he had adopted from Bolingbroke, and was alarmed when he found that his poem was generally interpreted as an apology for the freethinkers. Warburton is said to have qualified its doctrines as "rank atheism," and asserted that it was put together from the "worst passages from the worst authors." The essay was soon translated into the chief European languages, and in 1737 its orthodoxy was assailed by a Swiss professor, Jean Pierre de Crousaz, in an *Examen de l'essay de M. Pope sur l'homme.* Warburton now saw fit to revise his opinion of Pope's abilities and principles—for what reason does not appear. In any case he now became as enthusiastic in his praise of Pope's orthodoxy and his genius as he had before been scornful, and proceeded to employ his unrivalled powers of sophistry in a defence of the orthodoxy of the conflicting and inconsequent positions adopted in the *Essay on Man.* Pope was wise enough to accept with all gratitude an ally who was so useful a friend and so dangerous an enemy, and from that time onward Warburton was the authorized commentator of his works.

The *Essay on Man* was to have formed part of a series of philosophic poems on a systematic plan. The other pieces were to treat of human reason, of the use of learning, wit, education and riches, of civil and ecclesiastical polity, of the character of women, etc. Of the ten epistles of the *Moral Essays,* the first four, written between 1731 and 1735, are connected with this scheme, which was never completed.

There was much bitter, and sometimes unjust, satire in the *Moral Essays* and the *Imitations of Horace.* In these epistles and satires, which appeared at intervals, Pope was often the mouthpiece of his political friends, who were all of them in opposition to Walpole, then at the height of his power, and Pope chose the objects of his attacks from among the minister's adherents. Epistle III., "Of the Use of Riches," addressed to Allen Bathurst, Lord Bathurst in 1732, is a direct attack on Walpole's methods of corruption and on his financial policy in general; and the two dialogues (1738) known as the "Epilogue to the Satires," professedly a defence of satire, form an eloquent attack on the court. Pope was attached to the prince of Wales's party and he did not forget to insinuate, what was indeed the truth, that the queen had refused the prince her pardon on her death-bed. The "Epistle to Dr. Arbuthnot" contains a description of his personal attitude towards the Scriblerus and is made to serve as a "prologue to the satires." The gross and unpardonable insults bestowed on Lord Hervey and on Lady Mary Wortley Montague in the first satire "to Mr. Fortescue" provoked angry retaliation from both. The descriptions of Timon's ostentatious villa in Epistle IV., addressed to the earl of Burlington, was generally taken as a picture of Canons, the seat of John Brydges, duke of Chandos, one of Pope's patrons. Epistle II., addressed to Martha Blount, contained the picture of Atossa, which was taken to be a portrait of Sarah Jennings, duchess of Marlborough.

One of the worst imputations on Pope's character was that he left this passage to be published when he had in effect received a bribe of £1,000 from the duchess of Marlborough for its suppression through the agency of Nathanael Hooke (d. 1763). As the passage eventually stood, it might be applied to Katherine, duchess of Buckingham, a natural daughter of James II. Pope may have altered it with the intention of diverting the satire from the original object. To appreciate fully the point of his allusions requires an intimate acquaintance with the political and social gossip of the time, but apart from their value as a brilliant strongly-coloured picture of the period, Pope's satires have a permanent value as literature. It is justly remarked by Mark

Pattison (in his edition of the *Satires and Epistles*, 1866), that "these *Imitations* are among the most original of his writings." The vigour and terseness of the diction is still unsurpassed in English verse.

Pope's wit had won for him the friendship of many distinguished men, and his small fortune enabled him to meet them on a footing of independence. He paid long visits at many great houses, especially at Stanton Harcourt, the home of his friend Lord Chancellor Harcourt; at Oakley, the seat of Lord Bathurst; and at Prior Park, Bath, where his host was Ralph Allen. He died on May 30, 1744, and was buried in the parish church of Twickenham. He left the income from his property to Martha Blount till her death, after which it was to go to his half-sister Magdalen Rackett and her children. His unpublished mss. were left at the discretion of Lord Bolingbroke, and his copyrights to Warburton.

If we are to judge Pope fairly there are two features of his times that must be kept steadily in view—the character of political strife in those days and the political relations of men of letters. The age of Queen Anne was pre-eminently an age of intrigue. The Government was almost as unsettled as in the early days of personal monarchy, but it was policy rather than force upon which men depended for keeping their position. Secondly, men of letters were admitted to the inner circles of intrigue as they had never been before and as they have never been since; and Queen Anne's statesmen paid their principal literary champions with social privileges and honourable public appointments. Hence men of letters were directly infected by the low political morality of the unsettled time.

Pope's own ruling passion was the love of fame, and he had no scruples where this was concerned. His vanity and his childish love of intrigue are seen at their worst in his petty manoeuvres to secure the publication of his letters during his lifetime. These intricate proceedings were unravelled with great patience and ingenuity by Charles Wentworth Dilke, when the false picture of his relations with his contemporaries which Pope had imposed on the public had been practically accepted for a century. After manipulating his correspondence so as to place his own character in the best light, Pope deposited a copy in the library of Edward, second earl of Oxford, and then had it printed. The sheets were offered to Curll by a person calling himself P.T., who professed a desire to injure Pope, but was no other than Pope himself. The copy was delivered to Curll in 1735 after long negotiations by an agent who called himself R. Smythe, with a few originals to vouch for their authenticity. P.T. had drawn up an advertisement stating that the book was to contain certain answers from various peers. Curll was summoned before the House of Lords for breach of privilege, but was acquitted, as the letters from peers were not in fact forthcoming. Difficulties then arose between Curll and P.T., and Pope induced a bookseller named Cooper to publish a *Narrative of the Method by which Mr. Pope's Private Letters were procured by Edmund Curll, Bookseller* (1735). These preliminaries cleared the way for a show of indignation against piratical publishers and a "genuine" edition of the *Letters of Mr. Alexander Pope* (1737, fol. and 4to).

Unhappily for Pope's reputation, his friend Caryll, who died before the publication, had taken a copy of Pope's letters before returning them. This letter-book came to light in the middle of the 19th century, and showed the freedom which Pope permitted himself in editing. The correspondence with Lord Oxford, preserved at Longleat, afforded further evidence of his tortuous dealings. But against Pope's petulance and "general love of secrecy and cunning" have to be set, in any fair judgment of his character, his exemplary conduct as a son, the affection with which he was regarded in his own circle of intimates, and many well-authenticated instances of genuine and continued kindliness to persons in distress.

BIBLIOGRAPHY.—Various collected editions of Pope's *Works* appeared during his lifetime, and in 1751 an edition in nine volumes was published by a syndicate of booksellers "with the commentaries of Mr. Warburton." In 1769–1807 an edition was issued which included Owen Ruffhead's *Life of Alexander Pope* (1769), which was largely inspired by Warburton. The notes of many commentators, with some letters and a memoir, were included in the *Works of Alexander Pope*, ed. W. L. Bowles (10 vols., 1806). His *Poetical Works* were edited by Alexander Dyce (1856); by R. Carruthers (1858) for Bohn's Library; by A. W. Ward (*Globe Edition*, 1869), etc. Materials for a definitive edition were collected by John Wilson Croker, and formed the basis of what has become the standard version, *The Works of Alexander Pope* (10 vols., 1871–98), including unpublished letters and other new material, with introduction and notes by W. Elwin and W. J. Courthope. The life of Pope in vol. v. was contributed by Prof. Courthope. The chief original authority besides Pope's correspondence and Ruffhead's *Life* is Joseph Spence's *Anecdotes*, published by S. W. Singer in 1820. Samuel Johnson gives a good estimate of Pope in his *Lives of the Poets*. The best modern lives are that by Prof. Courthope already mentioned; and *Alexander Pope*, by Sir L. Stephen, in the *English Men of Letters* series (1880). *See* also George Paston, *Mr. Pope: his Life and Times* (1909). The first check to the admiration that prevailed during Pope's lifetime was given by the publication of Joseph Warton's *Essay on the Genius and Writings of Pope* (vol. i., 1757; vol. ii., 1782). Thomas Campbell's criticism in his *Specimens of the British Poets* provoked a controversy to which William Hazlitt, Byron and W. L. Bowles contributed. For a discussion of Pope's position as one of the great men of letters in the 18th century who emancipated themselves from patronage, *see* A. Beljame, *Le Public et les hommes de lettres en Angleterre au dix-huitième siècle* (1881); a section of Isaac D'Israeli's *Quarrels of Authors* is devoted to Pope's literary animosities; and most important contributions to many vexed questions in the biography of Pope, especially the publication of his letters, were made by C. W. Dilke in *Notes and Queries* and the *Athenaeum*. These articles were reprinted by his grandson, Sir Charles Dilke, in 1875, as *The Papers of a Critic*.

POPE, JOHN (1822–1892), American soldier, was born at Louisville, Ky., on March 16, 1822. He graduated at the United States military academy in 1842 and was assigned to the engineers. He served in the Mexican War, subsequently engaged in engineering and exploring work, and was commissioned captain in 1856. Early in the Civil War he was placed, as a brigadier general U.S.V., in charge of the district of Missouri, which by vigorous campaigning against guerrilla bands he quickly reduced to order. In 1862, along with the gunboat flotilla (commanded by Commodore A. H. Foote) on the Mississippi, Pope obtained a great success by the capture of the defences of New Madrid and Island No. 10, with nearly 7,000 prisoners. Pope subsequently joined Halleck, and in command of the Army of the Mississippi took part in the siege of Corinth. He was now a major general (U.S.V.). The reputation he had thus gained as an energetic leader quickly placed him in a high command, to which he proved to be quite unequal. The "Army of Virginia," as his new forces were styled, had but a brief career. At the very outset of his Virginian campaign Pope, by a most ill-advised order, in which he contrasted the performances of the western troops with the failures of the troops in Virginia, forfeited the confidence of his officers and men. The feeling of the Army of the Potomac (which was ordered to his support) was equally hostile, and the short operations culminated in the disastrous defeat of the second battle of Bull Run. Pope was soon compelled to realize the impossibility of retrieving his position, and resigned the command. Later, in command of the department of the North-West, he showed his former skill and vigour in dealing with Indian risings. In 1882 he was promoted to the full rank of major general, U.S. army. He died at Sandusky, O., on Sept. 23, 1892.

He was the author of various works and papers, including railway reports (*Pacific Railroad Reports* vol. iii.) and *The Campaign of Virginia* (Washington, 1865).

POPE, JOHN RUSSELL (1874–1937), American architect, was born in New York city on April 24, 1874. In 1895 he was fellow of the American Academy at Rome and in 1896–97 held the Schermerhorn travelling fellowship in architecture. In 1900, after attending the École des Beaux Arts in Paris, he began practice in New York city. In addition to many private residences he designed the Scottish Rite Temple, Washington (D.C.); Plattsburg (N.Y.) city hall; the Terminal station, Richmond (Va.); the McDonough memorial at Plattsburg; and the Lincoln memorial at Hodgenville (Ky.). He was chosen architect for the Roosevelt memorial and the Mellon art gallery in Washington (D.C.) and the Roosevelt memorial in New York city.

POPE, SIR THOMAS (*c.* 1507–1559), founder of Trinity College, Oxford, was born at Deddington, Oxfordshire, probably in 1507, and educated at Eton college, where he entered the court

of chancery. As clerk of briefs in the star chamber, warden of the mint (1534–1536), clerk of the Crown in chancery (1537), and second officer and treasurer of the court for the settlement of the confiscated property of the smaller religious foundations he obtained wealth and influence. In this last office he was superseded in 1541, but from 1547 to 1553 he was again employed as fourth officer, and was enriched by grants of monastic lands. In 1537 he was knighted. The changes made by Edward VI. were repugnant to him, but at the beginning of Mary's reign he became a member of the privy council, and he retained the royal favour under Elizabeth.

As early as 1555 Pope had begun to arrange for the endowment of a college at Oxford, for which he bought the site and buildings of Durham College, the Oxford house of the abbey of Durham, from Dr. George Owen and William Martyn. He received a royal charter for the establishment and endowment of a college of the "Holy and Undivided Trinity" on March 8, 1556. The foundation provided for a president, twelve fellows and eight scholars, with a schoolhouse at Hooknorton. The number of scholars was subsequently increased to twelve, the schoolhouse being given up. On March 28, the members of the college were put in possession of the site, and they were formally admitted on May 29, 1556. Pope died at Clerkenwell on Jan. 29, 1559, and was buried at St. Stephen's, Walbrook; but his remains were removed to Trinity College, where his widow erected a monument to his memory.

The life, by H. E. D. Blakiston, in the *Dict. Nat. Biog.*, corrects many errors in Thomas Warton's *Life of Sir Thomas Pope* (1772). Further notices by the same authority are in his *Trinity College* (1898), in the "College Histories" Series, and in the *English Historical Review* (April, 1896).

POPE, SIR WILLIAM JACKSON (1870–1939), British chemist, was born in London March 31, 1870, and was educated at Finsbury technical college, and the central technical college, London. From 1897 to 1901 he was head of the chemistry department at the Goldsmith's Institute, and in 1901 he became professor of chemistry at the municipal school of technology at Manchester, occupying the chair of chemistry in the university there from 1905 to 1908. In 1908 he was appointed professor of chemistry at Cambridge, where he was later elected a fellow of Sydney Sussex College. Pope carried out much valuable research. His earliest work was in crystallography, but later he turned to pure organic chemistry and made a special study of asymmetric compounds; he confirmed Le Bel's observation on optically active nitrogen compounds (1899) and also prepared the first sulphur (1900), tin (1900) and selenium (1902) compounds of this type. During the World War he served on Lord Fisher's Admiralty Inventions Board (1915), and was conspicuous for his work on poison gases, and for the active assistance he gave to chemical industries. Some of the results of his experimental work on "mustard-gas" and similar compounds were published in the *Journal of the Chemical Society* after the war. He was knighted in 1919, and was in addition the recipient of many British and foreign awards, including the Davy Medal of the Royal Society, in 1914.

POPERINGHE (pŏp′ur-ĭng′ę; popularly pŏp′ŭr-ĭng) is an ancient town in the province of West Flanders, Belgium, 12 mi. west of Ypres. Pop. (1939) 12,402. Its fine 11th century church is dedicated to St. Betin. During World War I it was the railhead, and served for rest billets for the troops in Ypres. It was here that the movement subsequently known as Toc H (*q.v.*) originated. In World War II it was occupied by Germany.

POPHAM, SIR HOME RIGGS (1762–1820), British admiral, entered the navy in 1778, and served with the flag of Rodney till the end of the war. In 1783 he was promoted lieutenant, and was for a time engaged on survey service on the coast of Africa. Between 1787 and 1793 he engaged in the Eastern trade, and undertook several surveys and rendered some services to the East India Company, which were officially acknowledged. For some years during the French Revolutionary wars he co-operated in a naval capacity with the military forces of Great Britain and her allies. He died at Cheltenham on Sept. 10, 1820. Popham was one of the most scientific seamen of his time. He did much useful survey work, and was the author of the code signals adopted by the admiralty in 1803 and used for many years.

POPHAM, SIR JOHN (*c.* 1531–1607), English judge, was born at Huntworth, in Somerset, about 1531. He was recorder of Bristol, and represented that city in parliament in 1571 and from 1572 to 1583. He was elected Speaker in 1580, and in 1581 became attorney-general, a post which he occupied until his appointment as lord chief justice in 1592. He presided at the trials of Sir Walter Raleigh and Guy Fawkes. Towards the end of his life Popham took a great interest in colonization, and was an advocate of the transportation system. His experiment, the Popham colony on the Kennebec river, was not a success. He died on June 10, 1607.

See Foss, *Lives of the Judges;* J. Winsor, *History of America;* vol. iii. He issued a volume of *Reports.* (1682). *E.R.* vol. 79.

POPILIA, VIA, the name of two ancient roads in Italy. (1) A high road running from the Via Appia at Capua to Rhegium, a distance of 321 m. right along the length of the peninsula, running through the interior, not along the coast. It was built in 159 B.C. by the censor M. Popilius Laenas or in 132 B.C. by the consul P. Popilius. (2) A high road from Ariminum to Aquileia (178 m.) along the Adriatic coast. It came into use when Aquileia was founded as a frontier fortress of Italy in 181 B.C. In 132 it was reconstructed by the consul P. Popilius. It ran along the shore strip (Lido) from Ariminum to Ravenna (33 m.).

POPISH PLOT: *see* OATES, TITUS.

POPLAR, an eastern metropolitan borough of London, England, bounded north by Hackney, south by the river Thames and west by Stepney and Bethnal Green, and extending east to the boundary of the county of London. Pop. (1938) 134,400. Area 3.5 sq.mi. The river Lea is believed to have been crossed towards the north of the modern borough by a Roman road, the existence of which is recalled by the district name of Old Ford; while Bow (formerly Stratford-le-Bow or Stratford-atte-Bowe) was so named from the "bow" or arched bridge which took the place of the ford in the time of Henry II. South of these districts lies Bromley; in the southeast the borough includes Blackwall; and a deep southward bend of the Thames here embraces the Isle of Dogs. Poplar falls within the great area named "East End." In the north a part of Victoria park is included, but there are only 100 ac. of open spaces in the borough, though it is not the least supplied in this respect. In Blackwall and the Isle of Dogs streets give place to the extensive East and West India docks (opened in 1806) and Millwall dock, with shipbuilding, engineering, chemical and other works along the river. Blackwall has been a shipping centre from early times.

The West India docks and Millwall dock, situated on the Isle of Dogs, have an area of 466 ac., of which 133 ac. is water. There are 6.75 mi. of quays. The capacity of the warehouses is about 120,000 tons and that of the rum vaults about 12,500 puncheons. Goods stored are principally hard woods, rum, sugar, grain and dates.

The West India docks include export and import docks covering a water area of 24.1 ac. and 28.7 ac. respectively, and a quayage length of 2,017 yd. and 2,289 yd., and a maximum depth of 26 ft.

In addition, West India docks include Black-wall basin with an area of 7.2 ac. and a depth of 26 ft.; Junction dock, area 1.3 ac. and depth of 25 ft.; South dock with an area of 36.3 ac., maximum depth of 29 ft. and quayage of 2,627 yd.; and South dock basin area 5.2 ac. and a depth of 29 ft. Millwall docks are now connected with the West India docks. The outer Millwall dock has a water area of nearly 25 ac. and quayage of 2,037 yd., while the inner dock area is 10.5 ac. with 1,638 yd. of quayage. Each has a maximum depth of 28 ft. The dock connection scheme included a new entrance lock 584 ft. long, 80 ft. wide, with a depth of 35 ft. on the sill, which would render the docks able to deal with ships up to 600 ft. in length. The East India docks to the east consist of Import and Export docks and a basin with total water area of 31.7 ac. and 3,042 yd. of quay, the depths in the Export and Import docks being 28 ft., and in the basin 32 ft.

An impounding station was built which raises the water in the docks 2 ft. above the tidal high water level. A quarantine station was built at the East India docks. Near the East India docks is

the settlement of St. Frideswide, supported by Christ Church, Oxford.

Important industries in Poplar include the making of paper, matches and clothing. The metropolitan borough of Poplar includes the Bow and Bromley and the South Poplar divisions of the parliamentary borough, each returning one member. For "Poplarism" *see* Poor Law.

POPLAR (*Populus*), the name of a small group of catkin-bearing trees belonging to the family Salicaceae, which includes the willows. The catkins of the poplars differ from those of willows in the absence of nectar glands; the male flowers contain from 4 to 80 stamens; the female bear a one-celled ovary, surmounted by the deeply cleft stigmas; the two- to four-valved capsule contains several seeds, each furnished with a long tuft of silky or cotton-like hairs. The leaves are generally either deltoid or ovate in shape, often heart-shaped at the base, and frequently with slender, laterally compressed petioles. Many of the species attain a large size, and all are of very rapid growth. The poplars are almost entirely confined to the north temperate zone, but a few approach or even pass its northern limit, and they are widely distributed within that area; they show, like the willows, a partiality for moist ground and often line the riversides in otherwise treeless districts. There are about 30 species, but the number cannot be very accurately defined, since there are many regional varieties and also widely diffused hybrids of uncertain origin. All yield a soft, easily worked timber. Many of the species are used for paper-making.

Of the European forms one of great importance is the white poplar or abele, *P. alba*, a tree of large size, with rounded spreading head and curved branches which, like the trunk, are covered with a grayish white bark, becoming much furrowed on old stems. The leaves are ovate or nearly round but with deeply waved, more or less lobed and indented margins and heart-shaped bases; the upper side is dark green, but the lower surface is clothed with a dense white down, which likewise covers the young shoots—giving, with the bark, a hoary aspect to the whole tree. A related form, *P. canescens*, the gray poplar of the nurseryman, is distinguished from the true abele by its smaller, less deeply cut leaves, which are gray on the upper side but not so hoary beneath as those of *P. alba*. Some authorities regard this form as a hybrid (*P. alba* × *tremula*).

Both trees occasionally attain a height of 90 ft. or more. The wood is very white, with soft and even grain, and is employed by turners and toy-makers; it is also suitable for the construction of packing cases, etc. The white poplar is an ornamental tree; it has, however, the disadvantage of throwing up numerous suckers for some yards around the trunk.

P. nigra, the black poplar, is a tree of large size, sometimes 100 ft. high, with dark, deeply-furrowed bark on the trunk, and ash-coloured branches; the smooth deltoid leaves, serrated regularly on the margin, are of the deep green tint which has given name to the tree; the petioles, slightly compressed, are only about half the length of the leaves. The black poplar is common in central and southern Europe and in some of the adjacent parts of Asia, but though abundantly planted in Great Britain, is not there indigenous. The wood is of a yellowish tint.

A closely related form is the well-known Lombardy poplar, *P. nigra* var. *italica*, remarkable for its tall, cypress-like shape, caused by the nearly vertical growth of the branches. It is probably a variety of the black poplar, and its native land appears to have been Persia or some neighbouring country; it was unknown in Italy in the days of Pliny, while from remote times it has been an inhabitant of Kashmir, the Punjab and Persia, where it is often planted along roadsides for shade; it was probably brought from these countries to southern Europe, and derives its popular name from its abundance along the rivers of Lombardy, where it is said to spring up naturally from seed, like the indigenous black poplar. It was introduced into Great Britain soon after 1750, if not earlier. The Lombardy poplar is valuable chiefly as an ornamental tree; its tall, erect growth renders it useful to the landscape gardener as a relief to the rounded forms of other trees, or as a contrast to the horizontal lines of the lake or riverbank. Its growth is extremely rapid and it often attains a height of 100 ft.

P. euphratica, believed to be the weeping willow of the Scriptures, is a large tree remarkable for the variability in the shape of its leaves, native to north Africa and western and central Asia.

In North America about 13 native species are found, together with some 15 well-marked varieties and some five or more hybrids, widely distributed throughout the continent. Most of these, especially the larger kinds, are generally called cottonwood.

The eastern cottonwood (*P. deltoides*), a very large, broad-headed tree, with deeply-furrowed, gray or dark brown on the older trunks, which divide into many great arms, and large, ovate, finely toothed leaves, 4 to 7 in. long, longer than broad, occurs only locally and infrequently from Vermont to Mississippi. Its immensely more abundant variety, the common cottonwood or necklace poplar (*P. deltoides* var. *virginiana*), differs chiefly in having smaller triangular or ovate-triangular leaves, about as broad as long. It grows native from Quebec to North Dakota and south to Florida and Texas, sometimes attaining a height of 150 ft. and a trunk diameter of 8 ft. The loosely-flowered fruiting aments form a pendent string, 6 to 10 in. long, of ripening pods, whence the name necklace poplar. The timber is used for lumber and pulpwood, and the tree is often planted for ornament. Numerous forms of this poplar are planted in Europe and America, probably mostly hybrids with forms of the European black poplar (*P. nigra*). Among these are the Carolina poplar (× *P. canadensis*), widely grown in streets and parks in the eastern states, a vigorous, upright tree, with strongly ascending branches, the trunk continuing through the top, and the Eugene poplar (× *P. canadensis* var. *eugeni*) which was originated in France in 1832. Both these forms bear only male flowers and hence do not produce the profusion of downy seeds which renders the common cottonwood somewhat objectionable as a street tree. The Norway or "sudden-sawlog" poplar, a very rapid-growing and hardy form, supposedly of Siberian origin, is probably either a variant of the common cottonwood or a hybrid of it. Since its distribution in 1904 from a Norwegian settlement in Minnesota it has been widely planted in the northwestern states. In seven years the "sudden-sawlog" poplar will grow from a small cutting to a height of 50 ft. or more and a trunk diameter of 6 to 8 in., producing quick shade, windbreaks, useful light timber and pulpwood.

As practically the only large tree in many parts of the interior region, where it grew along the watercourses, the cottonwood was utilized by the pioneers in an immense number of ways, but chiefly for soft lumber, fuel and quick shade. Its downy fruits, widely driven by the wind, readily take root in the wet sands of lake and river shores. Around the southern and eastern shores of Lake Michigan the cottonwood, because of this characteristic, is an important factor in the formation of dunes.

The swamp cottonwood or downy poplar (*P. heterophylla*), which is found from Connecticut to southern Illinois and southward to Florida and Louisiana, attains a height of 90 ft. and trunk diameter of 3 ft. It has dark, rough bark and large, broadly ovate leaves, 5 to 6 in. long, which are intensely woolly when young. This tree furnishes excellent pulpwood and the lumber known to the trade as black poplar.

The black cottonwood or California poplar (*P. trichocarpa*) together with its northern variety (var. *hastata*) comprise the largest broad-leaved tree indigenous to the Pacific coast region of North America, attains a height of 200 ft. and a trunk diameter of 8 ft. It grows from Alaska to Lower California and eastward to Idaho and Nevada. It has yellowish fissured bark and large ovate, finely toothed leaves 2 to 11 in. long, lustrous green above and whitish below. The timber is utilized for wooden ware and pulpwood.

The balsam poplar or tacamahac (*P. deltoides missouriensis*), the "liard" of the Canadian voyageurs, is a narrow-topped tree, sometimes 100 ft. high, with a diameter of 7 ft. at the stump. It has smooth gray bark, ovate, pointed, dark-green leaves, which are whitish below, and resinous buds with a pleasing balsamic odour. It is found along the northern border of the United States from Maine westward, southward in mountains to Colorado, Nevada

and Oregon, and northward nearly throughout Canada and Alaska to the Arctic circle. Like the cottonwood in the United States, the tacamahac was put to manifold uses by the early settlers in the prairie regions of Canada. The balm-of-gilead poplar (*P. candicans*) is similar to but smaller than the balsam poplar, with broad, heart-shaped leaves and very large, resinous, highly aromatic buds. It is widely planted in the northeastern states and Canada and also occurs as if native. It is thought to be a hybrid of European origin but perhaps partly of North American parentage.

In the Rocky mountain region and adjacent plains are found the lanceleaf cottonwood (*P. angustifolia*) and a foot-hill species (*P. sargenti*).

In the arid districts of the southwestern states there are seven species of cottonwood, all of more or less limited range, among which are the Fremont cottonwood (*P. fremonti*) and the Mexican cottonwood (*P. wislizeni*).

The white, the black, and the Lombardy poplar are widely planted in the eastern states and Canada, where the two first named have become more or less naturalized.

In 1940 the cut of cottonwood lumber in the U.S.A. was 153,562,000 bd. ft., lumbered chiefly in the Mississippi valley, mostly from the common cottonwood in the north and swamp cottonwood in the south. In 1899, the peak year of production, it was 421,575,000 bd. ft. (*See* ASPEN.)

See C. S. Sargent, *Manual of the Trees of North America* (1905, new ed. 1933); G. B. Sudworth, *Forest Trees of the Pacific Slope* (1908) and *Check List of the Forest Trees of the United States* (1927); L. H. Bailey, *Manual of Cultivated Plants* (1924).

POPLAR BLUFF, a city of southeastern Missouri, U.S.A., at the head of navigation on the Black river; the county seat of Butler county. It is on federal highways 60 and 67, and is served by the Frisco and the Missouri Pacific railways. Pop. (1950) 15,120. It was named from the tulip poplar trees which grew on the bluff of Black river. It marks the eastern border of the Big Springs country of the Ozark mountains. Wappapello and Clearwater dams provide a mammoth lake resort area, already noted for Keener spring and cave, hideout of the outlaw Jesse James. The industries include railway shops, shoes, lumber, wood handles, staves, tents, awnings, livestock, dairying, cotton and potatoes. It was incorporated as a town in 1870, as a city in 1892.

POPLIN. A fine and plain-ribbed fabric produced from any class of textile material and comprising a variety of different textures and qualities, and containing fine ribs or cords of uniform size extending across the width of the fabric, from selvedge to selvedge, *i.e.*, in the direction of the weft. The ribbed effect in a poplin fabric is obtained by employing a relatively high number of warp threads of fine counts of yarn and interweaving these on the principle of the plain calico weave, with picks of weft of coarse counts. Hence, during weaving, the finer and weaker warp threads bend or interlace quite freely under and over the *coarser* and stronger picks of weft which, therefore, lie in a perfectly straight line across the entire width of the fabric and thus develop the fine ribs or cords that characterize all poplin fabrics. Cotton poplin fabrics are used for making blouses, dresses, shirts and other garments. Irish poplin is composed of silk warp and worsted weft, and used for ties, dresses, coats and many other articles of clothing. The manufacture is of French origin and was brought to England by the Huguenots.

POPOCATEPETL (Aztec *popoca* "to smoke," *tepetl* "mountain"), a dormant volcano in Mexico 18° 59′ 47″ N., 98° 33′ 1″ W., which with the neighbouring Ixtaccihuatl (Aztec "white woman") forms the southeastern limit of the great basin known as the Valley of Mexico. As it lies in the state of Puebla and is the dominating feature in the views from the city of that name, it is sometimes called the Puebla volcano. It is the second highest summit in Mexico, its shapely, snow-covered cone rising to a height of 17,883 ft., or 813 ft. short of that of Orizaba, according to the American Geographical society. An elevation of 17,876 ft. was reported by the Mexican Geological survey in 1895, and one of 17,888 ft. was calculated by the Mexican Geographical society.

The bulk of the mountain consists of andesite, with some porphyry, obsidian, trachyte, basalt, and other similar rocks. It has a stratified cone which shows a long period of activity. At the foot of the eastern slope stretches a vast lava field—the "malpays" (*malapais*) of Atlachayacatl—which, according to Humboldt, lies 60 to 80ft. above the plain and extends 18,000ft. east to west with a breadth of 6,000ft. Its formation must be of great antiquity. The ascent of Popocatepetl is made on the north-eastern slope, where rough roads are kept open by sulphur carriers and timber cutters. Describing his ascent in 1904, Hans Gadow states that the forested region begins in the foothills a little above 8,000ft., and continues up the slope to an elevation of over 13,000ft. On the lower slopes the forest is composed in great part of the long-leaved *Pinus liophylla,* accompanied by deciduous oaks and a variety of other trees and shrubs. From about 9,500ft. to 11,500ft. the Mexican "oyamel" (*Abies religiosa*) becomes the principal species interspersed with evergreen oak, arbutus and elder. Above this belt the firs gradually disappear and are succeeded by the short-leaved *Pinus montezumae,* or Mexican "ocote"—one of the largest species of pine in the republic. These continue to the upper tree-line, accompanied by red and purple *Pentstemon* and light blue lupins in the open spaces, some ferns, and occasional masses of alpine flowers. Above the tree-line the vegetation continues only a comparatively short distance, consisting chiefly of tussocks of coarse grass, and occasional flowering plants, the highest noted being a little *Draba.* At about 14,500ft. horses are left behind, though they could be forced farther up through the loose lava and ashes. On the snow-covered cone the heat of the sun is intense, though the thermometer recorded a temperature of 34° in September. The reflection of light from the snow is blinding. The rim of the crater is reached at an elevation of approximately 17,500ft. The crater is elliptical in form, 2,008 by 1,312ft., and has a depth of 1,657ft. below the summit of the highest pinnacle and 673ft. below the lowest part of the rim, which is very irregular in height. The steep, ragged walls of the crater show a great variety of colours, intensified by the light from the deep blue sky above. Huge patches of sulphur, some still smouldering, are everywhere visible, intermingled with the snow and ice that fills the crevices and covers the ledges of the black rocks.

It is believed that Diego de Ordaz was the first European to reach the summit of Popocatepetl, though no proof of this remains further than that Cortés sent a party of ten men in 1519 to ascend a burning mountain. In 1522 Francisco Montano made the ascent and had himself let down into the crater a depth of 400 or 500ft. No second ascent is recorded until April and Nov., 1827 (*see* Brantz Mayer, *Mexico,* vol. ii.). Other ascents were made in 1834, 1848 and subsequent years, members of the Mexican geological survey spending two days on the summit in 1895.

POPOV, ALEKSANDR STEFANOVICH (1859–1906), Russian physicist and electrical engineer, among the earliest scientific investigators of electromagnetic waves (as later used in wireless communication), was born on March 16, 1859, in a mining village in the Ural mountains where his father was a priest. From school at Perm he went to St. Petersburg university, graduating in 1883 and becoming an assistant in the physics laboratory. Later he joined the staff of the Torpedo school at Kronstadt, where he lectured on mathematics and physics and subsequently became head of the physics department. There he had a well-equipped laboratory and a good library with foreign periodicals and books; these stimulated his interest in foreign research and particularly in the work of H. R. Hertz, many of whose experiments he repeated. He was greatly impressed also by the publication of a lecture and description of experiments given by Sir Oliver Lodge in June 1894 on *The Work of Hertz and Some of His Successors;* and he then began to develop a device for receiving electromagnetic waves. To detect the oscillations resulting from these waves he made various modifications to the coherer, containing metallic filings, used by Edouard Branly and Lodge; in particular, he added to his coherer an arrangement for automatically tapping back the filings to a sensitive condition after they had cohered on the reception of oscilla-

tions. By this means each received impulse of oscillations caused a bell to ring or a mark to be made on a simple recorder which could operate for 12 hr. at a time. This apparatus was used for detecting lightning discharges at a distance and was demonstrated at a meeting of the St. Petersburg Physical society in May 1895. Later, it was set up at the meteorological observatory, the coherer being connected to a lightning conductor and used for the study of atmospheric electrical discharges received at distances up to almost 20 mi. The receiver was described in the Physical society's journal (Jan. 1896) as a lightning recorder, but Popov expressed the hope that with certain improvements it might be employed for the reception of distant signals when a sufficiently strong source of oscillations had been discovered. In a second lecture before the society, in March 1896, Popov showed the transmission of Hertzian waves between different parts of the university buildings. At or before this time, similar demonstrations of the transmission of wireless signals over short distances were being given by Sir Henry Jackson, Lodge and Marchese Guglielmo Marconi; and it was in June 1896 that the last-named took out the first patent granted for wireless telegraphy based on the use of electric waves. The news of Marconi's work aroused Popov to fresh activity, and working in conjunction with the Russian navy he effected ship-to-shore communication over distances of about six miles by 1898. This was increased to about 30 mi. by the end of the following year, when he also visited wireless stations in operation in France and Germany. Unfortunately Popov's work was not sufficiently appreciated and supported by the Russian government, and in 1901 he returned to St. Petersburg as professor at the Electrotechnical institute, of which, a few years later, he was elected director. He died on Jan. 13, 1906 (Dec. 31, 1905, by the old Julian calendar). (R. L. S.-R.)

POPPY, any plant of the genus *Papaver,* the type of the family Papaveraceae. They are annual and perennial erect herbs containing a milky juice, with lobed or cut leaves and generally long-stalked regular showy flowers, which are nodding in the bud stage. The sepals, which are usually two in number, fall off as the flower opens, the four (very rarely five or six) petals, which are crumpled in the bud stage, also fall readily. The numerous stamens surround the ovary, which is surmounted by a flat or convex rayed disk bearing the stigmas. The ovary develops into a many-seeded short capsule opening by small valves below the upper edge. The valves are hygroscopic, responding to increase in the amount of moisture in the atmosphere by closing the apertures. In dry weather the valves open, and the small seeds escape through the pores when the capsule is shaken by the wind. The genus contains about 140 species, mostly natives of central and south Europe and temperate Asia. Five species occur in Great Britain; *P. rhoeas* is the corn poppy found in fields and waste places. Cultivated forms of this, with exquisite shades of colour and without any blotch at the base of the petals, are known as Shirley poppies. *P. somniferum,* the opium poppy, with large white or blue-purple flowers, is widely cultivated. (*See* Opium.)

The Oriental poppy (*P. orientale*) and its several varieties are fine garden plants, having huge bright crimson flowers with black blotches at the base. Many hybrid forms of varying shades of colour have been raised of late years. The Iceland poppy (*P. nudicaule*), is one of the showiest species, having gray-green pinnate leaves and flowers varying in colour from pure white to deep orange-yellow, orange-scarlet, etc. The Welsh poppy belongs to an allied genus, *Meconopsis;* it is a perennial herb with a yellow juice and pale yellow poppylike flowers. It is found in the southwest and north of England, and in Wales; also in Ireland and western Europe. The prickly poppy belongs to the related, tropical American genus *Argemone.*

A. grandiflora is a popular Central American annual with large, white flowers. To the same family belongs the horned poppy, *Glaucium flavum,* found on sandy seashores and characterized by the waxy bloom of its leaves and large golden-yellow short-stalked flowers. The plume poppies (*Macleaya*) are ornamental foliage plants of great beauty. The snow poppy (*Eomecon chionantha*) is a pretty Chinese perennial, having roundish slightly lobed leaves and pure white flowers about two inches across. The Mexican tulip poppy (*Hunnemannia fumariaefolia*), a perennial usually grown as an annual, has very showy yellow flowers.

The poppy group is well represented in western North America, especially in California, where about 20 native species, together with numerous varieties, are found. The best known is the California poppy (*Eschscholtzia californica*), with brilliant, orange-coloured flowers, widely grown in gardens and extensively naturalized in Australia and India. Other noteworthy Californian species, more or less cultivated, are the tree poppy (*Dendromecon rigida*), a rigid, leafy shrub, two to ten feet high, with golden-yellow flowers, about two inches across; the Matilija poppy (*Romneya coulteri*), a widely branched subshrub, three to eight feet high, with large, white, fragrant flowers, six inches across; the cream-cups (*Platystemon californicus*), a low, delicate annual, with light yellow flowers, one inch across; and the flaming poppy or wind poppy (*Meconopsis heterophylla*), bearing brick-red flowers, two inches across. (N. Tr.; X.)

COMMON CORN POPPY (PAPAVER RHOEAS) OF "FLANDERS FIELDS"

POPPY HEADS, in architecture, the finials or other ornaments which terminate the tops of bench ends of pews or stalls. They are sometimes small human heads, richly carved images, knots of foliage or finials and sometimes fleurs-de-lis simply cut out of the thickness of the bench end and chamfered. The term is probably derived from the French *poupée,* doll or puppet, rather than from the flower.

POPPY OIL (*Oleum papaveris*), a vegetable oil obtained by pressure from the minute seeds of the garden or opium poppy, *Papaver somniferum.* The white-seeded and black-seeded varieties are both used for oil pressing; but, when the production of oil is the principal object of the culture, the black seed is usually preferred. The qualities of the oil yielded by both varieties and the proportion they contain (from 50% to 60%) are the same. By cold pressing, seeds of fine quality yield from 30% to 40% of virgin or white oil (*huile blanche*), a transparent limpid fluid with a slight yellowish tinge, bland and pleasant to taste, and with almost no perceptible odour. On second pressure with the aid of heat an additional 20% to 25% of inferior oil (*huile de fabrique* or *huile russe*) is obtained, reddish in colour, possessed of a biting taste, and a linseedlike smell. The oil belongs to the linoleic or drying series, having as its principal constituent linolein; and it possesses greater drying power than raw linseed oil. Its specific gravity at 15° C. is 0.925.

Poppy oil is a valuable and much used medium for artistic oil painting. The fine qualities are largely used in the north of France (*huile d'oeillette*) and in Germany as a salad oil, and are less liable than olive oil to rancidity. The absence of taste and characteristic smell in poppy oil also leads to its being much used for adulterating olive oil. The inferior qualities are principally consumed in soapmaking and varnishmaking, and for burning in lamps. The oil is very extensively used in the valley of the Ganges and other opium regions for food and domestic purposes. By native methods in India about 30% of oil is extracted, and the remaining oleaginous cake is used as food by the poor. Ordinary poppy-oil cake is valuable feeding material, rich in nitrogenous constituents, with an ash showing an unusually large proportion of phosphoric acid. The seed of the yellow horned poppy, *Glaucium luteum,* yields from 30% to 35% of an oil having the same drying and other properties as poppy oil; and from the Mexican poppy, *Argemone mexicana,* is obtained a nondrying oil used as a lubricant and for burning.

POPULATION. The study of population is based upon information derived from two sources, namely enumerations or censuses and records of such events as births, marriages and deaths. It is beyond the capacity of private persons or organizations to collect this information; apart from the fact that the task is too vast there must be power, which governments alone possess, to require people to make returns and to record events. Therefore the information needed for this study is to be sought in the publications of governments and, since the energy and efficiency of government services vary from one country to another, the available information differs much in extent and accuracy from one area to another.

A census or enumeration is a counting of the people, usually repeated at regular intervals of time; when the count is made it is customary to take particulars concerning the sex, age, occupation and other characteristics of the persons enumerated. Thus a census yields a picture of a population at a particular date and, if there have been previous censuses, the changes that have taken place can be noted and investigated. But such comparisons will not throw much light upon the way in which these changes have come about; an increase of population between one census and another may be due to a surplus of births over deaths, to a surplus of immigrants over emigrants, to all causes acting together in the same direction, or to one cause acting with greater force in one way than that exerted by another cause acting in the contrary way. In order to find out what lies behind the changes revealed by censuses taken in a country at different dates, it is necessary to examine the figures relating to births, deaths, marriages and migration. These figures are collected continuously and not periodically and, just as in the case of a census, the opportunity may be taken to ask for additional information. Thus when a birth is registered, the age of the mother, the duration of her marriage and the occupation of the father may be recorded at the same time; and again, just as in the case of censuses, the practices of governments in this matter differ much from one country to another. The information collected by continuous registration of events is not only helpful in the interpretation of a series of censuses but is also used in conjunction with information derived from censuses to assess the probable future trend of population. But the information so collected is also most important in itself; for example, the analysis of death by age at death is the foundation upon which life insurance is based, and analysis by cause of death is a guide to the direction of improvement in medical and social services.

By the employment of figures from these two sources the study of population may be carried a long way. It can be shown, for instance, that in some countries the average size of family has declined over a period of years and a close analysis of the figures may indicate, if it does not prove, that certain possible causes of this decline are excluded and that the true explanation is to be found elsewhere. Analysis does in fact tend to show that the decline in the size of the family in western countries in the 20th century is due largely to voluntary limitation of births and not to any loss of procreative power. But at this point further inquiry needs evidence from other sources; if people have taken to limiting the size of their families, they must have done so for certain reasons. The search for these reasons needs an examination of changes in social and ethical ideals and in the social and economic forces which impinge upon marriage habits. At that point the study of population transgresses the limit set for this article; for it passes into the realm of sociological inquiry. Inquiry may also be made into the consequences of the population changes. In fact it was largely the desire to investigate the effect of population change upon economic welfare that led to the collection and analysis of information relating to population. Later an interest in the impact of such changes upon social welfare was added; urbanization (*q.v.*), for example, began to attract attention. But discussions relating to "over-population," however the phrase is understood, fall within the field of economic and social investigation and so outside the treatment adopted here.

This article falls into three parts. The first deals with world population as revealed by census material and the second with the movement of population as shown by registration and migration figures. In the third part census and registration material are brought together, and an attempt is made to sketch the history of world population.

WORLD POPULATION

Total.—In order to obtain a completely satisfactory figure for total world population the results of reliable censuses for all countries, conducted on a uniform basis at the same date, are needed. The real position is far from being so satisfactory, and the reasons why this is so may be set out under three heads.

First, there are those countries for which there was still, at mid-20th century, no census figure for any date; among them Ethiopia, Afghanistan, Liberia, Nepal, the Anglo-Egyptian Sudan and China. For these unenumerated countries the estimates found in the *Demographic Yearbook 1948* of the United Nations may be taken as the best available. But it is difficult to say what degree of confidence should be reposed in them. The estimate given for China, for instance, is 463,000,000; some of those, however, who have studied the available evidence for that country put the most likely total at little more than 400,000,000 while others put it at about 500,000,000. If the estimates as given in the *Demographic Yearbook* for the unenumerated countries are added up it is found that the total amounts to more than a quarter of the total estimated world population of more than 2,322,000,000 recorded in this publication of the United Nations. It follows that on this account alone there must be considerable doubt about the accuracy of the latter total.

Secondly, when the total of 1,709,000,000 given in the *Demographic Yearbook* for the enumerated countries is examined it is found that some of the countries included were enumerated only by a partial census. In certain African countries, for example, only the European population was counted and, since the Europeans constitute a very small fraction of the whole, the total given for these countries should be placed among the estimated rather than among the enumerated figures. If these countries were transferred from the enumerated to the estimated, about 60% of the world total would rank as estimated.

Thirdly, caution is needed even with the countries which have had a complete census. The definition of what constitutes the population differs from country to country; thus a census may or may not include aliens and may or may not include nationals living abroad, and the treatment of those in the armed forces away from home is not always the same. But these variations are tiresome rather than serious. It matters more that all census returns do not deserve the same degree of confidence. It is a great feat to have taken a census at all in countries where a large proportion of the population is not literate, but it remains a fact that under such conditions a very high degree of accuracy cannot be reached. There is also the difficulty arising from the fact that censuses are usually taken every ten years at the beginning of each decade. This means that a figure for the total population toward the end of a decade must be an estimate derived by adding to the last census figure the number of births and immigrants and subtracting from it the number of deaths and emigrants which have been recorded since the census was taken. But it is not as easy to record the movement of population as to take a census, and in some areas where the census is reasonably trustworthy the figures for the movement of population are admittedly inaccurate. Thus a postcensal estimate may depart widely from the true figure, and the fallibility of postcensal estimates has often been demonstrated by succeeding censuses. To all this must be added the fact that the taking of a census at the due date was omitted by certain countries during World War II; thus at mid-century the last census of Indonesia had been taken in 1930 and of Palestine in 1931, which rendered the task of estimating the population in 1950 still more troublesome. Moreover the dislocations caused by the war made postcensal estimation very difficult; the last census of the U.S.S.R. had been taken in 1939 and yielded a total of 170,000,000, and it was not possible for the estimate of 193,000,000 for 1946 to be very authoritative. The

Demographic Yearbook gave the world population as 2,324,971,000 for 1947, and this was as good an estimate as could be provided at mid-century; but it was subject to a considerable though undefinable margin of error. From the figures given in this publication Table I was constructed.

TABLE I.—*World Population (Mid-1947)*

	Area (in '000 sq.mi.)	Population (in thousands)	Area (per cent of total area)	Population (per cent of world total)	Density (per square mile)
Africa	12,564	187,666	24.11	8.07	14.94
North America	9,248	206,410*	17.74	8.88	22.32
South America	6,677	103,426	12.81	4.45	15.49
Asia	9,604	1,230,565†	18.6	53.32	127.87
Europe	1,930	382,997‡	3.7	16.47	198.44
Oceania	3,645	11,997	6.99	0.51	3.27
U.S.S.R.	8,359	193,000§	16.04	8.30	23.09
	52,117‖	2,324,971	100.00¶	100.00	44.61

*Including Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panamá and the Caribbean islands.
†Including 1946 estimate for Syria.
‡Including 1946 estimate for Yugoslavia.
§1946 est.
‖Excluding Antarctica of which the area is 6,205,000 sq.mi.
¶Total does not add up owing to rounding.

Density.—Of the total land surface of the world only about one-third is climatically suited for cultivation, and this third is unequally distributed as between the areas used in Table I. It is therefore not surprising that two of the areas, namely Asia and Europe (less the U.S.S.R.), stand out by reason of the fact that the percentage of the world population found in them greatly exceeds the percentage of the land surface within their boundaries; for this reflects the fact that Asia and Europe are unusually favoured and have a high proportion of cultivatable land. Nevertheless figures for density are not to be explained wholly on these lines. The proportion of the area of Europe which is cultivatable is not very different from that of the United States; but the density of population in the United States at mid-century was only 46 per square mile as compared with nearly 200 in Europe. Clearly historical factors come into play here. Looking more closely into the matter it becomes evident that figures based on continental and political frontiers may give an inadequate picture and, if they are disregarded, it emerges that the various factors making for concentration of population are very potent, since at least two-thirds of the world population are found living on about one-eighth of the land surface. The main areas of concentration are Europe south of the parallel 60° N., most of India and China, Japan, the coastal area of Tongking, Java, the Nile valley and the New England area of the United States. Although it is within these areas of concentration that, as would be expected, most of the very high densities are found (for example, Java and Madura with 975, England and Wales with 712, the Netherlands with the same, Belgium with slightly less and Japan with 575 per square mile), there are cases of very high density outside the area, notably Bermuda with 1,625. Even in Africa where, except for Egypt, density is generally low there is a density of 250 in Zanzibar and Pemba and 175 in Ruanda-Urundi. The case of Egypt is the best example of the extent to which density can be misleading if calculated for a political area. The density of population for that country, which is reached by taking into account the whole area included in its boundaries, is 50 per square mile; but in fact the whole population lives in the Nile valley and delta, and in that area the population is 1,375 per square mile. Other examples are afforded by Australia and Canada. The density in Australia as a whole is 2.8, but rises to 4.4 per square mile if the two-fifths of the continent which are desert are excluded. In Canada as a whole the density is about 3 per square mile, but rises to more than 8 if the Yukon and the Northwest Territories together with the barren parts of the prairie provinces and of Quebec are excluded.

Urbanization.—It is possible to discuss the density of population for the world as a whole because the area of each country is known and in addition, as explained, a figure for the population of each country, however insecurely based, can be given. But information relating to urbanization covers only about half the land surface. Moreover this information must be used with care because every government has its own method of classifying its population into urban and rural. Thus in the United States the urban population was that found in incorporated places with 2,500 inhabitants and over until the 1950 census when urban population was redefined to also include those living in the suburban area of large cities and unincorporated places of more than 2,500 population. In England the urban population is those who live in local government areas classed as boroughs and urban districts. Nevertheless, in spite of the differences in the bases upon which they are founded, the figures do give a picture, though rough, of the different degree of urbanization as between one country and another. These figures can be supplemented by others because most countries which supply information about urban and rural population, also classify their towns by size. Table II gives the percentage of population living in urban conditions for 14 countries, and in the cases of 11 of them the percentage of the whole population of the country formed by those living in towns of 50,000 and over is also shown.

TABLE II.—*Density and Urbanization**

Country	Density (per square mile)	Urban population (per cent of total)	Pop. of towns with 50,000 and over (per cent of total)
England and Wales	712	80	50.9
Netherlands	712	54	40.9
Belgium	690	60	17.3
Japan	525	49	†
Italy	375	45	25.5
India and Pakistan	215	13	5.7
France	187	53	21.7
Egypt	50 (1,375)‡	25	16.6
United States	46	56	34.4
Ceylon	25	15	†
New Zealand	16	60	30.4
Argentina	13	61	42.7
Canada	3 (8)‡	54	27.4
Australia	3 (4)‡	69	†

*Compiled from latest census figures available in 1950.
†Information not available.
‡Figures in parentheses are for the inhabited area.

The countries in Table II are arranged in descending order of density per square mile. It is at once evident that urbanization is not related to density. Sparsely populated countries such as Canada and Australia are highly urbanized. Urbanization is linked with industrialization, and is low in India, Pakistan and Ceylon; indeed in India and Pakistan, where the density is higher than in France, urbanization is less developed than in any other country shown in Table II. There is no close connection between urbanization and the percentage of the population living in large towns. A country can be highly urbanized like Belgium and yet have less than one-fifth of its population living in towns with 50,000 inhabitants or more. If, as some think, it is over-large towns rather than urbanization which constitute a social problem, it is important to be aware that the two phenomena are not very closely associated.

Literacy.—Many countries have ceased to ask questions concerning literacy when taking a census—no doubt because illiteracy is no longer a serious problem for them. Such figures as exist must be used with the utmost care since the definition of illiteracy and the method of ascertainment differ much from one country to another. Figures are given in Table III for 14 countries.

TABLE III.—*Illiteracy*

Country	Date	Percentage of illiterates among those 10 years of age and over
Sweden	1930	0.1
Canada	1931	3.8
United States	1930	4.3
Italy	1931	21.6
Spain	1940	23.5
Bulgaria	1934	31.4
Greece	1928	40.8
Yugoslavia	1931	45.2
Mexico	1940	51.6
Peru	1940	56.6
Brazil	1940	56.7
Turkey	1935	79.1
Egypt	1937	85.2
India and Pakistan	1931	91.0

TABLE IV.—*Distribution of Population by Age and Sex*

Country	Year of census or estimate	Males				Females				Sex ratio: males to females	
		0–14	15–44	45–64	65+	0–14	15–44	45–64	65+	All ages	15–45
Belgium	1947	21.3	44.9	24.4	9.4	19.9	43.4	25.3	11.4	.963	.999
Czechoslovakia	1947	25.4	47.7	20.1	6.7	23.3	46.1	22.2	8.3	.945–	.975–
Denmark	1947	26.2	45.2	20.5	8.1	24.6	44.9	21.6	8.9	.981	.989
England and Wales	1947	22.2	46.3	22.3	9.2	20.0	43.9	24.4	11.7	.937	.992
France	1948	23.2	45.1	22.3	9.4	20.5	42.0	25.2	12.3	.900	.968
Greece	1940	33.9	45.0	15.3	5.8	32.2	45.0	16.1	6.7	.992	.991
Ireland	1947	28.6	45.4	17.4	8.6	26.3	45.1	19.1	9.5	.959	.968
Netherlands	1946	29.2	45.5	18.3	7.0	27.6	45.5	19.2	7.7	.990	.997
Norway	1945	23.1	48.9	19.7	8.3	21.2	47.5	21.2	10.1	.965	.994
Portugal	1940	33.9	45.2	15.2	5.4	30.1	44.5	17.6	7.5	.926	.939
Spain	1948	31.5	45.9	16.8	5.8	28.6	46.7	17.5	7.2	.922	.998
Sweden	1945	22.4	46.7	21.6	9.3	21.2	45.5	22.8	10.5	.991	1.017
Switzerland	1947	24.0	46.4	21.5	8.1	21.9	44.6	23.4	10.1	.944	.982
United States	1947	26.5	45.7	20.7	7.1	25.4	46.5	20.4	7.7	.993	.977
Australia	1947	25.2	45.6	21.2	7.3	24.3	45.0	21.5	8.5	1.005	1.021
Canada	1947	28.2	45.7	18.8	7.3	28.1	46.7	18.0	7.2	1.036	1.014
South Africa	1946	30.8	46.9	16.1	6.1	30.2	46.6	16.9	6.2	1.014	1.020
India and Pakistan	1931	40.0	46.3	11.6	2.1	40.0	46.6	11.2	2.2	1.064	1.058

Age and Sex.—When a census is taken it is almost always the case that questions are included relating to age and sex; figures do in fact exist which make it possible to permit a distribution by age and sex for about two-thirds of the population of the world. The ascertainment of age offers much difficulty. Even in countries where there is little or no illiteracy, the reporting of age in answer to questions is far from accurate; this is evident from the bias which is exhibited toward ages ending in 0, 2, 5 and 8, and steps must therefore be taken to correct such bias. The statistical treatment of persons who do not know their ages offers more serious difficulties. The group is so large in some countries that to show it in the tables in that form would make the statistics nearly worthless. There are two main ways of dealing with this group; one is for the enumerator to assign an age to those who cannot tell their age and the other is to distribute the members of the group among the age groups by some formula. But it is not ascertainment of age that alone causes trouble. If it is desired to institute international comparisons, difficulty arises from the fact that all countries do not employ the same method of setting out their figures; in one country the figures may be for the age group 15 to 44, and in another for the age group 15 to 49. In Table IV the population of 17 countries is shown as distributed by age and sex.

Attention may first be paid to the sex ratio which is shown as males to one female. The figures for the sex ratio are given for the population as a whole and also for that fraction of the population which is between the ages of 15 and 45, namely the ages at which reproduction takes place. An inspection of the last two columns of Table IV brings out the following points: the general rule is for females to exceed males, though the excess is less marked in the age group 15 to 45 than in the whole population; an excess of males is found in certain "new" countries and also in India, Pakistan and Ireland. The explanation of these facts is along the following lines. It is an almost invariable rule that more boys are born than girls; it follows that, if in all other matters things are equal as between males and females, the excess of males at birth would be maintained at all ages. But other things are not equal. Males show higher mortality rates than females; this is partly because males are out and about more than females and so more often meet with accidents. Indeed war may be regarded as a case, at least until the advent of civilian bombing, where males are especially subject to risk of death through violence. In part also the excess mortality of males arises because they are more liable to fall victims to disease. In fact death thins the ranks of males more quickly than the ranks of females. It follows that although males are in a majority in the earlier years of life, there comes an age group in which the two sexes are equal, to be followed by older age groups in which females preponderate. The age group 15 to 45 is of special interest because it includes those of marrying age. In this group, for the reasons just given, the sexes are more nearly equal than in the whole population. But there are countries where males outnumber females; these are the new countries and certain countries peopled by non-Europeans. In the case of the new countries immigration is the explanation since males nearly always preponderate over females among migrants. In regard to such countries as India the explanation would seem to be the great value set on sons and the care consequently spent on raising them, coupled with the very early marriage of girls and the resulting strain on their health.

Age distribution is also a matter of great importance. In Table IV four age groups are shown, of which the first (ages 0 to 14) and the last (65 and over) roughly represent the dependents supported by the young adults (15 to 44) and the older adults (45 to 64). The difference between a non-European country such as India, with less than 14% of the population over the age of 45, and England and Wales, with 31.5% over 45, is very striking. But there are also remarkable differences between European countries. In northern and western Europe between 9% and 10% of the population is over the age of 65, whereas in southern and eastern Europe between 5% and 6% are of that age. Differences in mortality and fertility are responsible for these contrasts. But when interpreting the present situation the effect of population growth in the immediate past must be borne in mind; if a population has doubled in 65 years, those 65 years of age and above are the remnants of a population only half the present size. It follows that in these circumstances the aged are underrepresented in the sense that if numbers remained stable and other things were unchanged, they would come to form in time about twice as large a fraction of the total as they do now.

As mentioned above, figures for age distribution are available for about two-thirds of the population of the world. In a publication of the United Nations, *World Population Trends, 1920–1947* (1950), an attempt has been made to estimate the age grouping of the total world population. (*See* Table V.) The following

TABLE V.—*Estimated Percentages of Population in Three Major Age Groups in Various Regions of the World (around 1947)*

Region	Estimated percentage of population		
	Under 15	15–59	60 and over
World total	36	57	7
Africa	40	55	5
America:			
U.S.A. and Canada	25	64	11
Latin America	40	55	5
Asia:			
Near east	40	54	6
South-central Asia	40	56	4
Japan	37	55	8
Remaining far east	40	55	5
Europe:			
North-west-central Europe	24	62	14
Southern Europe	30	59	11
Eastern Europe*	34	59	7
Oceania	28	62	10

*Including the Asiatic part of the U.S.S.R.

comment on the table is found: "North-West-Central Europe and U.S.A.-Canada show rather similar age distributions with about one-fourth of the population under 15 years of age. The same is the case with the European populations of Oceania. These are populations with low fertility and mortality. Southern and Eastern Europe have a somewhat higher proportion of children. At the other extreme, Africa, Latin America, the Near East, South-

Central Asia and the Remaining Far East show a rounded value of 40 per cent for the under 15 group. The economic significance of these differences in the proportion of children in relation to the proportion of persons of productive age is evident."

Marital Status.—The condition of the population in relation to marriage is another matter of importance, but the information available relates to less than half the population of the world and is often out of date. Once again international comparisons are difficult; in Table VI the married are those in *de facto* stable unions. In this table the position is shown for 11 European countries, for 3 countries of European origin (the figures for South Africa are for Europeans only) and for India. The part of the population considered in each case is that aged 15 and over. The most remarkable case in this list is that of India, where marriage is virtually universal for females. But there are noteworthy differences between the other countries. Ireland is a country of little marriage and in that aspect stands in marked contrast to France. The new countries are, on the whole, countries where the unmarried are relatively uncommon.

TABLE VI.—*Marital Status*

Country	Year	Percentage of population married, widowed, divorced or separated, aged 15 and over	
		Males	Females
Belgium	1930	67.5	70.8
Czechoslovakia	1947	68.6	75.2
Denmark	1945	67.5	71.0
England and Wales	1931	64.4	64.6
France	1936	71.7	77.1
Ireland	1937	52.4	55.4
Netherlands	1930	60.9	62.7
Norway	1930	55.1	56.8
Portugal	1940	58.8	62.0
Sweden	1945	64.0	68.2
Switzerland	1941	60.8	63.6
United States	1940	66.8	74.2
Canada	1941	60.2	67.0
New Zealand	1945	67.6	70.8
South Africa	1941	64.5	72.7
India	1931	81.9	96.4

MOVEMENT OF POPULATION

Births and Deaths.—For those countries which collect figures for the annual number of births and deaths it is possible to calculate birth rates and death rates. The number of births or deaths in a year is related to the total population in that year and is shown as so many births or deaths per 1,000 of the population. Thus a birth rate of 30 means that for every 1,000 of the population there were 30 births for the year in question. If for any country there is a birth rate of 30 and a death rate of 20, there is for that country in that year a net gain or a natural increase of 10 per 1,000. In such a calculation changes caused by migration movements are left out of account. Statistics giving the annual number of births and deaths are available for countries which are estimated to contain about 60% of the total world population. But the number of countries with accurate vital statistics is small; indeed, for only a small fraction of the total world population are fully trustworthy figures available. Nevertheless an attempt was made under the auspices of the Department of Social Affairs of the United Nations to estimate the world position in this matter. This is admittedly a hazardous venture. Those who undertook it were obliged to rely heavily on sources of information other than those found in official statistics, such as studies of fertility and mortality made locally. In that way unsatisfactory official figures were adjusted, and rates were estimated for countries for which official figures were lacking. But it was possible to do no more for certain countries than to estimate the limits within which the actual rates probably lay. Moreover it was not thought possible to make even this global calculation for a date later than 1937, since the data available ten years later did not permit a global estimate with the same degree of trustworthiness as for 1937. The result of these calculations are set out in Table VII.

TABLE VII.—*Estimated Annual Births and Deaths for Regions of the World (around 1937)*

Region	Rate per thousand of population		Approximate number (in millions)	
	Births	Deaths	Births	Deaths
World total	34–38	24–27	73–81	51–59
Africa	40–45	30–35	6.8–7.6	5.1–5.9
America:				
U.S.A. and Canada	17	11	2.4	1.5
Latin America	40–45	20–25	5.0–5.7	2.5–3.2
Asia:				
Near east	40–45	30–35	2.6–3.0	2.0–2.3
South-central Asia	40–45	30–35	15.1–17.0	11.3–13.2
Japan	28	17	2.0	1.2
Remaining far east	40–45	30–35	25.1–28.2	18.8–21.9
Europe:				
North-west-central Europe	17	13	3.3	2.5
Southern Europe	23	16	1.9	1.3
Eastern Europe	30–34	17–21	8.5–9.6	4.8–5.9
Oceania	20	11	0.2	0.1

It will be seen that if the lowest birth rate and the highest death rate for the world as a whole is taken for 1937, there was in that year a natural increase of 7 per 1,000, whereas taking the highest birth rate and the lowest death rate there was a natural increase of 14 per 1,000. Translating this into numbers, there was an addition to the world population in 1937 of not less than 14,000,000 and not more than 30,000,000. When the regions are compared it emerges that birth rates and death rates differ far more than rates of natural increase. This is because low birth rates and low death rates go together as do high rates; in this way the effect of rates which are either very high or very low are more or less neutralized. The authors of this calculation said that despite changes since 1937 the differences between the vital rates of different regions of the world were so large that the regional distribution of the world total of births and deaths was probably the same in broad outline in 1949 as it was before World War II. They also stated that since 1937 there had been little sign of any change in the birth rates in those countries with the highest rates, but that in countries with the lowest birth rates before World War II there were significant increases. They added that for those countries with trustworthy data there was a general tendency over a long period for the death rate to decline and that this decline, though in some cases halted during World

TABLE VIII.—*Birth Rates, Death Rates and Natural Increase for Certain Countries*

Country	1932			1939			1947		
	Birth rates	Death rates	Natural increase	Birth rates	Death rates	Natural increase	Birth rates	Death rates	Natural increase
Belgium	17.8	13.3	4.5	15.5	13.9	1.6	17.8	13.3	4.5
Czechoslovakia	20.1	13.9	6.2	18.6	13.3	5.3	23.8	12.0	11.8
Denmark	17.9	11.0	6.9	17.8	10.1	7.7	22.1	9.7	12.4
England and Wales	15.3	12.0	3.3	14.8	12.1	2.7	20.5	12.3	8.2
France	17.3	15.8	1.5	14.6	15.3	−.7	21.0	13.0	8.0
Ireland	19.1	14.6	4.5	19.1	14.2	4.9	23.1	14.9	8.2
Italy	23.8	14.7	9.1	23.6	13.4	10.2	21.9	11.4	10.5
Netherlands	22.0	9.0	13.0	20.6	8.6	14.0	27.8	8.1	19.7
Norway	16.0	10.6	5.4	15.9	10.2	5.7	21.6	9.3	12.3
Poland	28.9	15.0	13.9	...	...	...	...	...	...
Portugal	29.9	17.1	12.8	26.2	15.3	10.9	24.1	13.3	10.8
Sweden	14.5	11.6	2.9	15.4	11.5	3.9	18.9	10.8	8.1
Switzerland	16.7	12.2	4.5	15.2	11.8	3.4	19.3	11.3	8.0
Canada	22.5	9.9	12.6	20.4	9.7	10.7	28.6	9.4	19.2
Australia	16.9	8.6	8.3	17.6	9.9	7.7	24.1	...	...
New Zealand	17.1	8.0	9.1	18.7	9.2	9.5	26.4	9.4	17.0
U.S.A.	17.4	10.9	6.5	17.3	10.6	6.7	25.8	10.1	15.7
Egypt	42.5	28.5	14.0	42.0	25.8	16.2	...	...	...
Japan	32.9	17.7	15.2	26.6	17.8	8.8	34.8	14.8	20.0

War II, had later continued. On the other hand there were no data for measuring the effects of the war in regions with the highest death rates. These statements are illustrated in Table VIII for certain countries for which trustworthy figures were available.

Fertility and Mortality.—The birth and death rates mentioned above are known as "crude" rates. They measure important facts; they show how the population was moving, whether it was increasing or decreasing and at what rate, in a particular year. But these crude rates may be misleading if they are taken as measuring the actual forces of birth and death, or of fertility and mortality. This statement can be illustrated as follows. Women within the reproductive age alone can bear children, and of these women those in the younger age groups bear children more frequently than those in the older groups. Suppose that in a country, because it is a new country peopled with young immigrants, women of reproductive age, and especially of the younger reproductive groups, form a higher proportion of the total populations than in an old country, then, other things being equal, the birth rate will be higher in the former country. By other things being equal is meant that in both countries marriage habits are alike and that the chance of a woman of a given age bearing a child is the same in both countries. That this must be so can be seen if it is remembered that "the force of birth" or fertility is like a rate of interest, and if the same rate of interest is applied to capital sums of different amounts it will yield different dividends. Similarly, crude death rates may be misleading. Suppose that the chance of dying at each age in a year is the same in two towns, one of which is largely peopled by young workers and the other by retired people, the latter will have a higher death rate. The assumption in this case is that fundamental health conditions are alike in both towns; but it might well be that the second town was the more healthful of the two and yet showed a higher death rate because old people went there to die. Differences in mortality rates are in fact very marked. The infant mortality rate, for example, measures the number of live-born children who die in the first year of life. In 1947 it was 25 per 1,000 in New Zealand, 28.5 in Australia, 32 in the United States, 33.6 in the Netherlands, 41.6 in England and Wales, 45.5 in Canada, 66.0 in France, 82.4 in Italy, 107.9 in Portugal, 111.4 in Hungary, 152.8 (1945) in Egypt and 198.8 in Rumania.

Expectation of Life.—Since mortality rates vary so much from country to country it follows that the average number of years that a new-born baby may be expected to live varies greatly. In Table IX the average number of years that a new-born baby, born at the date stated, might be expected to live is shown for both sexes for various countries; the mortality conditions upon which the calculations are made are those prevailing in the years indicated. It will be seen that not only are the differences between countries very large, but also that the expectation of life has increased owing to advances in medicine and improvements in health services. The table does not show one fact of some interest which is a consequence of a relatively high rate of infant mortality; if a baby survives the first year of life, its expectation of life becomes greater than it was at birth.

TABLE IX.—*Expectation of Life at Birth*

Country, period and sex	Average length of life expected at birth	
	Male	Female
Belgium		
1891–1900	45.39	48.84
1928–1932	56.02	59.79
France		
1898–1903	45.31	48.69
1908–1913	48.49	52.41
1920–1923	52.19	56.09
1928–1933	54.30	59.02
1933–1938	55.94	61.64
Netherlands		
1900–1909	51.0	53.4
1910–1920	55.1	57.1
1921–1930	61.9	63.5
1931–1940	65.5* 65.7†	67.2
Sweden		
1901–1910	54.53	56.98
1911–1920	55.60	58.38
1921–1930	60.97	63.16
1931–1935	63.22	65.33
1936–1940	64.30	66.92
England and Wales		
1910–1912	51.50	55.35
1920–1922	55.62	59.58
1930–1932	58.74	62.88
New Zealand‡		
1901–1905	58.09	60.55
1911–1915	60.96	63.48
1921–1922	62.76	65.43
1931	65.04	67.88
1934–1938	65.46	68.45
United States		
1900–1902§	47.88	50.70
1909–1911§	49.86	53.24
1939–1941	61.60	65.89
Egypt		
1936–1938	35.65	41.48
India‖		
1891–1901	23.63	23.96
1901–1911	22.59	23.31
1921–1931	26.91	26.56

*Including war losses.
†Excluding war losses.
‡Excluding Maoris.
§Based on data for the 10 death-registration states of 1900.
‖Including Burma.

Net Reproduction Rates.—It has already been pointed out that although birth rates and death rates provide information of much importance they may be misleading if taken as measuring the strength of the forces upon which the future trend of population will depend. Thus the birth rate may be high because the proportion of young married women in the population is large, or the death rate may be low because the proportion of elderly persons in the population is low. In order to obtain a measure of the combined effect of the impact of current fertility and mortality rates upon a population, the net reproduction rate has been devised. The object of this rate is to show whether a population, if the prevailing rates of fertility and mortality were to continue unchanged, would eventually increase, decrease or remain stable. It does in fact demonstrate whether 100 new-born girls exposed to the fertility and mortality rates experienced in a year or other period will in their turn bear 100, or more or less than 100, girl babies. It is most important to appreciate the basis of the calculation. To make it for the year or period in question, the likelihood that a woman of given age will bear a girl baby or, in technical terms, the age-specific fertility rates must be known. We must also know how many girl babies will survive to each year in the child-bearing period. Given this knowledge the story of 100 new-born girl babies can be followed. The mortality rates, being what they are, will reduce 100 to a smaller figure when reproductive age is reached and to a still smaller figure at the end of the reproductive period. It can in fact be ascertained just how many out of 100 will survive to each year of age. But since the chance of bearing a girl baby at each year in the reproductive period is also known, it can be said how many girl babies in all will be born from the survivors of the original 100. If 100 are born the rate is 1, and the population is replacing itself in the long run; if more or less than 100 are born, the rate is more or less than 1, and the population is tending either toward increase or decrease in the long run.

TABLE X.—*Net Reproduction Rates*

Country	Year	Net rate of reproduction
England and Wales	1933	0.747
	1934	0.766
	1935	0.764
	1936	0.774
	1937	0.785
	1938	0.810
	1939	0.808
	1940	0.772
	1941	0.761
	1942	0.853
	1943	0.900
	1944	0.996
	1945	0.909
	1946	1.111
United States	1940	1.023
	1941	1.076
	1942	1.190
	1943	1.233
	1944	1.171
	1945	1.144
	1946	1.359
Belgium	1939	0.859
	1947	1.002
France	1930	0.930
	1935	0.870
	1940	0.820
	1944	0.940
Norway	1935	0.746
	1940	0.858
	1945	1.075
Sweden	1935	0.739
	1940	0.812
	1945	1.147
Switzerland	1936	0.790
	1940	0.795
	1946	1.158
Australia	1930	1.130
	1935	0.945
	1940	1.017
	1945	1.244

An inspection of Table X shows that the net reproduction rate was low in many countries before World War II but then rose. On this showing, therefore, some countries were not replacing themselves in the decade before the war. In the cases of the United States and of England and Wales the rates are shown for a number of successive years, and it will be observed that there were considerable differences between one year and the next. It can hardly be supposed the forces bearing on the population fluctuate in this manner, and indeed these fluctuations do indicate that the usefulness of the rate as an indication of trends is limited. This fact may be illustrated by considering the part played by fertility. What matters in the long run is the size of

the completed family. Now suppose that married couples are having three children on the average; they may postpone the birth of a child for a time because they fear war or unemployment and yet have their three children in the end. If many married couples decide on postponement for a period of a year or more, then in that period the age-specific fertility rates will be low and the net reproduction rate will fall. Later conditions may improve and then there is no longer reason for postponement; the children are born and the net reproduction rate rises. In the case of England and Wales there is little doubt that fear of unemployment between wars and the impact of World War II in its early years led to postponement, and that later many postponed births took place. It follows that although the net reproduction rate is a useful index, great care must be used when drawing inferences from it. If a country has a rate below unit, it may be found on careful investigation that temporary forces are at work which depress the rate; contrariwise a rate above unit may well be swollen by equally temporary causes. In the case of England and Wales it is likely that the rate did understate the amount of replacement before World War II and overstated it after the war. Therefore the rate is not a perfect measure of the trend of the combined effect of the forces at birth and death so far as the detection of the long-run forces governing population trends are concerned. No better index has been devised, and it may be that no satisfactory index can be constructed. The assessment of the position of any population in relation to replacement is a matter involving judgment and it cannot be that all, however well informed, will judge alike.

GROWTH OF WORLD POPULATION

Population History.—Earlier in this article it has been shown that the estimated world population for 1947 was subject to a considerable margin of error. Improvement in methods of counting has not been continuous, and in some countries the situation in this respect has deteriorated at certain periods. Nevertheless, in general the knowledge of world population has improved decade by decade. It follows that as we go back in time information becomes less and less accurate. The earlier figures have been examined with great care by experts in this field of study, and the results may be summarized as follows. Figures based upon direct evidence of a fairly trustworthy character exist for Europe back to 1770; in the earlier decades after 1770 these figures seldom or never reach the accuracy of a modern census, but they are better than those founded on indirect evidence. Before 1770 there are figures of equal validity for certain European countries, for England and Wales back to 1700, for instance; but in no case are figures of this degree of accuracy available for the 17th century. For the United States there are figures which reach the standard in question from 1750 onward; but, although there are satisfactory figures for New France from 1665 to 1750, acceptable figures for Canada as a whole begin only in 1850. For Australia and New Zealand satisfactory figures for the white population also begin in 1850. Thus for three out of the six continents population history can be carried back in this way for at least a century. But that is not so in the case of any of the other three continents. It is true that for certain countries in these continents there are reasonably good figures from earlier years. In the case of Africa there are data for Algeria and Egypt from the latter half of the 19th century, and for South Africa from about the beginning of the 20th century. In the case of Asia there are figures for India from 1872, and for Ceylon, Java and the Philippines from before 1900, and there are records for Japan from 1721 to 1848, and again from 1873 onward.

It follows from these facts that no history of world population can be constructed which is based entirely on figures reaching the degree of accuracy indicated above; even for Europe such a history only begins in 1770. If anything is to be said, recourse must be had to partial figures and indirect evidence of any kind that bears upon the matter. All such evidence was reviewed with great care by Walter F. Willcox, who published figures in 1929 for the growth of world population since 1650. It must be understood that in order to do this Willcox had to rely on evidence that was admittedly most precarious. A single instance may be given which illustrates the sort of procedure employed by him. For Europe satisfactory figures begin in 1770. For 1750 Willcox gives a figure based on a revision of a contemporary estimate made by J. P. Süssmilch. For 1650 Willcox makes use of the work of Julius Beloch who, about the beginning of the 20th century, examined the available evidence and published an estimate of the population of Europe in 1600. Willcox came to the conclusion that there is no evidence of growth of population in Europe between 1600 and 1650 and therefore used Beloch's figure for 1600 as the best available for 1650. It can readily be seen that if the figure for Europe in 1650 is on such a tenuous basis, the figures for the other continents, for which data are still more sparse, can be no better than informed guesses. But nothing better is available, and Willcox's figures, revised in view of certain considerations of which mention need not be made here, are set out in Table XI. To his figures thus revised are added figures for 1933 as given by the *Statistical Yearbook* of the League of Nations and figures for 1947 as given by the *Demographic Yearbook* of the United Nations. When due allowance has been made for the tentative nature of the estimate, there is nevertheless a good case for supposing that the population of the world has quadrupled in the last three centuries. It may also be taken as certain that the continents have not shared equally in this expansion. Although Asia has maintained its predominant position, Europe has gained somewhat and Africa has fallen markedly behind.

TABLE XI.—*Estimated Population of the World, 1650–1947*
(in millions)

Continent	1650	1750	1800	1850	1900	1933	1947
Europe*	100	140	187	266	401	519	540
North America†	1	1.3	5.7	26	81	137	157
Central and South America	12	11.1	18.9	33	63	125	153
Oceania	2	2	2	2	6	10	12
Africa	100	95	90	95	120	145	188
Asia*	330	479	602	749	937	1,121	1,276
World total	545	728	906	1,171	1,608	2,057	2,326
(Percentage distribution)							
Europe*	18.3	19.2	20.7	22.7	24.9	25.2	23.2
North America†	0.2	0.1	0.7	2.3	5.1	6.7	6.7
Central and South America	2.2	1.5	2.1	2.8	3.9	6.1	6.6
Oceania	0.4	0.3	0.2	0.2	0.4	0.5	0.5
Africa	18.3	13.1	9.9	8.1	7.4	7.0	8.1
Asia*	60.6	65.8	66.4	63.9	58.3	54.5	54.9
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*The official figures for the U.S.S.R. do not show how the population of that country is distributed as between Europe and Asia. In order to make the data for 1933 and 1947 comparable with those for the period 1650 to 1900, the total population of the U.S.S.R. has been allocated to the two continents on the basis of such information as is available.
†North America includes United States, Canada, Newfoundland, Labrador, Alaska, Greenland, and St. Pierre and Miquelon.

Factors in Population History.—It has been made clear that knowledge of the movement of population is far less extensive and accurate than of population totals. Information relating to the former in past times is in fact very sparse; reliable figures exist only for a few countries and it is possible to do no more than attempt to detect the relative importance of the factors involved. Reference may first be made to the part played by migration movements since 1650. Migration movements have been very important; but Europeans and Africans alone have been extensively involved in them. It has been estimated that 20,000,000 Africans were taken from their homes and transported overseas, and no doubt the operation of the slave trade had a considerable effect upon the population of Africa south of the Sahara. The movement of Europeans overseas, though less in proportion to the numbers at home, was more important in its results; this overflow from Europe, amounting to more than 50,000,000 between 1846 and 1932, brought North and South America and Oceania under European control. Moreover, the planting of European settlements overseas was followed by the application of European techniques to agriculture and industry. The growth of population in these oversea settlements was due in part to continued immigration from Europe and in part to a surplus of births over deaths. Elsewhere growth of population was due to natural increase alone. A population can begin to grow by natural increase either because the birth rate rises or because the death rate falls. The course of events in certain European countries has been carefully investigated. It is possible that the birth rate rose somewhat, for example in England in the 18th century, as a result of earlier marriages which became possible with the abolition of apprenticeship and the passing away of conditions and conventions inimical to early marriage. But it is certain that the lowering of the death rate was far more important. Many things conspired to lower the death rate—advances in medicine, improved sanitation, more healthful living conditions, purer water supply, etc. These changes were effective because the food supply was increasing with improvements in agriculture; in the absence of such improvements the decline in the death rate would have been checked by famine. Far less is known about the factors at work in Asia; but there is reason to believe that once again the governing factor was a decline in the death rate. In Asia, however, those causes which led to a decline in the death rate in European countries for the past century or more, have hardly yet begun to operate. It would seem that the decline must be attributed in the main to the cessation of chronic wars, feuds and raids, and the attainment of internal peace and security which followed the imposition of European rule in such countries as India and Java. There is evidence that the death rate is beginning to fall further as the result of the adoption of western sanitary practices and the application of western medical knowledge. But the population in many of these countries is already very dense, and it is a question as to whether the fall may not be checked by lack of a sufficient food supply. In these countries a factor, which began to operate in France early in the 19th century and from the last quarter of that century in other European countries, has not yet made its appearance. This factor is the fall in the birth rate. The statistics relating to this fall are all compatible with, and indeed point strongly to, the conclusion that it is due to deliberate family limitation. Because of this fall, natural increase has been held in check, and indeed has diminished, in most countries in Europe and of European origin. Thus countries fall roughly into two groups, those in which both rates are controlled and those in which the death rate alone is checked.

The Trend of Population.—From the point of view of total world population, migration movements are merely a shifting of people from one country to another. But they have repercussions upon the

country of emigration, and still greater repercussions on countries of immigration whose growth may be greatly stimulated thereby. The signs are, however, that by mid-20th century the epoch of migration movements had ended; during the second quarter of the century these movements declined to a low level and did not seem likely to revive. The trend of population in each of the chief countries of the world would therefore be determined almost wholly by the local balance between the forces of fertility and mortality. In that group of countries where fertility was still uncontrolled about three-quarters of the world population is found. In these countries there is immense scope for further reduction of mortality rates; an inspection of Tables IV and IX will show that much has still to be achieved in India in order to bring conditions into line with those in western Europe. It is well worthy of note that new discoveries make possible sudden and dramatic reductions in mortality rates such as were brought about by the virtual conquest of malaria by DDT in certain areas. On this basis a rapid upsurge of population could be expected; it was indeed in progress in 1950 in India, Pakistan, Egypt, Ceylon and other countries where internal peace and orderly administration then prevailed. Control of fertility in the long run alone can prevent disaster in the shape of famine; how long disaster can be staved off through better farming, migration and the application of scientific knowledge none can say. In those countries where fertility is controlled the outlook is very different. Control of fertility by modern methods of family limitation is new in human experience, and caution must be exercised in the interpretation of the limited evidence available. It would seem, however, that once the practice of family limitation is accepted, the control of fertility is very effective. Within 50 years of the adoption of the practice, certain European countries, though still showing a surplus of births over deaths because of the peculiar age distribution of their populations, were only just replacing themselves in the sense that a continuation of the prevailing fertility and mortality rates would have led to a stabilization of numbers. Indeed some of these countries were not replacing themselves in this sense. Since there was no reason to suppose that the fall in fertility had come to an end, there seemed to be reason to anticipate that in due course the population of these countries would begin to decline, and that the decline would continue until fertility was raised. That was the position before World War II. It was still too early at mid-century to interpret the figures for 1939–47 as shown in Table VIII. The tremendous events of those years had profound repercussions, and the sharp decline and the sharp recovery of the birth rate in many countries are certainly in large part to be attributed to World War II. But there is also some reason to believe that the decline in fertility may have been checked, and moreover checked at about the point where population is replacing or nearly replacing itself. In any case it can be said that, whereas before 1939 many European countries and some countries of European origin were heading toward an ultimate decline in population, by 1950 it was no longer clear that this was so. But this statement should be taken as meaning that the trend of population in these countries had become doubtful and not as meaning that it had clearly undergone a fundamental change.

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(A. M. C.-S.)

POPULATION ECOLOGY. A relatively recent research interest among biologists is the study of groups of organisms as contrasted with the study of individuals. As is well appreciated, much of biological knowledge rests upon the morphology, physiology and biochemistry of those units that comprise the organism, *e.g.,* cells, tissues, systems, and upon knowledge of the entire organism considered as a whole. However, it is becoming increasingly evident that significant problems and principles emerge when the reactions of animals considered as populations are investigated. This has many parallels in scientific inquiry including biology. Thus, to learn about tissues, a cell as a single unit, groups of cells and the particular tissue itself all must be subject to analysis. This is equally true of population research. Not only is it essential to understand the interactions between an individual and its surroundings but, also, it is equally necessary to understand those new interactions that emerge when the group operates as a unit within its particular physical environment. This, once accomplished, is logically followed by consideration of different kinds of populations so that a corpus of general information about the subject is built. It is in this way that population biology grows as a unified science in its own right.

Population biology falls into two broad categories: population genetics and population ecology. The first, concerned with the processes of organic evolution, lies outside the scope of this article but is treated elsewhere (*see* EVOLUTION, ORGANIC). The second forms the subject matter here to be discussed. A general distinction between the two subdivisions can be drawn as follows. The student of population genetics is primarily concerned with events within the population leading to qualitative hereditary differences—with the transmission in time of genes through the group and with those agents that affect this transmission such as mutation, selection (*q.v.*), isolation, breeding structure and so on. The student of population ecology on the other hand is concerned primarily with quantitative events within the population —with those environmental factors, regardless of type, which affect the group's size, its composition and its growth and life history. This distinction between these two major fields becomes somewhat arbitrary if carried too far, because actually both depend to a considerable extent upon each other.

The subject matter of ecology (*see* ECOLOGY, ANIMAL) can be considered under four categories, each of which represents a grade of biological organization of increasing functional and structural complexity. The four are: the individual organism, the single species population, the mixed or several species population and the community. Knowledge of the ecology of single organisms—that is, of the interactions between one animal and its immediate environment—is designated autecology and is fundamental for an understanding of populations. Similarly, information about populations is fundamental for an understanding of communities—those complex plant and animal assemblages existing in nature as essentially self-sustaining units. Although, when investigating a population, the ecologist must be informed about the autecological relations of its members, he must also study the groups as such. It follows, too, when communities are studied, that, in addition to research on the component populations, a suitable synthesis can not be formulated without analysis of the communities as wholes.

The primary focus of population research is on numbers. A population may be defined appropriately in several ways: "The organisms, collectively, inhabiting an area or region"; or, in another version, "A group of living individuals set in a frame that is limited and defined in respect of both time and space." These definitions have at least four implications: number of individuals, likeness of kind enumerated, aliveness and limitation of universe in space and time. In other words, the definition of a biological population deals with these questions: (1) How many organisms are there? (2) Are the forms counted biologically alike? (3) Are members of the group living? (4) Where do the forms live and in what places?

Census Methods.—Since the study of populations involves a count of those organisms present in a circumscribed area or volume, it follows that the single most significant technical procedure in population research is the taking of an adequate census. This assumes several forms, depending upon the particular situation. Population size is usually determined, or at least approximated, by one of the following six methods:

(1) *Total Count of all Individuals of all Stages or Classes.*—This is the only single census method that is completely accurate. It counts in a delimited environment every individual regardless of age, sex, stage of development or location. It is only occasionally that the method can be used because: (a) the number of animals usually is too great; (b) it is technically impossible or at best not feasible; and (c) the precision it affords is not worth the effort. Modern censuses of human populations for civilized countries approach the perfection the total census method demands.

(2) *Total Count of all Individuals of a Certain Stage or Class.*—This method is used either because it is sufficient to know only how many members of a specified category are present within a population or else it represents the best that can be done under the circumstances. For example, in censusing an insect population the student may be concerned only with the number of adults and ignore, say, the number of eggs, larvae and pupae.

(3) *The Method of Sampling.*—This is the usual method employed in estimating population size. It assumes that the investigator can form a judgment about the entire group, however delineated, by withdrawing replicated aliquots. This method can be highly accurate when the pattern of distribution of the forms is understood and the samples are taken with this in mind. On the other hand, it is replete with pitfalls at the hands of the unskilled and can lead to gross errors of interpretation.

The successful application of sampling methods depends on firsthand information about the ecology of the group under study; on a knowledge of what constitutes an adequate sample, followed by appropriate statistical treatment of the data once collected, and, above all, on wisdom and judgment in evaluation of the findings.

(4) *The Method of Biomass.*—This method utilizes weights of population samples (biomass) instead of counts of individuals. The weights are always reported relative to some defined spatial unit and may be either treated directly as such in analysis of the data or else converted into number of individuals.

(5) *The Registration Method.*—This method requires that, after an initial census has been taken, each birth, death, immigration and emigration within the population shall be recorded at stated time intervals. Population size is then enumerated as follows:

$$\text{population size} = \text{initial size} \pm (\text{births} + \text{immigrations} - \text{deaths} + \text{emigrations}).$$

This method is of minor practical importance because it frequently is difficult to obtain the requisite facts about births, deaths and dispersion, and because it is usually simpler to count the members directly.

(6) *The Method of Marking.*—This useful technique is gaining rapid adoption among students of insect and mammal populations. In one of its variants the procedure is as follows: a known number of marked animals is turned loose within the habitat. It is assumed that, since these presumably redistribute themselves as they were before being caught, then in a sample taken later the proportion of marked to unmarked forms can be determined with total population size estimated by solving this equation:

$$\frac{\text{total number of marked animals released}}{\text{total number of unmarked animals}} = \frac{\text{marked animals caught in census period}}{\text{unmarked animals caught in census period}}.$$

The unknown to be solved for is the denominator of the first fraction—a solution readily obtainable by simple algebra.

(7) *Indirect Methods.*—Sometimes it is impossible to count numbers of animals at all but it is possible to approximate their abundance only by some product of their activity—the greater the product, the larger the size of the group. This is the poorest of all census methods and is, or should be, used only as an extension of other techniques or as a last resort. These are certain manifestations that have been utilized in estimating population numbers: the number of foecal pellets (rabbits, foxes); of shed antlers (deer); of tracks (rabbits, birds); pelt records (fur-bearing mammals of commercial significance); the frequency of vocalization (bird calls, howls, etc.), and so on.

In certain instances, as has been recommended, various methods can be combined to advantage.

Scope of Population Ecology.—Modern population research falls into the following practical categories:

(1) Studies of natural (field) populations. These are both intraspecies (single species) and interspecies (several species) in character.
(2) Studies of experimental laboratory populations (both intraspecies and interspecies).
(3) Studies of human populations (intraspecies).
(4) Epidemiological studies (interspecies, as interpreted in this article).
(5) Theoretical population ecology (both intraspecies and interspecies).

Natural population studies usually deal with the distribution, total size, territorial relations, predation and other interspecies competitions and the relation of the population to its immediate physical environment.

Insects, fishes and their planktonic foods, birds and mammals have been most studied as natural populations.

Laboratory population studies make their prime contribution through control of the physical and biotic environment. They attempt to analyze a specific group relationship that would be either extremely difficult or impossible to study in many natural populations. The objective of such research is to illuminate population operations by means of relatively simple, yet not artificial, models, and then to apply the results to groups in nature. In the laboratory these are the general problems most studied: at the intraspecies level, population growth form, analysis of population density and the effects of density on reproduction and death; at the interspecies level, competition for a shared food supply or niche in which to live, and the interactions between predators, parasites and prey.

Microorganisms (protozoa, bacteria, yeasts), insects and certain rodents have been employed most extensively in such investigations.

Human population studies are treated elsewhere from various points of view (*see* SEX RATIO: *Human, at Birth and Death;* DEATH, BIOLOGICAL ASPECTS OF; LONGEVITY).

Epidemiological studies as viewed here are limited to population aspects of host-parasite interactions, although some students refer to epidemics of single species. Many of these are statistical, deal with pathogenic organisms and hence are of clinical significance. Such diseases in epidemic form as tuberculosis, diphtheria, the common cold, influenza, acute anterior poliomyelitis, septic sore throat, typhoid fever, typhus, sleeping sickness and malaria have been investigated from this point of view. In these instances man is the host organism, but the findings are of distinct importance for population ecology. In a recent book by F. M. Burnet, himself a medical scientist, entitled *Biological Aspects of Infectious Disease,* the following pertinent statement appears: "Other workers with an appreciation of modern developments in biology are finding that infectious disease can be thought of with profit along ecological lines as a struggle for existence between man and micro-organisms of the same general quality as many other types of competition between species in nature."[1]

In addition to the studies with a clinical motivation there exist important laboratory studies of host-parasite interactions using insect materials.

Theoretical population ecology is still in an early stage of development. Workers have concentrated to date on three aspects: mathematical rationalizations, the problem of the origin and integration of social groups and synthesis of knowledge to build a conception of population integration, that is, how a group as such is controlled through its own functional organization.

Natality, Mortality and Dispersion.—In all scientific inquiry there are particular focal points of study. The physicist stresses the behaviour of atoms and molecules; the geneticist, the transmission and physiology of genes; the cytologist, the structure of the cytoplasm and the nucleus, and so on. The student of population ecology is always concerned in final analysis with three composite statistical factors—natality, mortality and dispersion, and those forces that affect them. These factors shape the course of population growth form, its composition and survival as to age, sex and stage of development, and its distribution in space and time. Natality has the effect of increasing the size of the group. Mortality, the total deaths exhibited by the population, has the effect of decreasing the size of the group. Dispersion can operate, at least temporarily, in either direction depending upon the form it assumes, numbers being increased by immigrations and decreased by emigrations.

Natality can be viewed as either potential or realized. Potential natality is that maximum number of eggs that the species can produce; realized natality is the birth rate. Were potential natality realized, each individual member of the population would need to exist under ideally optimal conditions. Obviously, this situation is rarely if ever attained in nature, which suggests that populations characteristically produce many fewer offspring than their physiological capacities allow. A valid ecological generalization is that species with high natality potentials are subject to excessive mortality of their eggs, while the converse is typically true for species with lower natality potentials. For example, P. S. Galtsoff (1930) estimates that a single oyster has the capacity of producing 55,000,000–114,000,000 eggs during a lifetime, when it

[1]By permission of the Cambridge University Press.

is clear that only a relatively few of these mature. Similarly, J. L. Hart and A. L. Tester (1934) report that a population of 1,000,000–9,000,000 herring in certain areas of the Strait of Georgia produce annually 8,000,000,000–75,000,000,000 eggs, of which perhaps 95% hatch and less than 0.1% reach maturity. On the other hand, the potential natality of the human female is comparatively low but the realization of this potential in terms of reproductive effort is high.

It is meaningful also to view mortality as potential or realized. F. S. Bodenheimer (1938) has defined the former, which he calls "physiological longevity," as ". . . the average longevity of individuals of a population living under optimal conditions and of genetically homogeneous stock," and the latter, which he calls "ecological longevity," as ". . . the empirical average longevity of the individuals of a population under given conditions." (F. S. Bodenheimer, *Problems of Animal Ecology*, Oxford University Press.) If a population is studied under situations approaching potential mortality, and if these data, expressed as survival against time, are then compared with a similar population under known conditions of realized mortality, the difference between the two curves indicates that approximate part of the total mortality caused by a suboptimal environment and that part which would occur even under the most favourable conditions. In a sense, potential mortality connotes the best that a group can do in terms of its life duration, while realized mortality connotes how much a group actually is decimated when confronted with hazards of various sorts. Among these hazards may be mentioned such items as unfavourable climate, excessive crowding, adverse biotic pressures engendered by predatory and parasitic organisms and accidents.

Obviously, great differences exist between species in the extent of ecological mortality to which they are subjected, some regularly having many deaths because of many causes and others having few deaths because of few causes, with numerous gradations between. Populations of grasshoppers living under exposed conditions in plain and prairie habitats exemplify a group with a high realized mortality; honeybees living protected in hives with a highly perfected social organization exemplify a group with relatively low realized mortality.

Cases of potential mortality that approach the theoretical conditions have been reported by R. Pearl and S. L. Parker (1924) on *Drosophila melanogaster*, by B. Noyes (1922) and Pearl and C. R. Doering (1923) on the rotifer *Proales decipiens* and by B. P. Wiesner and N. M. Sheard (1935) on laboratory populations of albino rats. Ecological mortality has been assessed by Bodenheimer for natural populations of the locust, *Schistocerca*. He reported these specific mortalities for the various stages of the life cycle: eggs 13%, nymphal period 67.5% and adult period 19.5%. Not all causes of death were accounted for, but it does seem clear that the eggs are particularly subject to insect parasitization and fungus disease, while the nymphs and adults are eaten by lizards, birds, small mammals and, sometimes, by man.

Although it is necessary to discuss natality and mortality as if they are single factors, it becomes immediately apparent, however, that it is their interaction that is significant in terms of the behaviour of the total population. Thus, a high birth rate taken by itself is of minor value without knowledge of the corresponding death rate reported for the same group over the same time interval. Such a birth rate might suggest that the population is vigorously expanding, while actually, as is so frequently true, the death rate could be so severe that members added by reproduction are cancelled by deaths, with the result that the population remains stationary. Similarly, a low birth rate does not necessarily indicate a declining population, because it may be associated with a correspondingly lower death rate. A single empirical statistic has been proposed, known as the birth-death ratio or vital index, which shows at a glance this relationship between natality and mortality. This is defined as 100 births÷deaths, and yields upon solution the number of births for each 100 deaths. In the absence of sustained immigration or emigration a vital index greater than 100 shows that the group is growing; less than 100, that the group is contracting, and equal to 100, that the group is stationary.

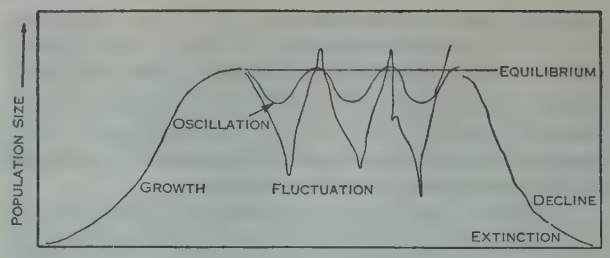


FIG. 1.—STYLIZED REPRESENTATION OF POPULATION GROWTH FORM

The interactions of natality and mortality are decisive in controlling the growth form of populations only when the group is not dispersing over its territory to any extent or when it is not adding to or subtracting from its membership as a result of migratory phenomena. Thus, as mentioned earlier, the pattern of movement of animals must be considered in all population studies, in addition to reproduction and death, whenever it effectively alters size or composition. Dispersion may take the form either of slight movements or rearrangements within the population, mass movements of the group itself or income from immigrations and outgo from emigrations. In nearly all natural populations such movements are occurring either sporadically or with considerable regularity. When these are of a magnitude to alter markedly the size of the population, internal adjustments must occur. Characteristically, but with exceptions, if a group loses constituents, the spaces thus made available are filled through more effective reproduction. If it gains members through the influx of new organisms, the pressure of competition for food, shelter, mates, etc., increases and a higher death rate is brought about.

Population Growth Form.—As populations pass through their life history they assume certain patterns that are called, collectively, growth form. Knowledge of growth form is basic for the development of population ecology in that it provides a single numerical statement about how groups have behaved in time. It is obvious that a particular growth form is the product of the interactions between natality, mortality and dispersion. The following somewhat arbitrary phases constituting the growth form can be recognized and are stylized in fig. 1.

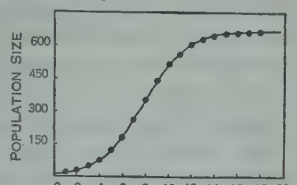
I. The period of positive growth (the population increasing).
II. The period of equilibrium (equilibrium is defined as mean numerical stability).
III. Oscillations and fluctuations (departures from equilibrium).
  A. Oscillations (relatively symmetrical departures).
  B. Fluctuations (relatively asymmetrical departures).
IV. The period of negative growth (consistent and progressive decline of the population below equilibrium or below the lower range of usual fluctuations and/or oscillations that jeopardize the population's survival).
V. Extinction (the disappearance of the population).

The growth (*q.v.*) of populations usually follows a sigmoid curve when represented by number of organisms on the ordinate axis against time on the abscissal axis. This holds for many species of animals, including man, and abundant data have been accumulated for both laboratory and natural groups. In fact, a considerable segment of population biology has been concerned with fitting such data with a particular equation known as the logistic curve that, upon solution, yields a growth curve which is characteristically S-shaped. Fig. 2 from Pearl, *The Biology of Population Growth* (1930) illustrates this curve when applied to the multiplication of yeast cells within a spatially limited environment. The smoothed line is the calculated function, the dots are the actual census counts. The curve demonstrates that rate of growth is at first slow, then rapid, then slow again as the maximal number possible (asymptote) under the existing ecological conditions is approached.

After this asymptote is attained, assuming there are no marked changes in the exploitable potentialities of the environment, several courses are open to the population. It can maintain itself with slight variability at the mean maximal size (equilibrium); it can oscillate in even and regular dips and peaks about that maximum (oscillation); it can vary above and below the averge equi-

librium value in a more-or-less irregular fashion (fluctuation) or it can steadily contract (decline). If the contraction continues, the entire population dies (extinction).

Initial sigmoid population growth is rarely demonstrable with any precision in nature, primarily because most groups have long since passed that original phase of their life history when censused. It can be demonstrated readily in the laboratory, however. Nor is equilibrium, oscillation, protracted decline or extinction often seen under field conditions. Most groups react so sensitively within themselves and with their surroundings that an even, sustained equilibrium is unusual. Oscillations demand such a regularity and repeatability of causal mechanisms that they too are rare events. A population decline that jeopardizes the future survival of the group is seen somewhat more often in nature, especially following an unfavourable climatic disturbance leading to increased mortality or decreased food supply or after exposure to a particularly virulent epidemic, but it too is exceptional. The extinction of definitive populations is likewise infrequent. Cases of species extinction are known, and occasionally the underlying reasons are understood; but as a rule populations are adaptable enough so that they compensate in one way or another for environmental vicissitudes before their contraction goes irreparably far.



ADAPTED FROM PEARL, "THE BIOLOGY OF POPULATION GROWTH" (KNOPF)

FIG. 2.—THE LOGISTIC GROWTH OF A LABORATORY POPULATION OF YEAST

Thus, by elimination, fluctuation remains the usual event so far as population growth form is concerned. Populations characteristically vary above and below an average equilibrium value. This variation may be caused by chance alone, but it is more likely to result from fundamental, yet temporary, adjustments between the group and its effective environment. The magnitude of the variation can be great or small in terms of total population size (ordinate axis), in terms of the time intervals between the fluctuations (abscissal axis) and in terms of the species involved.

Density-Independent and Density-Dependent Factors.—It is necessary to develop population ecology beyond a consideration of natality, mortality and growth form. While these aspects constitute the background for such studies in the sense that interactions of the first two induce a pattern of growth, it is clear that they in turn are influenced by factors of ecological origin. These, falling into two broad categories known as density-independent and density-dependent factors, merit brief definition and illustration (*see* bibliography, H. S. Smith).

It will be apparent from the earlier discussion that, as a population passes through the phases of growth form, the degree of crowding, or density, of its members characteristically varies to a considerable extent. Certain factors of the environment have virtually the same effect on the group's members regardless of this density relation, and these are called density-independent. Another set of factors, known as density-dependent, achieve notably different results when crowding is slight, as compared with the results obtaining when crowding is extreme. Thus, a particular unfavourable temperature might eliminate through mortality 60%, say, of a population, whether that population had a census of 100 or 1,000 members per unit area. On the other hand, this same population might not be vulnerable to predatory attack, or to disease in epidemic form, when composed of only 100 individuals but, alternatively, highly vulnerable when 10 times larger. These important distinctions can be clarified by actual cases.

Density-independent factors are largely products of the physical-chemical environment. Density-dependent factors stem primarily from biotic interactions between organisms. For terrestrial populations the more usual density-independent factors are the following: temperature (high, low and alternating), precipitation (both excess and deficient), wind and storms, atmospheric pressure, humidity, light and certain aspects of food supply. For aquatic populations, the physical and chemical qualities of the water, water movements, light penetration, substratum effects and, again, selected aspects of food supply constitute the more characteristic density-independent agents.

A satisfactory illustration of a density-independent interaction between a particular environmental factor and a particular population is afforded by the report of Gordon Gunter (1941) on the relation of unusually low temperatures to mortality of fishes inhabiting the gulf waters of the Texas coast. The winter of 1939–40 was severe in this area and on Jan. 18, 1940, an extremely cold wave brought about a drop in temperature within a few hours from 65° to 25° F., and then reached 16° that night. Many fish died from the cold, as was ascertained by experimental seining and the presence of corpses along the beaches. These deaths were also reflected in the fishery statistics reported annually for this region. For example, while the months of February–March–April for 1938 yielded 1,331,302 lb. of fish, and the same months for 1939 yielded 911,133 lb.; the catch for 1940, subsequent to the cold spell mentioned above, was only 335,431 lb. Unquestionably, this decline reflects direct mortality caused by cold. When these statistics are broken down in various ways, as for example by localities and species, the same point holds. Of all the forms, the flounders were the most susceptible. The catch of these was 94.8% less after the cold days than it was for the winter months immediately preceding the unusual temperatures. This clearly illustrates a density-independent phenomenon in that the mortality is directly caused by temperature and appears to be unrelated to the density of the various fish populations.

Studies of the pollution of waters by industrial wastes, when coupled with the consequent effects of this chemical poisoning upon a particular population, offer further instructive examples of density-independent operations. This phenomenon is well-known for a number of species, and frequently it can be shown that mortality stands in direct proportion to the kind and quantity of the pollutant but is primarily independent of the crowding of the group members. In general, the pollutants affect organisms in several ways. Acting directly, they can predispose to infection, increase egg and juvenile mortality, drive motile forms from their habitats and actually kill the adult members of the population subjected to them. Acting indirectly, they can reduce oxygen supply, harm or at least change the flora and further limit the habitats and food supply.

Although many examples could be selected to illustrate the density-independent action of pollution, a cogent one is that reported by P. S. Galtsoff, W. A. Chipman, A. D. Hasler and J. B. Engle (1938) concerned with oyster populations of the York river in Virginia. The years from the 1920s have seen a progressive decline of this population and the industry depending upon it. This started with the liberation of trade wastes into the river by a pulp mill. Apart from pollution, the York river is favourable for oyster culture. Careful comparative studies with ecologically similar neighbouring streams well populated with oysters shows this to be true. This fact, along with the observed reduction of oysters following pollution, incriminates the latter as the causal agent. Experimental studies in the laboratory demonstrated that the wastes had a decided effect upon the mollusc's physiology. The pollutant induced a prolonged contraction of the adductor muscles with the consequence that the shells remained closed for undue periods of time, thus interfering with respiration and feeding. Also, the pollutant inhibits the ciliary activity of the gills, thereby preventing water from circulating with its customary efficiency. Such impairments of the oysters' physiology causes the individuals to be dwarfed, and they fail to store normal levels of glycogen. The entire case is proved, for when the oysters were returned to clean water and provided they had not been exposed to the poison for too long, their normal rate of growth was restored and glycogen was again deposited in adequate amounts.

Thus, a single density-independent factor, pollution, is identified, its effect on population decline is appraised and the physiological channels through which it acts are experimentally detected. It is interesting to note in passing that the authors found some oysters which resisted the pollution enough to continue to sur-

vive and reproduce and so maintain a relatively small population in the York river.

Although the above examples of density-independent operations deal with aquatic populations, it should be pointed out that terrestrial forms have also been actively studied from this point of view. In fact, much of the research along this line actually was developed by ecologically minded entomologists (*see* bibliography, B. P. Uvarov; A. J. Nicholson; H. S. Smith; W. R. Thompson).

Analysis of population density has been an active research interest of the population ecologist and leads, of course, into a consideration of density-dependent factors—those agents whose effect upon the population varies with the crowding of its members. A systematic treatment of population density falls under three categories: the sorts of processes and events that are known to be influenced by density; the type of end result brought about by density regardless of the mechanisms involved (density as related to growth form) and the constitution of density *per se*.

A wide variety of processes are known to be affected by changes in density. Among these the following should be mentioned: the three primary variables governing population growth form—natality, mortality and dispersion—and such responses as the postembryonic development of insects; the individual growth of organisms; the rate of oxygen consumption; protection from noxious agents in the surrounding environment; resistance of marine forms to sea water diluted as to salt content; aggregating activity of bacteria and protozoa; sex determination and, occasionally, even the modification of anatomical characters.

Operating through reproduction and mortality, density affects the growth form of populations either by inducing decline or stimulating growth. The former aspect has been extensively studied and much is known of it. The latter aspect has received the active attention of W. C. Allee (1931) and his associates who have marshalled many data showing that, under a wide variety of conditions, organisms crowded to some degree respond more effectively than others of their own kind that are either isolated, or nearly so, or else exist under extremely dense conditions. This optimal population effect has been advanced as evidence for an unconscious co-operation—an expression of the fact that, through its own integrative mechanisms, a group of certain size and composition is better adjusted within its environment, usually with reference to its survival, than is one either larger or smaller.

Analytical studies have shown that population density usually brings about an effect through one of two mechanisms. In some cases it is the actual behaviour relations between organisms that are responsible for the observed result, such interactions varying in their intensity with the degree of crowding. In other cases, density may operate through some secondary effect upon the environment as, for example, reduction of the available food supply or addition of waste products to the habitat, both of which obviously change with the size of the population. Two examples, the relation of crowding to production of eggs by cultures of the fruit fly (*Drosophila melanogaster*) and the conditioning of flour by beetles (*Tribolium confusum*), illustrate these points.

The *Drosophila* case was originally investigated by Pearl (1932) and has been extended by F. W. Robertson and J. H. Sang (1944). Pearl demonstrated that as the population density of adult flies increases, the number of eggs produced per individual female decreases. In other words, fecundity is inversely proportional to crowding. In an analysis of the causal factors underlying this effect, experiments were set up that varied the air volume in the culture bottles in the presence of initial fly densities ranging from 1 to 128 paired *Drosophila*, with the area of agar surface to which the flies were exposed the same in all cases. It was reported that, while this volume of air above the surface had no significant effect on oviposition, the degree of crowding of the flies on the agar was highly significant. That is to say, the real density effect is essentially limited to one niche within the system. Through a careful series of observations on the behaviour of crowded and uncrowded flies, Pearl concluded that *Drosophila* will not oviposit if they are in contact with, or disturbed by, other flies, and that individual flies do not obtain as much food under such conditions even though there is an ample supply available. This was called interference or collision, and it was suggested that the probability of collisions between flies on the surface of the agar plate increased with the density. This investigation thus links the population effect through egg production to two behaviour mechanisms—the inability of the flies to lay eggs and to feed adequately when disturbed by their fellows. The later experiments of Robertson and Sang showed that the reduced fecundity associated with crowding reported by Pearl could occur only when the flies were competing for food and therefore inadequately nourished because of this competition.

As suggested above, density can also affect a population by altering the habitat as well as by influencing the interactions between the component organisms. It has been shown for the flour beetle (Thomas Park and Nancy Woollcott, 1937, and Park, 1941) that, as these beetles occupy their flour which they never leave, they modify it through reduction of its nutritive value and the liberation of harmful waste products. This modification, designated environmental conditioning, is density-dependent because the degree of such conditioning is related in time to the number of beetles that have inhabited the flour. Conditioning thus emerges as a population product owing its existence entirely to the alteration of the habitat by the group activity. Studies have shown that *Tribolium* populations always decline when the medium (flour) is not renewed, that it thus becomes progressively more conditioned and that this is a cause of decline as well as an effect. It has been demonstrated that the conditioning operates primarily by reducing the beetles' fecundity and, secondarily, by extending the duration of their metamorphosis and increasing the mortality of this period.

Although density-independent and density-dependent factors have been treated as though they fall into discrete categories, the impression should not be left that this is always true. One environmental factor, or several in conjunction, frequently can operate in both ways at the same time. In fact, for natural populations this may be the rule rather than the exception.

Summary.—Even with so adumbrated a treatment as that developed in this article, the following points should be apparent and are offered as a general summary:

(1) That populations as such may be effectively studied in the field or laboratory either as intraspecies or interspecies units, using many sorts of species from widely divergent habitats.

(2) That such study forms an integral part of ecology and is closely related to population genetics, evolution and biometry.

(3) That the population constitutes a distinct level of biological organization and is to be thought of as a fundamental, responsive unit within its particular environment.

(4) That, since population size furnishes a convenient end index of many population phenomena and since size is usually determined by counting, census methods become the single most significant technique for population ecology.

(5) That the change in size of populations with time is divisible into certain continuous phases spoken of collectively as growth form.

(6) That growth form is under the control of prior interactions between natality, mortality and dispersion. Natality as a single factor is related to population increase; mortality, to population decrease; and dispersion may induce either result depending upon the pattern it assumes.

(7) That natality, mortality and dispersion are in turn influenced by ecological factors falling into two broad categories, density-independent and density-dependent.

(8) That population density affects many responses in addition to natality, mortality and dispersion; that it can favour both population growth and decline, depending upon local conditions, and that it can operate either through actual behaviour interactions between constituent organisms or through modifications imposed upon the habitat.

Research Areas of Population Ecology.—In concluding this article it is meaningful to list those actual problems which characterize the significant research areas under study by population ecologists. These are as follows:

(1) Numerical studies describing population growth form.

(2) The effect of weather and other factors of the physical environment on growth form.

(3) Analysis of population equilibria.

(4) The problems of underpopulation, optimal population and overpopulation. This involves analyses of population density from various points of view.

(5) The productivity of populations, and factors that influence it.

(6) The problem of the optimum yield. Simply stated, this means to what extent can a group be exploited and still maintain itself?
(7) Description and analysis of population cycles.
(8) Analysis of dispersion within and between groups.
(9) Analysis of ranges and territories established and inhabited by natural populations.
(10) Epidemiological aspects of the interactions between host and parasite populations.
(11) Intraspecies and interspecies competitions.
(12) The organization of social populations; as, for example, the social insects, infra-human primate hordes and man.
(13) Improvements and extensions of population census techniques.
(14) Study of population integration; that is, those interactions between the factors that control population activities.

Several brief comments are appropriate about these problems. It is clear that some of them are primarily intraspecies, some primarily interspecies and some can be either, depending upon how the problem is specifically formulated. It can be stated didactically that all 14 problems have significant theoretical content for ecology generally and, also, that many of them have decided economic applications. Population studies assume a pragmatic value for man: (1) when a desirable species is not perpetuating itself to a great enough extent and something needs to be done about it; (2) when a species is so heavily exploited by man that he must intervene in an effort to counteract the exploitation by artificially stimulating the species to increase (this is a special case of [1] above and is illustrated by the fishing industry or by problems centring on the conservation of game and fur-bearing animals); (3) when a noxious form, for example an insect pest, endangers a particular crop or product and either must be exterminated or controlled; and (4) when a pathogenic population endangers the public health and, again, must be controlled or eradicated. These situations as stated in the above four rubrics can not be solved with any lasting validity, and without unforeseen complications, unless the entire population is viewed as an integral, functional part of its complete environment, the analysis then proceeding accordingly. Specifically, it could prove unwise to stimulate or decimate populations beyond their normal growth form solely on the grounds that the species were valuable or deleterious to man's interests. Such procedures may do more harm than good. For example, the indiscriminate use of such a potent insecticide as DDT in eliminating admittedly injurious organisms from an area might, by also eliminating locally necessary species, bring about irreparable damage even if measured only in terms of economic loss. It seems inescapable that real understanding of these applied problems of ecological character must rest upon extensive knowledge of the fundamental biology involved, and it is here that population ecology can contribute in a practical way to human well-being in addition to its more intangible, but equally exciting, contribution of a strictly intellectual nature.

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POPULONIA, an ancient seaport town of Etruria, Italy (Etruscan *Pupluna*), at the north end of the peninsula of Monte Massoncello, at the south end of which is situated the town of Piombino (*q.v.*). The place, almost the only Etruscan town built directly on the sea, was situated on a lofty hill now crowned by a conspicuous mediaeval castle and a poor modern village (Populonia). It commands a fine view, and Corsica is sometimes visible, though not Sardinia, as Strabo and, following him, Lord Macaulay erroneously state. Considerable remains of its town walls, of large irregular, roughly rectangular blocks (the form is that of the natural splitting of the schistose sandstone), still exist, enclosing a circuit of about 1½ mi. The remains existing within them are entirely Roman—a row of vaulted substructions, a water reservoir and a mosaic with representations of fishes. Strabo mentions the existence there of a lookout tower for the shoals of tunny fish. There are numerous tombs outside the town, from the Villanova period (9th century B.C.) to the middle of the 3rd century B.C. Under heaps of ancient slag removed for resmelting at the present day, a considerable number of chambered inhumation tombs of the 8th–7th century B.C. have been discovered; all were originally covered by circular mounds of earth; the roof was a false dome, formed by the projection of each course of stones beyond the one below it. The remains of a temple, devastated in ancient times, were also found. The iron mines of Elba, and the tin and copper of the mainland, were owned and smelted by the people of Populonia; hot springs too lay some 6 mi. to the E. (Aquae Populaniae) on the high road—Via Aurelia—along the coast. At this point a road branched off to Saena (Siena). According to Virgil the town sent a contingent to the help of Aeneas, and it furnished Scipio with iron in 205 B.C. It offered considerable resistance to Sulla, who took it by siege; and from this dates its decline, which Strabo, who describes it well, already notes as beginning, while four centuries later Rutilius describes it as in ruins. The harbour, however, continued to be of some importance, and the place was still an episcopal see under Gregory the Great.

See A. Minto, *Populonia* (Florence, 1922) for a full description.

PORBANDAR, a native state of India, in the Western India States Agency, Bombay, extending along the southwest coast of the peninsula of Kathiawar. Area, 642 sq.mi.; pop. (1941) 146,-648. Tribute, to the British government, Baroda and Junagadh, £2,232. The chief is a Jethwa Rajput. Limestone is largely produced, and ghi exported. The town of Porbandar is the maritime terminus of the Kathiawar railway system. Pop. (1941), 48,493. A large trade is conducted with coastal ports, the Persian gulf and the east coast of Africa. There are manufactures of silk and cotton, cement; and cotton-ginning and pressing factories.

PORBEAGLE (*Lamna cornubica*), a species of shark, belonging to the Selachians (*q.v.*). The body is short and stout and contrasts strikingly with its much-attenuated tail which is strengthened by a keel on each side and terminates in a powerful caudal fin. It has formidable pointed teeth, but is a fish eater, not considered dangerous to man. The porbeagle attains a length of 10 to 12 ft. and is a pelagic fish chiefly of warm seas but not rare in the North Atlantic and Mediterranean and frequently wandering to British and more rarely to North American shores as far as Nova Scotia. (*See* SHARK.)

PORCELAIN: *see* POTTERY AND PORCELAIN.

PORCELAIN ENAMELLING. A porcelain enamel is a ceramic enamel. It is a thin layer of glass fused to a metal to enhance its beauty, to prevent corrosion, or both. Porcelain-enamelled iron is used extensively for both domestic and industrial articles. In addition to its use for kitchenware, bathtubs and sinks, it is used extensively for table tops, refrigerators, washing machine tubs and stoves. Industrially, it is used for adver-

tising signs, chemical and food tanks of large sizes, for hospital furniture, meat market, grocery and restaurant equipment and has found extensive application in architecture for the facing of the outsides of buildings. A porcelain enamel, being a glass, has the properties of glass; namely, its hard, glossy surface and resistance to solution, corrosion and scratching. The metal backing and design greatly influence its strength and resistance to damage. The quality of porcelain enamels varies greatly, depending upon the glass used, the design and the manufacturing technique. (*See* also ENAMEL; GLASS.)

History.—Although the term "porcelain enamel" did not come into common use until about 1929, porcelain enamelling, vitreous enamelling or enamelling, as it was sometimes called, actually dates back to an early period in history. No date can be set concerning the beginning, but the first enamelling was in the form of glass beads fused to copper, gold and silver decorative ware. This type of ware was classed as jewellery and highly prized.

Later, a type of ware called cloisonné was gradually developed. Cloisonné was made by first outlining areas on a gold surface by soldering tiny gold wires in place. A finely milled paste made from powdered glass and water was spread into the area between these wires. This was dried and then the ware was placed in a furnace at a temperature sufficient to melt the glass to a smooth layer. Several applications were generally made to give sufficient thickness, and various colours were used in the different areas, thus producing elaborate designs. After the final application of the enamel, the ware was polished off smooth with an abrasive so that the gold wires appeared as uniform boundaries between the different areas of enamel.

Champlevé was made by a modification of this process in which the metal was gouged out, leaving ridges between the areas to be enamelled. Another interesting early development was that of miniature painting in which the powdered glass suspended in water was used by artists for painting small pictures.

Manufacture.—Although these early developments took many years, the transition from an art to an industry in the early part of the 19th century proceeded very rapidly. Cast-iron dry-process enamels were the first to be used on a large scale. In this process, the castings, such as bathtubs, were first sandblasted to give them a clean surface. The grip or ground coat was then applied. This ground coat consisted of a powdered glass, clay, water suspension with a consistency about like that of cream. This was dipped, slushed or sprayed on the cool casting and allowed to dry. The ware was then introduced into a furnace at about 900° C. and allowed to come to the temperature of the furnace. The hot ware was withdrawn from the furnace and powdered glass dusted through a screen over it. This powdered glass melted as it fell on the hot ware and formed a continuous layer of enamel.

Several applications were generally applied, returning the ware to the furnace for reheating before each application. This process is particularly applicable to the manufacture of heavy castings.

Another process which has come into common use is that of wet-process cast-iron enamelling. This is used on lightweight or thin castings and has been adopted extensively in the stove industry. In this process, the ground coat is generally applied, as a suspension of the glass with clay in water, dried and then fired in a furnace at about 750° C. The ware is removed from the furnace, cooled, the second coat applied and then refired. This process is sometimes known as the U.S. process for enamelling cast iron.

Sheet-steel enamelling has become the most extensive process used for porcelain enamels. In this process, the sheet steel is fabricated and put through a cleaning and pickling process which prepares the surface for enamelling. Sheet-steel enamelling requires a ground coat containing a small percentage of cobalt to give it adherence. This ground coat is applied by the wet process, dried and then fired in a furnace at about 830° C. After the ware has been removed from the furnace and cooled, a second coat of cover enamel is applied by the wet process. This cover coat may be of any desired colour and may have special properties depending upon the use to which the ware is to be put. It is commonly sprayed or dipped onto the ware, allowed to dry and then fired at about 830° C. Additional coats of enamel are sometimes applied, and finally the decoration is applied and fired into the last coat. Although enamelling is an important industry in most countries, the use of automatic equipment, technical control and mass production is outstanding in the United States.

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PORCH, originally a roofed structure, usually open at the sides, to protect the entrance of a building; loosely used of any projecting portico, or even of any colonnade and, in the United States, of any roofed structure open at the sides and front, attached to a house or other building; synonymous with veranda or piazza. Thus, a sleeping porch is such a structure usually opening from an upper story, arranged for sleeping in the open air.

Of the porch proper there are few extant remains prior to the classic period, although Egyptian wall paintings seem to indicate their occasional use with houses. The most important Greek porches are those of the Tower of the Winds at Athens (1st century B.C.), in which two columns of a simple Corinthian order carried a pediment. A similar porch exists in the so-called villa of Diomed at Pompeii. Houses in Rome sometimes had long colonnades facing the street which served as porches. During the Romanesque period simple projecting porches covering the western doors of churches gradually replaced the earlier basilican colonnaded narthices. Especially interesting are the projecting porches of the Italian Romanesque, such as are found in Zeno Maggiore at Verona (12th century), in which the columns are carried on marble lions (as frequently in Lombard work) and at Modena (12th century) and Parma (13th century). In Apulia there are many similar porches of distinct Lombard character.

In France, especially in Burgundy, an even greater development of the porch occurred, in which it became a vaulted structure of great height and importance, two or more bays long and sometimes as wide as the entire church. The great porch of the abbey church at Vezelay (1132–40), sometimes termed an antechurch, is the largest and richest. In Norman work in England church porches are more frequently at the sides of the nave than at the west end. An interesting example is that at Southwell minster (early 12th century).

The English love of picturesqueness sometimes developed the porch to such an extent that it became almost a separate building which was called a "galilee," like that at Durham (1175). Galilees in mediaeval churches are supposed to have been used sometimes as a court of law, or a place where corpses were placed before interment, but the galilee probably served chiefly as a chapel for penitents before their admission to the body of the church. Many fantastically rich projecting porches occur in French Flamboyant churches, such as that of the church of Notre Dame at Alençon (*c.* 1500), the pentagonal porch of S. Maclou at Rouen (*c.* 1520) and the little side entrance of the cathedral at Albi (early 16th century).

The same richness of porch design is not found in English Gothic churches, where western doors are often small and unimportant; an exception, all the more remarkable for its unique character, is the west front of Peterborough cathedral (*c.* 1220), in which the doors are deeply recessed within great arches, 81 ft. high, forming a most impressive porch. The other type of porch, the small projecting gabled feature projecting from the north or south walls of the nave, was, however, highly developed throughout the course of English Gothic. In small examples, in parish churches, the porches are usually of wood, with a richly decorated bargeboard, running up the gable, and often panels of intricate tracery at the sides. In the larger city churches there was frequently a room over the porch, sometimes known as a porch chamber and sometimes incorrectly termed a parvis. These seem to have been used sometimes as vestries, sometimes as treasuries and sometimes as chantry chapels. Similar porches, with chambers above, occur occasionally in Tudor mansions, as in the house of Compton Winyates (*c.* 1520).

In Germany churches of the Flamboyant Gothic period are frequently decorated with western porches of the most fantastic richness, with a great use of cusping, pierced tracery and canopy

work. Such is the double-arched entrance of the cathedral at Ulm (*c.* 1390), by Ulrich von Ensingen, and the triangular porch of the cathedral at Regensburg, by M. Roritzer (1482–86).

During the Renaissance the porch was usually treated as a portico (*q.v.*), but simple porches of two or four columns were exceedingly common features of the late 18th-century houses of England and the United States. (T. F. H.)

PORCUPINE, the name of the largest European terrestrial rodent, distinguished by the spiny covering from which it takes its name. The European porcupine (*Hystrix cristata*) is the typical representative of a family of old world rodents, the Hystricidae, all the members of which have the same protective covering. They range over the south of Europe, the whole of Africa, India and the Malay Archipelago as far east as Borneo. They are all stout, heavily built animals, with blunt rounded heads, fleshy mobile snouts and coats of thick cylindrical or flattened spines, which form the whole covering of their body and are not intermingled with ordinary hairs. Their habits are strictly terrestrial. The common porcupine, which occurs throughout the south of Europe and North and West Africa, is replaced in South Africa by *H. africaeaustralis* and in India by the hairy-nosed porcupine (*H. leucura*).

BY COURTESY OF THE LONDON ZOOLOGICAL SOCIETY

CRESTED PORCUPINE (HYSTRIX CRISTATA)

There are several smaller species with long tails in northeast India, the Malay region and Africa. In the new world the porcupines are represented by the family Erethizontidae. The spines are mixed with long soft hairs. They are less nocturnal in their habits, and with one exception live entirely in trees; certain of the species accordingly have long prehensile tails. They include three genera, of which the first is represented by the Canadian porcupine (*Erethizon dorsatum*), a stout, heavily-built animal, with long hairs almost or quite hiding its spines, four front and five hind toes and a short, stumpy tail. It is a native of the greater part of Canada and the United States, wherever there is any remnant of the original forest left. *Coendou* contains some eight or ten species, known as tree porcupines, found throughout tropical South America, with one extending into Mexico. They are of a lighter build than the ground porcupines, with short, close spines, often mixed with hairs, and prehensile tails. The hind feet have only four toes, owing to the suppression of the first.

PORDENONE, IL (1483–1539), Italian painter of the Venetian school. He was born at Corticelli, near Pordenone, in Friuli. His real name was Giovanni Antonio de Sacchi. Vasari's statement that his family name was Licinio has been disproved. In 1535 King John of Hungary knighted him, and thenceforth he called himself Regillo. Il Pordenone was a pupil of Pellegrino di S. Daniele, of the Friulian school of painting, but the leading influence which formed his style was that of Giorgione, and in his early works, such as his fine altarpiece at Susegana and the frescoes in the Palace chapel of S. Salvatore, this influence is very apparent. His later work displays the influence of Correggio and Michelangelo. He executed many works at Pordenone, Spilimbergo, and elsewhere in Friuli. He worked in Treviso, Mantua, Genoa and Cremona. He was asked to execute large mural designs in Venetian palaces, and was so popular in Venice that he seems to have fancied himself the equal of Titian. On one occasion the senate gave him a commission in preference to the great master of Cadore. Unfortunately, his fresco work in Venice has perished. In 1529 he worked in Piacenza, where is one of his most celebrated pictures "St. Catherine disputing with the Doctors of Alexandria." By Hercules II. of Ferrara he was commissioned to execute a series of designs for tapestry illustrating the *Odyssey*. These were described in detail by Ridolfi but are no longer extant. That duke invited him to Ferrara, in 1538, to execute some work in perspective, but Pordenone died there soon after his arrival and was buried on Jan. 14, 1539. Of his pictures in the Venetian academy "The Glory of S. Lorenzo Giustiniani" is the most notable.

See C. Ridolfi, *Le Meraviglie dell' Arte* (edit. v. Hadeln, 1914–24).

PORDENONE, a town of the province of Udine, Venetia, Italy, 30 m. W. by S. of Udine on the railway to Treviso. Pop. (1936) 12,179 (town); 22,174 (commune). It was the birthplace of the painter generally known as Il Pordenone (*q.v.*). Paintings from his brush adorn the cathedral (which has a fine brick campanile), and others are preserved in the Gothic town hall. Cotton industries are active, also silk and pottery.

PORFIRIUS, PUBLILIUS OPTATIANUS, Latin poet, possibly a native of Africa, flourished during the 4th century A.D. He has been identified with Publilius Optatianus, who was *praefectus urbi* (329 and 333), and may have been a Christian. For some reason he had been banished, but having addressed a panegyric to the Emperor Constantine the Great, he was allowed to return. Twenty-eight poems are extant under his name, of which 20 were included in the panegyric. They have no value except as curiosities and specimens of perverted ingenuity. Some of them are squares, others represent in their shape a syrinx, an organ or an altar; while the 28th poem (the *versus anacyclici*) may be read backwards without any effect upon sense or metre. The best edition of the poem is by L. Müller (1877).

See O. Seeck, "Das Leben des Dichters Porphyrius," *Rhein. Mus.* (1908).

PORI, formerly Björneborg, a seaport of Finland in 61° 29′ N., 21° 43′ E., on the Kumo river, 18 mi. from its harbours, Reposaari and Mäntyluoto. Pop. (1940 census) 22,661. It imports coal, coke and flour, and exports timber and timber products. The river is 9 ft. deep. The town has ship-repairing yards, but vessels larger than 300 or 400 tons have to be careened. Reposaari, the "town harbour," used only for local traffic, is usually icebound from December to March. Mäntyluoto is the new harbour, equipped with cranes, railroad tracks and quays for five large steamers, being ice-free until January.

PORIFERA, a phylum and class of the animal kingdom comprising the sponges (*q.v.*).

PORISM. *Porisms* is the title of a lost treatise by Euclid, the author of the *Elements,* for our knowledge of which we are indebted to the *Collection* of Pappus of Alexandria, who mentions it and gives a number of lemmas necessary for understanding it. Pappus states that the porisms of Euclid are neither theorems nor problems, but are in some sort intermediate; and they were regarded accordingly by many geometers, who looked merely at the form of the enunciation, as being actually theorems or problems, though the definitions given by the older writers showed that they better understood the distinction between the three classes of propositions. They regarded a theorem as directed to *proving* what is proposed, a problem as directed to *constructing* what is proposed and finally a porism as directed to *finding* what is proposed (*εἰς πορισμὸν αὐτοῦ τοῦ προτεινομένου*). Pappus goes on to say that this last definition was changed by certain later geometers, who defined a porism on the ground of an accidental characteristic as *τὸ λεῖπον ὑποθέσει τοπικοῦ θεωρήματος*, that which falls short of a locus-theorem by a (or in its) hypothesis.

Proclus points out that the word was used in two senses. One sense is that of *corollary,* a result unsought, but seen to follow from a theorem. On the *porism* in the other sense he adds nothing to the definition of the older geometers except to say that the finding of the centre of a circle and the finding of the greatest common measure are porisms (Proclus, ed. Friedlein, p. 301).

Pappus gives a complete enunciation of a porism derived from Euclid, and an extension of it to a more general case. This porism, expressed in modern language, asserts that—given four straight lines of which three turn about the points in which they meet the fourth, if two of the points of intersection of the three lines lie each on a fixed straight line, the remaining point of intersection will also lie on another straight line. The general enunciation applies to any number of straight lines, say $(n+1)$, of which n can turn about as many points fixed on the $(n+1)$th. These n straight lines cut, two and two, in $\frac{1}{2}n(n-1)$ points, $\frac{1}{2}n(n-1)$ being a triangular number whose side is $(n-1)$. If, then, they are made to turn about the n fixed points so that any $(n-1)$ of their $\frac{1}{2}n(n-1)$

points of intersection, chosen subject to a certain limitation, lie on $(n-1)$ given fixed straight lines, then each of the remaining points of intersection, $\frac{1}{2}(n-1)(n-2)$ in number, describes a straight line. Pappus gives also a complete enunciation of one porism of the first book of Euclid's treatise. This may be expressed thus: If about two fixed points P, Q we make turn two straight lines meeting on a given straight line L, and if one of them cut off a segment AM from a fixed straight line AX, given in position, we can determine another fixed straight line BY, and a point B fixed on it, such that the segment BM′ made by the second moving line on this second fixed line measured from B has a given ratio λ to the first segment AM. The rest of the enunciations given by Pappus are incomplete, and he merely says that he gives thirty-eight lemmas for the three books of porisms; and that these include 171 theorems.

The lemmas which Pappus gives in connection with the porisms are interesting historically, because he gives (1) the fundamental theorem that the cross or anharmonic ratio of a pencil of four straight lines meeting in a point is constant for all transversals; (2) the proof of the harmonic properties of a complete quadrilateral; (3) the theorem that, if the six vertices of a hexagon lie three and three on two straight lines, the three points of concourse of opposite sides lie on a straight line.

During the last three centuries many geometers have attempted to restore the lost porisms. The geometer P. de Fermat (1601–65) wrote a short work under the title *Porismatum euclidaeorum renovata doctrina et sub forma isagoges recentioribus geometris exhibita* (see *Oeuvres de Fermat*, i., 1891); but two at least of the five examples of porisms which he gives do not fall within the classes indicated by Pappus. Robert Simson was the first to throw real light upon the subject. He first succeeded in explaining the only three propositions which Pappus indicates with any completeness (*Phil. Trans.*, 1723). Later he investigated the subject of porisms generally in a work entitled *De porismatibus tractatus; quo doctrinam porismatum satis explicatam, et in posterum ab oblivione tutam fore sperat auctor*, and published after his death in a volume, *Roberti Simson opera quaedam reliqua* (Glasgow, 1776). Simson's treatise, *De porismatibus*, begins with definitions of theorem, problem, datum, porism and locus.

Respecting the porism Simson says that Pappus's definition is too general, and therefore he will substitute for it the following: "Porisma est propositio in qua proponitur demonstrare rem aliquam vel plures datas esse, cui vel quibus, ut et cuilibet ex rebus innumeris non quidem datis, sed quae ad ea quae data sunt eandem habent relationem, convenire ostendendum est affectionem quandam communem in propositione descriptam. Porisma etiam in forma problematis enuntiari potest, si nimirum ea quae data demonstranda sunt, invenienda proponantur." A locus (says Simson) is a species of porism. Then follows a Latin translation of Pappus's note on the porisms, and the propositions which form the bulk of the treatise. These are Pappus's thirty-eight lemmas relating to the porisms, ten cases of the proposition concerning four straight lines, twenty-nine porisms, two problems in illustration and some preliminary lemmas.

John Playfair's memoir (*Trans. Roy. Soc. Edin.*, 1794), a sort of sequel to Simson's treatise, had for its special object the inquiry into the probable origin of porisms. Playfair remarked that the careful investigation of all possible particular cases of a proposition would show that (1) under certain conditions a problem becomes impossible, (2) under certain other conditions, indeterminate or capable of an infinite number of solutions. These cases could be enunciated separately, were in a manner intermediate between theorems and problems and were called "porisms." Playfair accordingly defined a porism thus: "A proposition affirming the possibility of finding such conditions as will render a certain problem indeterminate or capable of innumerable solutions." Though this definition of a porism appears to be most favoured in England, Simson's view has been most generally accepted abroad, and has the support of the great authority of Michel Chasles.

In *Liouville's Journal de mathématiques pures et appliquées* (1855), P. Breton published *Recherches nouvelles sur les porismes d'Euclide*, in which he gave a new translation of the text of Pappus, and sought to base thereon a view of the nature of a porism more closely conforming to the definitions in Pappus. This was followed in the same journal and in *La Science* by a controversy between Breton and A. J. H. Vincent, who disputed the interpretation given by the former of the text of Pappus, and declared himself in favour of the idea of F. van Schooten, put forward in his *Mathematicae exercitationes* (1657), in which he gives the name of "porism" to one section. According to Schooten, if the various relations between straight lines in a figure are written down in the form of equations or proportions, then the combination of these equations in all possible ways, and of new equations thus derived from them, leads to the discovery of innumerable new properties of the figure, and here we have porisms. These discussions, however, did not carry forward the work of restoring Euclid's *Porisms*, which was left for Chasles. His work (*Les Trois livres de porismes d'Euclide*, 1860) makes full use of all the material found in Pappus, but we may doubt its being a successful reproduction of Euclid's actual work. An interesting hypothesis as to the *Porisms* was put forward by H. G. Zeuthen (*Die Lehre von den Kegelschnitten im Altertum*, 1886). Observing, *e.g.*, that the intercept-Porism is still true if the two fixed points are points on a conic, and the straight lines drawn through them intersect on the conic instead of on a fixed straight line, Zeuthen conjectures that the *Porisms* were a by-product of a fully developed projective geometry of conics. It is a fact that Pappus's Lemma 31 (though it makes no mention of a conic) corresponds exactly to Apollonius's method of determining the foci of a central conic (*Conics*, iii. 45–47 with 42).

The three porisms stated by Diophantus in his *Arithmetica* are propositions in the theory of numbers which can all be enunciated in the form "*we can find* numbers satisfying such and such conditions"; they are sufficiently analogous therefore to the geometrical porism as defined in Pappus and Proclus.

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(T. L. H.)

PORK. Pork is the flesh of the domestic pig used for food. It is the most popular meat in the American dietary, probably because its cost is usually lower than that of other meats and because of the variety of ways in which it can be used. Pork is used both fresh and cured. Because of its high fat content, pork is an energy food. The lean of pork is a good source of high-quality protein, phosphorus and iron. Pork is rich in vitamin B_1 or thiamin. Pork liver is one of the best sources of food iron.

Pigs are among the most efficient converters of grain and by-product feeds to fat. The majority of pigs are marketed during the winter and spring months. Since the major portion of the pork carcass is processed by curing, the marketing of pork products may be spread out over the entire year. Most pigs are marketed at 6 to 12 months of age and at weights ranging from 185 to 250 lb. Pigs are usually dressed packer style; *i.e.*, head off, leaf lard and ham facings off and centre split. The average dressing yield is 69%.

Soft Pork.—The flesh of immature pigs and also that from pigs which have been fed feeds high in soft fats, is likely to be soft. Such pork does not firm up on chilling, is unattractive and, therefore, is discriminated against by consumers. Soybeans, peanuts, rice polish and mast, when used extensively, produce soft pork. The nutritive value of soft pork is as high as firm pork.

Pork carcasses are classified as butcher, packing and bacon hogs. Butcher carcasses are smooth, high-quality, well-finished carcasses suitable for choice, fresh and cured cuts. Packer hogs are usually coarse, low-grade, under- or over-finished carcasses which must be used for lower-priced products. A considerable number of sows which have been discarded from the breeding herds gravitate into this class. Bacon carcasses are light in weight, moderately finished and suitable for making Wiltshire

sides (*see* BACON) or choice breakfast bellies.

Grades of pork carcasses and cuts are fewer in number than of beef and lamb. This is due to the fact that most pigs are slaughtered when they are relatively young and nearly all pigs are well-fattened at slaughter time. Consequently, there is less difference between grades. Grades are frequently designated numerically, No. 1, No. 2, No. 3 and cull; or choice, good, medium and cull.

The ideal pork carcass should be compact, straight-sided and thick-fleshed. The shanks should be short and the ham plump and the loin thickly-fleshed. The belly or bacon should be deep, long and smooth. The shoulder should be compact and should blend into the body smoothly.

A choice carcass should be well but not excessively fattened. The fat down the back should be about 1½ in. thick, although there will be some variation with different classes and weights of carcasses. Both excessive or deficient fat will cause a lowering of grade. The fat down the back should be uniform in thickness, firm, white and flaky, not rubbery.

Quality in a pork carcass is indicated by a thin, white skin free from wrinkles; fine joints and shanks. The lean should be a bright pink and fine-textured.

The most sought-after cuts of pork are ham, loin and belly or bacon. Hams are usually cured and may be sold regular (skin on), skinned, or boned. The loin is usually sold fresh, being used for roasts and chops. Heavy loins are sometimes boned out after the tenderloins are removed. The boneless loin strips are cured and smoked as Canadian style bacon.

The entire shoulder is called a long-cut or New York style shoulder which is used as a fresh cut. Many shoulders are cut in two, the lower half usually being cured as a picnic shoulder. The upper half has the layer of fat (clear plate) removed after which it is designated a Boston style of butt which is used for roasts and steaks. Sometimes the blade bone also is removed from the butt in which case the butt is known as a boneless butt. Boneless butts are usually cured and smoked.

The fat back, the covering over the loin, if more than 1¼ in. thick, may be cured in dry salt. If less than 1¼ in. thick, it is skinned and rendered for lard. The fatty covering over the shoulder is cured if sufficiently thick. The jowl or cheek also may be cured and smoked.

The belly or bacon if of choice quality, may be cured and smoked. Low-grade bellies are used for dry salt meats.

To a large degree, weight determines dollar-and-cents values of pork cuts. Within certain limits, the lighter-weight cuts are preferred because of their leanness.

The major portion of the pork carcass may be cured or processed. The proportion actually cured will depend upon price differentials between cured and fresh cuts. Pork trimmings are used for a wide variety of sausages and lunch meats. The fat of the pig is rendered into lard which is one of the most popular culinary fats. It is almost completely digestible, has a wide plastic range and produces very tender, flaky pastry. Lard is manufactured by three methods; kettle rendered, steam rendered and dry rendered. The best lard is made by the kettle-rendered process in which the hashed lard is cooked in an open kettle with constant stirring. Most of the commercial lard is made by the prime steam method whereby the stock is cooked in a tank by steam under pressure and in direct contact with the lard. Refined lard is prime steam lard which has been bleached either with Fuller's earth or activated charcoal. Sometimes lard stock is hashed and rendered in a steam-jacketed cooker. This is known as dry rendering. About 13% of the live weight of a pig is lard.

Pork Cookery.—Since pork muscle is sometimes infested with the larvae of the parasite Trichina (*Trichinella spiralis*) it is imperative that pork should always be thoroughly cooked.

Fresh pork may be roasted by cooking in an uncovered pan in an oven at 350° F. The term baking is more frequently applied where cured cuts are prepared in an oven. It is recognized that moist heat (braising) is faster and more thorough in the penetration, therefore, most pork roasts are browned and then cooked in a covered roaster. Cured cuts are frequently cooked in a covered utensil with a small amount of liquid or entirely immersed in liquid (simmering). A ham cooked by the latter method is frequently called a "boiled" ham, although the cooking should be done below the boiling point for best quality of product. Pork chops or steaks are usually browned in a hot skillet, after which the cooking is completed in a covered utensil either with or without added liquid.

Pork By-products.—The by-products of hog slaughter are less valuable proportionately than those of cattle or sheep. Aside from sausage and lard, there are edible offal such as livers, hearts, tongues, brains, pork feet, ears, lips, snouts, tails and chitterlings (made from the large intestine). Pigskin is a light but durable leather suitable for gloves, insoles and novelties. Some pigskin is used for gelatin manufacture. Hog casings are used for sausage. Pig stomachs are used for sausage containers and are a source of pepsin. Some of the glands are used in making pharmaceutical preparations. Pork fat not suitable for edible use is designated as grease. It is used for soapmaking and other industrial uses. Animal feeds are made from residues not suitable for human food. Hog hair is used for upholstery and insulation. (For diagram of cuts of pork *see* COOKERY.)

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POROS or PORO ("the Ford"), Greece, an island off the east coast of the Morea, separated at its western end by a narrow channel from the mainland at Troezen, and consisting of masses of limestone and trachyte connected by a sandy isthmus. The harbour town faces S. toward the mainland. The English, French, and Russian plenipotentiaries met at Poros in 1828 to discuss the basis of the Greek government.

The ancient Calauria, with which Poros is identified, was traditionally given by Apollo to Poseidon in exchange for Delos; and in historic times was famous for a temple of the latter, the centre of an amphictyony of maritime states—Hermione, Epidaurus, Aegina, Athens, Prasiae, Nauplia, and Orchomenus, the distribution and legends of which suggest that their association goes back to Minoan times. Here Demosthenes took sanctuary with "gracious Poseidon," and, when this threatened to fail him, sought death. The temple of Doric architecture, excavated in 1894, lay on a ridge commanding a view of Athens and the Saronic gulf. Traces also of porticoes and other buildings remain.

See Chandler, *Travels;* Leake, *Morea;* Le Bas, *Voyage archéologique;* Curtius, *Peloponnesos;* Pouillon-Boblaye, *Recherches;* Bursian, *Geographie von Griechenland;* Rangabé "Ein Ausflug nach Poros," in *Deutsche Revue* (1883); and S. Wide, in *Mitteilungen d. deutsch. Inst. Athen.* (1895), vol. xx.

PORPHYRIO, POMPONIUS, Latin grammarian and commentator on Horace, possibly a native of Africa, flourished during the 2nd century A.D. (according to others, much later). His *scholia* on Horace, which are still extant, mainly consist of rhetorical and grammatical explanations. It is probable that the *scholia* have been much altered by copyists.

See edition of the *Scholia* by A. Holder (1894). *See* also C. F. Urba, *Meletemata porphyrionea* (1885); E. Schweikert, *De Porphyrionis . . . scholiis Horatianis* (1865); F. Pauly, *Quaestiones criticae de . . . Porphyrionis commentariis Horatianis* (1858).

PORPHYRY (Πορφύριος) (A.D. 233–*c.* 304), Greek scholar, historian, and Neoplatonist, was born at Tyre, or Batanaea in Syria. He studied grammar and rhetoric under Cassius Longinus (*q.v.*). His original name was Malchus (king), which was changed by his tutor into Porphyrius (clad in purple), a jesting allusion to the colour of the imperial robes. In 262 he went to Rome, attracted by the reputation of Plotinus, and for six years devoted himself to the study of Neoplatonism. Having injured his health by overwork, he went to live in Sicily for five years. On his return to Rome, he lectured on philosophy and endeavoured to render the doctrines of Plotinus intelligible to the ordinary understanding. His most distinguished pupil was Iamblichus. When advanced in years he married Marcella, a widow with seven children and an enthusiastic student of philosophy. Nothing more is known of his life, and the date of his death is uncertain.

Of his numerous works on a great variety of subjects the fol-

lowing are extant: *Life of Plotinus* and an exposition of his teaching in the Ἀφορμαὶ πρὸς τὰ νοητά (*Sententiae ad intelligibilia ducentes*, Aids to the study of the Intelligibles). The *Life of Pythagoras*, which is incomplete, probably formed part of a larger history of philosophy down to Plato. His work on Aristotle is represented by the *Introduction* (εἰσαγωγή) to and *Commentary* (ἐξήγησις, in the form of questions and answers) on the *Categories*. The first, translated into Latin by Boëtius, was extensively used in the middle ages as a compendium of Aristotelian logic; of the second only fragments have been preserved. His Χρονικά, a chronological work, extended from the taking of Troy down to A.D. 270.

Other grammatical and literary works are Ὁμηρικὰ ζητήματα (*Quaestiones homericae*); and *De antro nympharum*, in which the description in the *Odyssey* (xiii, 102–112) is explained as an allegory of the universe. The Περὶ ἀποχῆς ἐμψύχων (*De abstinentia*), on abstinence from animal food, is especially valuable as having preserved numerous original statements of the old philosophers and the essence of Theophrastus' Περὶ εὐσεβειας (*On Piety*). It also contains a long fragment from the *Cretans* of Euripides. The Πρὸς Μαρκέλλαν is an exhortation to his wife Marcella to practise virtue and self-restraint and to study philosophy. The letter to the Egyptian priest Anebo, dealing with religious questions, was answered by a member of the school of Iamblichus, who called himself Abammon, in the *De mysteriis*. It is frequently referred to by Eusebius, Cyril and Augustine. Eusebius preserved fragments of the Περὶ τῆς ἐκ λογίων φιλοσοφίας (*De philosophia ex oraculis haurienda*), in which he expressed his belief in the responses of the oracles of various gods as confirming his theosophical views.

Porphyry is well known as a violent opponent of Christianity and defender of Paganism; of his Κατὰ Χριστιανῶν (*Adversus Christianos*) in 15 books, perhaps the most important of all his works, only fragments remain. Porphyry's view of the book of Daniel, that it was the work of a writer in the time of Antiochus Epiphanes, is given by Jerome. There is no proof of the assertion of Socrates, the ecclesiastical historian, and Augustine, that Porphyry was once a Christian.

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On Porphyry and his works generally, *see* J. A. Fabricius, *Bibliotheca Graeca* (edit. Hailes, 1790–1809); article in *Suidas* (edit. G. Bernhardy, 1853); Eurapius, *Lives of the Philosophers* (with Eng. trans. by W. C. Wright, 1922); Lucas Holstenius, *De vita et Scriptis Porphyrii* (Cambridge, 1655); M. N. Bouillet, *Porphyre, son rôle dans l'école neoplatonicienne* (1864); A. I. Kleffner, *Porphyrius der Neuplatoniker* (Paderborn, 1896); W. Christ, *Geschichte der griechischen Litteratur* (1898); J. E. Sandys, *History of Classical Scholarship* (1906); J. Bidey, *Vie de Porphyre* (Ghent, 1913). *See* also C. P. Mason in W. Smith, *Dict. of Greek and Roman Biography* (1849), and for philosophy, T. Whittaker, *The Neo-Platonists* (2nd ed., 1918) and NEOPLATONISM.

PORPHYRY, in petrology, a beautiful red volcanic rock (Gr. πορφύρεος, Lat. *purpureus*, purple), which was much used by the Romans for ornamental purposes when cut and polished. The famous red porphyry (*porfido rosso antico*) came from Egypt, but its beauty and decorative value were first recognized by the Romans in the time of the emperor Claudius. It was obtained on the W. coast of the Red sea, where it forms a dike 80 or 90 ft. thick. For a long time the knowledge of its source was lost, but the original locality has been rediscovered at Jebel Dhokan, and the stone is again an article of commerce. In a dark red groundmass it contains many small white or rose-red plagioclase felspars, black shining prisms of hornblende, and small plates of iron oxide. The red of the felspars and of the groundmass is unusual in rocks of this group, and arises from the partial conversion of the plagioclase felspar into thulite and manganese epidote. These minerals also occur in thin veins crossing the rock. Many specimens show effects of crushing and in extreme cases this has produced brecciation.

Many igneous rocks possess the scattered crystals of larger size in a fine-grained groundmass which characterize the porphyries (*see* PETROLOGY), and most lavas and many of the rocks which occur as dikes and sills have porphyritic structure. The use of the term porphyry is now restricted to a series of rocks which are of intrusive origin and contain much porphyritic felspar (with or without quartz or nepheline). The porphyritic intrusive rocks with large crystals of augite, olivine, biotite and hornblende are for the most part grouped under the lamprophyres. Furthermore, it has become usual to subdivide the porphyries into two classes; in one of these the phenocrysts are mainly orthoclase, in the other mainly plagioclase felspar. The first series is known as the "porphyries," the second as the "porphyrites." There are porphyries which correspond chemically and mineralogically to granites, syenites and nepheline-syenites; while the porphyrites form a series parallel to the diorites, norites and gabbros. In each case the porphyritic type occurs generally as dikes and thin sheets which consolidated beneath the surface but probably at no great depth (hypabyssal rocks).

The principal subdivisions of the group are the granite porphyries, the syenite-porphyries and the elaeolite-porphyries. In all of them porphyritic orthoclase or alkali felspar is the characteristic mineral. The granite porphyries and quartz porphyries consist mainly of orthoclase, quartz and ferromagnesian mineral, usually biotite but sometimes hornblende, augite or enstatite. Granite porphyries are exceedingly common in all regions where acid intrusive rocks occur. Many granite masses are surrounded by dikes of this kind, and in some cases the chilled margin of a granite consists of typical porphyry.

The syenite-porphyries, like the syenites, are less common than the granite porphyries and granites. They are characterized by an abundance of orthoclase and a scarcity or absence of quartz. The phenocrysts are orthoclase (and oligoclase), biotite, hornblende or augite; the groundmass is principally alkali felspar with sometimes a little quartz. In many specimens the felspars of the second generation form a mosaic of ill-shaped grains, in others they are little rectangular crystals which may have a fluxion arrangement (orthophyric type of groundmass). Some of the rocks formerly known as orthoclase-porphyries belong to this group; others are ancient trachytic lavas (orthophyres). Closely related to the syenite-porphyries is the rhomb-porphyry of south Norway and East Africa. In these the large felspars have rhomb-shaped sections owing to their peculiar crystalline development. Olivine, augite and biotite occur in these rocks, but there is no quartz or soda-lime felspar. The porphyritic felspars contain both soda and potash and belong to anorthoclase. Rhomb-porphyries occur as dikes connected with the syenites (laurvikites of southern Norway), and many ice-borne boulders of these rocks have been found among the drift deposits of the east of England.

Elaeolite- and leucite- (syenite) porphyries form apophyses and dikes around nepheline- and leucite-syenite intrusions. The former contain porphyritic nepheline which is often weathered to soft, finely crystalline aggregates of white mica and other secondary products, as in the well-known liebenerite-porphyry of Tirol and gieseckite-porphyry of Greenland. The felspars of these rocks are albite, orthoclase and anorthoclase and they often contain soda augite and amphiboles. Elaeolite-porphyries occur along with nepheline-syenites in such districts as the Serra de Monchique, south Norway, Kola, Montreal. Allied to them are the tinguaites (so called from the Serra de Tingua, Brazil), which are pale-green rocks with abundant alkali felspar, nepheline, needles of green aegirine, and sometimes biotite and cancrinite. As a rule, however, these are not porphyritic. Grorudites are

quartz-tinguaites free from nepheline, and sölvsbergites are tinguaitic rocks in which neither quartz nor nepheline occur. The two last have been described from the Oslo district in Norway, but tinguaites are known with nepheline-syenites in many parts of the world, *e.g.*, Norway, Brazil, Portugal, Canada, Sweden, Greenland.

The following analyses of porphyries of different types show the chemical composition of a few selected examples:—

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	K_2O	Na_2O	H_2O
I	72.51	13.31	tr.	3.87	1.50	0.60	6.65	0.43	0.60
II	67.18	16.65	0.55	2.15	1.54	2.35	2.91	4.03	0.75
III	71.60	13.60	2.40	..	0.21	2.30	3.53	5.55	0.70
IV	58.82	21.06	3.26	0.70	1.38	3.03	3.70	6.83	1.26
V	45.18	23.31	6.11		1.45	4.62	11.16	5.94	1.14
VI	54.46	19.96	2.34	3.33	0.61	2.12	8.68	2.76	5.20
VII	75.20	12.65	1.53	0.28	0.26	0.60	4.14	5.67	0.12

I, Elvan or granite porphyry (with pinite after cordierite)—Prah Sands, Cornwall. II, Granophyre—Armboth, Cumberland. III, Granophyre—Carrock Fell, Cumberland. IV, Rhomb-porphyry—Tönsberg, Norway. V, Elaeolite-porphyry—Beemerville, New Jersey. VI, Tinguaite—Kola. VII, Grorudite—Assynt, Scotland.

Porphyrites.—The porphyrites as above mentioned are intrusive or hypabyssal rocks of porphyritic texture, with phenocrysts of plagioclase felspar and hornblende, biotite or augite (sometimes also quartz) in a fine groundmass. The name has not always been used in this sense, but formerly signified rather decomposed andesitic and basaltic lavas of Carboniferous age and older. Both the red and green porphyry of the ancients are more properly classified in this group than with the granite porphyries, as their dominant felspar is plagioclase and they contain little or no primary quartz. Porphyrites occur as dikes which accompany masses of diorite, and are often called diorite-porphyrites; they differ from diorites in few respects except their porphyritic structure. The phenocrysts are plagioclase, often much zoned, with central kernels of bytownite or labradorite and margins of oligoclase or even orthoclase. In a special group there are corroded blebs of porphyritic quartz: these are called quartz porphyrites, and are distinguished from the granite porphyries by the scarcity or absence of orthoclase. The hornblende of the porphyrites is often green but sometimes brown, resembling that of the lamprophyres, a group from which the porphyrites are separated by their containing phenocrysts of felspar, which do not occur in normal lamprophyres. Augite, when present, is nearly always pale green; it is not so abundant as hornblende. Dark brown biotite is very common in large hexagonal plates. The groundmass is usually a crystalline aggregate of granular felspar in which plagioclase dominates, though orthoclase is rarely absent. Diorite-porphyrites have almost as wide a distribution as granite porphyries, and occur in all parts of the world where intrusions of granite and diorite have been injected; they are in fact among the commonest hypabyssal rocks.

To gabbros and norites certain types of porphyrite correspond which have the same mineral and chemical composition as the parent rocks but with a porphyritic instead of granitic structure. Norite-porphyrites have porphyritic plagioclase (labradorite usually) with hypersthene or bronzite, often altered to bastite. They accompany norite masses in Nahe (Prussia) and Tirol.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	H_2O
I	64.94	17.50	0.69	3.94	2.59	2.83	3.11	3.44	1.36
II	61.58	18.84	4.68	..	6.59	2.04	1.49	4.27	1.61
III	56.85	16.70	5.92	7.13	5.97	3.25	1.91	2.78	0.54

I, Quartz-porphyrite—Lippenhof, Schwarzwald. II, Porphyrite—Esterel, France. III, Norite-porphyrite—Klausen, Tirol. (J. S. F.)

PORPOISE, the name often applied to all the smaller cetaceans, but properly restricted to the genus *Phocoena*. The porpoise attains a length of 5½ ft. The head is rounded in front, lacking the characteristic beak of the dolphins, and the underjaw projects slightly. The wide mouth is bounded by stiff, immobile lips. The low dorsal fin is triangular. In colour the porpoise is black or dark gray above and white below, with black flippers. The shape of the porpoise's teeth is characteristic. The porpoise prefers bays, estuaries and coasts to the open sea and inhabits the North Atlantic, entering the Baltic in summer; but it is rare in the Mediterranean. It feeds on salmon, mackerel, pilchards and herrings. In former days it was a common article of food. The "porpoise hide" of commerce is now obtained largely from the beluga (*q.v.*). A second species, which may, however, be merely a variety, inhabits the Black sea; one or, more probably, two other species inhabit the La Plata region. The Pacific porpoise is now placed in a separate genus. The allied *Neomeris phocoenoides* from the Indian ocean and Japan has no dorsal fin. (*See* CETACEA.)

BY COURTESY OF THE N.Y. ZOOLOGICAL SOCIETY
THE COMMON PORPOISE (PHOCOENA PHOCOENA)

Porpoise oil, obtained from the soft fat of the head and jaw of the common porpoise has recently come into general use as a lubricant in the manufacture of watches, clocks and other delicate mechanisms made of hard steel. Its value lies chiefly in the fact that it is free from a tendency either to gum or thicken by oxidation or to corrode metal, and in its ability to withstand exposure to very low temperatures without freezing or thickening to any great extent.

PORPORA, NICCOLA [or NICCOLO] **ANTONIO** (1686–1767), Italian operatic composer and teacher of singing, was born in Naples on Aug. 19, 1686. His first opera, *Basilio,* was produced at Naples; his second, *Berenice,* at Rome. Both were successful, and he followed them up by innumerable compositions of like character; but his fame rests chiefly upon his unequalled power of teaching singing. At the Conservatorio di Sant' Onofrio and the Poveri di Gesu Cristo he trained Farinelli, Caffarelli, Mingotti, Salimbeni, and other celebrated vocalists. Unfortunately no written account of his method exists; all that remains is the tradition as handed down by his pupils. In 1725 Porpora visited Vienna, but the Emperor Charles VI disliked his florid style, especially his constant use of the *trillo.* He then settled in Venice, teaching regularly in the schools of La Pietà and the Incurabili. In 1729 he was invited to London as a rival to Handel; but his visit was unfortunate. Little less disastrous was his second visit to England in 1734, when even the presence of his pupil, the great Farinelli, failed to save from ruin the dramatic company of Lincoln's Inn Fields theatre, set up in opposition to that directed by Handel. The sequence of dates and visits in Porpora's life are variously stated by different biographers. The electoral prince of Saxony and king of Poland had invited him to Dresden to become the singing master of the electoral princess, Maria Antonia, and in 1748 he is supposed to have been made *Kapellmeister* to the prince. Difficult relations, however, with Hasse and his wife resulted in his departure, of which the date is not known. From Dresden he is said to have gone to Vienna, where he gave lessons to Joseph Haydn (*q.v.*), and then to have returned some time between 1755 and 1760 to Naples. From this time Porpora's career was a series of misfortunes. His last opera, *Camilla,* failed; and he became so poor that the expenses of his funeral were paid by subscription.

PORRENTRUY (1,400 ft.), a town in the northern or French-speaking part of the canton of Berne, Switzerland, a station on the railways Basle-Delémont Delle and Altkirch-Mulhouse. It has famous schools and is an industrial centre with 2,348 inhabitants the great majority of whom are Roman Catholics. The castle overlooking the town was once the residence of the bishop of Basle. Population of commune (1930) 5,805.

PORRIDGE (an altered form of "pottage," Fr. *potage,* soup, that which is cooked in a pot), a food made by stirring meal, especially oatmeal, in boiling water and cooking it slowly until the whole becomes soft. The dish and its name are particularly identified with Scotland; in Ireland it is commonly known as "stirabout." The former application to a broth made of vegetables or of meat and vegetables thickened with barley or other meal is

obsolete, and the earlier "pottage" is the usual word employed. The form "porridge" apparently dates from the 16th century. In "porringer," a porridge bowl, the *n* is inserted as in "passenger" and "messenger."

PORSENA (or PORSENNA), **LARS,** king of Clusium in Etruria. He is said to have undertaken an expedition against Rome in order to restore the banished Tarquinius Superbus to the throne. He gained possession of the Janiculum, and was prevented from entering Rome only by the bravery of Horatius Cocles (*q.v.*). Porsena then laid siege to the city, but was so struck by the courage of Mucius Scaevola that he made peace on condition that the Romans restored the land they had taken from Veii and gave him 20 hostages. He subsequently returned both the land and the hostages (Livy, ii, 9–15; Dion. Halic., v, 21–34; Plutarch, *Poplicola,* p. 16–19). This story is probably an attempt to conceal a great disaster. According to other authorities, the Romans were obliged to surrender the city, to acknowledge Porsena's supremacy, to abandon their territory north of the Tiber, to give up their arms, and in future to use iron for agricultural purposes only. It is curious that, in spite of his military success, Porsena made no attempt to restore the Tarquinian dynasty. Hence it is suggested that the attack on Rome was merely an incident of the march of the Etruscans, driven southward by the invasion of upper Italy by the Celts, through Latium on their way to Campania. This would account for its transitory effects, and the speedy recovery of the Romans from the blow. With the departure of Porsena all traces of Etruscan sovereignty disappear (*see* Tacitus, *Hist.* iii, 72; Pliny, *Nat. Hist.* xxxiv, 39 [14]; Dion. Halic. v, 35, 36, vii, 5). The tomb at Chiusi described by Pliny (*Nat. Hist.* xxxvi, 19) as that of Porsena cannot have been his burial place (*see* CLUSIUM).

For a critical examination of the story, *see* Schwegler, *Römische Geschichte,* bk. xxi, 18; Sir G. Cornewall Lewis, *Credibility of Early Roman History,* ch. xii, 5; W. Ihne, *Hist. of Rome,* vol. i; E. Pais, *Storia di Roma,* i, ch. iv (1898); Macaulay's *Lays of Ancient Rome* gives a dramatic version of the story.

PORSON, RICHARD (1759–1808), English classical scholar, was born on Dec. 25, 1759, at East Ruston, in Norfolk, of humble parents. After attending the village school, he was entered on the foundation of Eton in 1774, and in 1778, through the generosity of Sir George Baker, the physician, entered Trinity college, Cambridge, of which he became a fellow four years later. The publication of his *Notae breves ad Toupii emendationes in Suidam* in 1790 established his fame as a scholar. During the same year, in the *Gentleman's Magazine,* he wrote the three letters on Hawkins's *Life of Johnson,* which have been reprinted in Kidd's *Tracts and Criticisms of Porson,* and in a volume of Porson's *Correspondence.* They are admirable specimens of his dry humour, and prove his intimate acquaintance with Shakespeare and the other English dramatists and poets. In the same periodical, in the course of 1788 and 1789, the *Letters to Archdeacon Travis, on the spurious verse i. John v. 7* (collected in 1790 into a volume), written in defense of Gibbon, had appeared. In 1792, his fellowship being no longer tenable by a layman, Porson moved to London, but in November of the same year was elected to the Greek professorship at Cambridge. Apart from his duties, the tragedians, Aristophanes, Athenaeus, and the lexicons of Suidas, Hesychius and Photius occupied most of his time.

In 1795 there appeared from Foulis' press at Glasgow an edition of *Aeschylus* in folio, printed with the same types as the Glasgow *Homer,* without a word of preface or anything to give a clue to the editor. Many new readings were inserted in the text with an asterisk affixed, while an obelus was used to mark many others as corrupt. It was at once recognized as Porson's work; he had superintended the printing of a small edition in two volumes 8vo, but this was kept back by the printer and not issued till 1806, still without the editor's name. There are corrections of many more passages in this edition than in the folio; and, though the text cannot be considered as what would have gone forth if with his name and sanction, yet more is done for the text of Aeschylus than had been accomplished by any preceding editor. It formed the substratum for all subsequent editions. It was printed from a copy of Pauw's edition corrected, which is preserved in the library of Trinity college.

Soon after this, in 1797, appeared the first instalment of what was intended to be a complete edition of Euripides—an edition of the *Hecuba.*

In the preface he pointed out the correct method of writing several words previously incorrectly written, and gave some specimens of his powers on the subject of Greek metres. The notes are very short, almost entirely critical; but so great a range of learning, combined with such felicity of emendation whenever a corrupt passage was encountered, is displayed that there was never any doubt as to the quarter whence the new edition had proceeded. He avoided the office of interpreter in his notes, which may well be wondered at on recollecting how admirably he did translate when he condescended to that branch of an editor's duties.

His work, however, did not escape attack; Gilbert Wakefield had already published a *Tragoediarum delectus;* and, conceiving himself to be slighted, as there was no mention of his labours in the new *Hecuba,* he wrote a "diatribe extemporalis" against it, a tract which for bad taste, bad Latin and bad criticism it would not be easy to match. Gottfried Hermann of Leipzig, then a very young man, who had also written a work on Greek metres, which Dr. Peter Elmsley styled "a book of which too much ill cannot easily be said," issued an edition of the *Hecuba,* in which Porson's theories were openly attacked. Porson at first took no notice of either, but went on quietly with his Euripides, publishing the *Orestes* in 1798, the *Phoenissae* in 1799 and the *Medea* in 1801, the last printed at the Cambridge press, and with the editor's name on the title page. But there are many allusions to his antagonists in the notes on such points as the final *v,* the use of accents, etc.; and on v. 675 of the *Medea* he holds up Hermann by name to scorn in caustic and taunting language. And it is more than probable that to Hermann's attack we owe the most perfect of his works, the supplement to the preface to the *Hecuba,* prefixed to the second edition published at Cambridge in 1802.

The metrical laws promulgated are laid down clearly, illustrated with an ample number of examples, and those that militate against them brought together and corrected, so that what had been beyond the reach of the ablest scholars of preceding times is made clear to the tyro. The laws of the iambic metre are fully explained, and the theory of the pause stated and proved, which had been only alluded to in the first edition. A third edition of the *Hecuba* appeared in 1808, and he left corrected copies of the other plays, of which new editions appeared soon after his death; but these four plays were all that was accomplished of the projected edition of the poet. Porson lived six years after the second edition of the *Hecuba* was published, but his natural indolence and procrastination led him to put off the work. He found time, however, to execute his collation of the Harleian ms. of the *Odyssey,* published in the Grenville *Homer* in 1801, and to present to the Society of Antiquaries his wonderful conjectural restoration of the Rosetta stone.

In 1806, when the London institution was founded (then in the Old Jewry, since removed to Finsbury Circus), he was appointed principal librarian with a salary of £200 a year and a suite of rooms; and thus his latter years were made easy as far as money was concerned.

Among his most intimate friends was James Perry, the editor of the *Morning Chronicle;* and this friendship was cemented by his marriage with Perry's sister, Mrs. Lunan, in Nov. 1796. The marriage was a happy one for the short time it lasted, as Porson became more attentive to times and seasons, and would have been weaned from his habits of drinking; but she sank in a decline a few months after her marriage (April 12, 1797), and he returned to his chambers in the Temple and his old habits. Perry's friendship was of great value to him in many ways; but it induced him to spend too much of his time in writing for the *Morning Chronicle;* indeed he was even accused of "giving up to Perry what was meant for mankind," and the existence of some of the papers he wrote there can be only deplored.

For some months before his death he had appeared to be fail-

ing: his memory was not what it had been, and he had some symptoms of intermittent fever; but on Sept. 19, 1808, he was seized in the street with a fit of apoplexy, and after partially recovering died on Sept. 25 at the age of 49. He was buried in Trinity college, close to the statue of Newton, at the opposite end of the chapel to where rest the remains of Richard Bentley.

In learning, Porson was superior to Valckenaer; in accuracy, to Bentley. It must be remembered that in his day the science of comparative philology had scarcely any existence; even the comparative value of mss. was scarcely considered in editing an ancient author. With many editors, mss. were treated as of much the same value, whether they were really from the hand of a trustworthy scribe, or what Bentley calls "scrub manuscripts," or "scoundrel copies."

Thus, if we are to find fault with Porson's way of editing, it is that he does not make sufficient difference between the mss. he uses, or point out the relative value of early copies whether in ms. or print. Thus he collates minutely Lascaris' edition of the *Medea,* mentioning even misprints in the text, rather from its rarity and costliness than from its intrinsic value. And his wonderful quickness at emendation has sometimes led him into error, which greater investigation into mss. would have avoided; thus, in his note on Eur., *Phoem.* 1373 an error, perhaps a misprint (κε for με), in the first edition of the scholiast on Sophocles has led him into an emendation of v. 339 of the *Trachiniae* which clearly will not stand. But his most brilliant emendations, such as some of those on Athenaeus, or on the *Supplices* of Aeschylus are such as to convince the reader of their absolute certainty; and this power was possessed by Porson to a degree no one else had ever attained. No doubt his mathematical training had something to do with this; frequently the process may be seen by which the truth has been reached.

A few words are called for on his general character. No one ever more loved truth for its own sake; few have sacrificed more rather than violate their consciences, and this at a time when a high standard in this respect was not common. In spite of his failings, few have had warmer friends; no one more willingly communicated his knowledge and gave help to others; scarcely a book appeared in his time or for some years after his death on the subjects to which he devoted his life without acknowledging assistance from him. And if it be remembered that his life was a continued struggle against poverty and slight and ill-health, rather than complain that he did little, we should wonder how he accomplished so much.

His library was divided into two parts, one of which was sold by auction; the other, containing the transcript of the Gale Photius, his books with ms. notes, and some letters from foreign scholars, was bought by Trinity college for 1,000 guineas. His notebooks were found to contain, in the words of Bishop Charles James Blomfield, "a rich treasure of criticism in every branch of classical literature—everything carefully and correctly written and sometimes rewritten—quite fit to meet the public eye, without any diminution or addition." They have been carefully rearranged, and illustrate among other things his extraordinary penmanship and power of minute and accurate writing. Much remained unpublished. James Henry Monk, his successor as Greek professor, and Charles James Blomfield (both afterwards bishops) edited the *Adversaria,* consisting of the notes on Athenaeus and the Greek poets, and his prelection on Euripides; Peter Paul Dobree, afterwards Greek professor, the notes on Aristophanes and the lexicon of Photius. Besides these, from other sources, Professor Thomas Gaisford edited his notes on Pausanias and Suidas, and Thomas Kidd collected his scattered reviews. And, when Bishop Burgess attacked his literary character on the score of his *Letters to Travis,* Professor Thomas Turton (afterwards Bishop of Ely) came forward with a vindication.

See Barker, *Porsoniana* (London, 1852); Kidd, "Imperfect Outline of the Life of R.P.," prefixed to his collection of the *Tracts and Criticisms;* the *Life* by J. S. Watson (1861); *Dict. Nat. Biog.;* and J. E. Sandys, *History of Classical Scholarship,* ii (1908). Porson's publications include: *Notae in Xenophontis anabasin* (1786); *Appendix to Toup* (1790); *Letters to Travis* (1790); *Aeschylus* (1795, 1806); *Euripides* (1797–1802); *Adversaria* (Monk and Blomfield, 1812); *Tracts and Criticism* (Kidd, 1815); *Aristophanica* (Dobree, 1820); *Notae in Pausaniam* (Gaisford, 1820); *Photii lexicon* (Dobree, 1822); *Notae in Suidam* (Gaisford, 1834); *Correspondence* (Luard, edited for the Cambridge Antiquarian Society, 1867). Dr. Turton's vindication appeared in 1827.

PORT: *see* Port Wine; *see* also Rule of the Road at Sea.

PORT ADELAIDE: *see* Adelaide.

PORTADOWN, market town, urban district, Co. Armagh, N. Ireland, on the river Bann and the G.N.R., 25 mi. W.S.W. of Belfast. Pop. (1951) 17,202. Area 1.2 sq.mi. Linen and cotton are manufactured; there is considerable agricultural trade.

PORTAELS, JEAN FRANÇOIS (1818–1895), Belgian painter and teacher of art, was born at Vilvorde, Belgium, on April 30, 1818, and studied at the Brussels academy. In 1874 Portaels was appointed director of the academy of Brussels. His works include decorative paintings in the church of St. Jacques-sur-Caudenberg; biblical scenes and genre pictures, portraits, oriental scenes and pictures of fancy female figures, many of which are in the Brussels gallery. But it is as a teacher of art that Portaels is famous. He died at Brussels on Feb. 8, 1895.

See E. L. de Taeye, *Peintres belges contemporains.*

PORTAGE, a city of Wisconsin, U.S., 30 mi. N. of Madison, on the Wisconsin river; the county seat of Columbia county. It is at the western end of the ship canal connecting the Wisconsin and the Fox rivers; is on federal highways 16 and 51; and is served by the Chicago, Milwaukee, St. Paul and Pacific and the Soo Line railways. Pop. (1950) 7,334; (1940) 7,016. It is a shipping point for dairy products, grain, tobacco, sandstone, granite, jasper and the products of its several manufacturing plants. As the Fox and the Wisconsin rivers are there only 2 mi. apart, this was the natural point for the portage on the route from Lake Michigan to the Mississippi. It was used by Pierre Radisson and M. C. Groseilliers in 1655 and by Jacques Marquette and Louis Jolliet in 1673. From about 1712 to 1743 the Fox Indians intermittently disputed the white man's right to passage. The first white settler (1793) was Lawrence Barth. In 1797 Jacques Vieau established a trading post there, which by 1820 was a thriving fur depot. A temporary military post was established by the United States during the Red Bird uprising (1827). Fort Winnebago was begun in 1828. The canal was completed in 1856.

PORTAGE LA PRAIRIE, a port of entry and the chief city of Portage la Prairie county, Manitoba, Can., 56 mi. W. of Winnipeg, on the Canadian Pacific and the Canadian National railways at an altitude of 856 ft. above the sea. Pop. (1951) 8,511. The name had its origin in the fact that its situation on the Assiniboine is at the south end of a portage from Lake Manitoba used by the French fur traders. Industries include foundry and machine works and major brickyards.

PORTALEGRE, a Portuguese district and a city on the Lisbon-Madrid railway. City pop. (1950) 27,825. Dist. pop. (1950) 197,838. Portalegre is the Roman *Amaea* or *Ammaia,* and Roman and prehistoric remains have been discovered there.

PORTALES, a city in eastern New Mexico, U.S., and the county seat of Roosevelt county. It is about 85 mi. N.E. of Roswell on the Atchison, Topeka and Santa Fe railroad, and is on U.S. highway 70. The altitude is 4,000 ft. Pop. (1950) 8,112; (1940) 5,104. The city lies in the Portales valley, which is rendered fertile by irrigation. Dairying and diversified farming are carried on there, and manufactures include peanut processing, brooms, dairy products, canned goods and cotton. Portales was incorporated as a city in 1930. It is the home of Eastern New Mexico university.

PORTALIS, JEAN ETIENNE MARIE (1746–1807), French jurist, was born at Bausset in Provence on April 1, 1746. From 1778 to 1781 he was one of the assessors or administrators of Provence. In Nov. 1793, after the republic had been proclaimed, he went to Paris and was thrown into prison, being the brother-in-law of Joseph Jérôme Siméon, the leader of the federalists in Provence. On being released he practised as a lawyer in Paris; and in 1795 he was elected by the capital to the *conseil des anciens,* becoming a leader of the moderate party opposed to the directory. As a leader of the moderates he was proscribed at

the coup d'état of Fructidor, but he escaped to Switzerland and did not return till Bonaparte became first consul. Bonaparte made him a *conseiller d'état* in 1800, and then charged him, with F. D. Tronchet, Bigot de Préameneu and Jacques de Maleville, to draw up the *Code Civil*. Of this commission he was the most industrious member, and many of the most important titles, notably those on marriage and heirship, are his work. In 1801 he was placed in charge of the department of *cultes* or public worship, and had the chief share in drawing up the provisions of the concordat. He died at Paris on Aug. 25, 1807.

PORT ANGELES, a city of northwestern Washington, U.S., on the Strait of Juan de Fuca, opposite Victoria, B.C., 60 mi. from the Pacific ocean at Cape Flattery and 90 mi. N.W. of Seattle; a port of entry and the county seat of Clallam county. It is on federal highway 101 and is served by the Chicago, Milwaukee, St. Paul and Pacific and the Port Angeles Western railways, by auto ferries and steamers to the cities on Puget sound, and by ocean steamship lines. Pop. (1950) 11,233. It is the headquarters for the Olympic National park. The city fronts on Port Angeles bay, a fine natural harbour, very deep, without a bar, rock or shoal. Mt. Angeles (7,000 ft.) is the immediate background, and beyond rise the peaks of the majestic Olympics, many of which are still unnamed and unexplored. Port Angeles has manganese mines and manufactures lumber, shingles and paper. It was incorporated in 1890.

PORT ARTHUR, a city on Thunder bay, a northwestern arm of Lake Superior, Canada, and on the Canadian National and Canadian Pacific railways and the Trans-Canada highway. The passenger and freight ships of the Great Lakes transportation systems meet the rail lines of western Canada there, and a seaplane base is in the harbour. Pop. (1951) 31,161. There are about 50 important producing gold mines in the tributary area to the northeast. Extensive and rich haematite iron ore deposits at Steep Rock lake are tributary to the west, but most of the Steep Rock ore is shipped via special ore docks at Fort William. However, Port Arthur has the largest grain storage and shipment capacity on the continent. There are extensive pulp and paper mills; shipbuilding and repair are important industries; and lumbering is a major activity.

PORT ARTHUR (RYOJUN), a harbour in Kwantung Leased Territory, S. Manchuria at southern extremity of the Liao-tung peninsula (38° 48′ N. and 121° 20′ E.)—the only part of the short coast-line of Manchuria which is ice-free throughout the year. The town was given this name by Admiral Seymour when British forces were there in 1860. It occupies a strong strategic position, commanding the entrance to the Gulf of Pechihli and the opposite peninsula of Shantung. Its main interest is historical. Until the Chino-Japanese War it was the chief Chinese naval arsenal, but in 1894 it fell to Japan which was, however, forced by the European Powers to retrocede it to China, along with the whole Liao-tung peninsula, almost immediately after the ratification of the Treaty of Shimonoseki. Russia was anxious to secure an ice-free Chinese port as a base for her Pacific fleet, and the capture of Kiaochow by the Germans in 1897 provided the necessary occasion for her to occupy with warships Port Arthur and Talienwan (Dairen). The British Government was "not opposed to the lease by Russia of an ice-free commercial port connected by rail with the Trans-Siberian Railway," but it was pointed out that "questions of an entirely different kind were opened if Russia obtained control of a military port in the neighbourhood of Peking." Russia, regarding Port Arthur as necessary for the protection of Talienwan, refused to change its status as a closed military port. In 1898 by agreement, Russia acquired from China the lease of the Liao-tung peninsula (including Port Arthur) for 25 years and the right to construct the branch railway from Harbin to Port Arthur and Talienwan. Subsequent events showed that Russia had been seeking a fortress rather than an ice-free port on the Pacific. Port Arthur was made an apparently impregnable stronghold and along with Talienwan accommodated 20,000 Russians by the end of 1899. During the Russo-Japanese War, it was the main strength of Russia and only fell to the Japanese after a terrific siege by land which cost Japan some 30–40,000 casualties. By the treaty of Portsmouth (1905) Port Arthur was transferred to Japan. As part of the famous Twenty-one demands in 1915 the Japanese lease of Kwantung and the railway as far as Changchun was extended to a period of 99 years. Port Arthur was formerly the seat of government of the Japanese leased territory of Kwantung, but its importance diminished after the period during which it was the stronghold of Russian influence on the Pacific, and the chief town in South Manchuria, with a population of more than 42,000. The port, based on a fine natural harbour, entirely land-locked save on the south, is used as a naval base. A branch railway and excellent motor-road connect it with Dairen, the first port of China, the seat of government after 1937, and the real terminus of the South Manchuria railway. The new town, dating from the Russian occupation, has been constructed on modern lines and is a popular summer resort because of its splendid beaches. Port Arthur has a population (1938) of 145,286, of whom 13,391 are Japanese. The town contains modern hotels and hospitals and advanced education facilities. (*See* KWANTUNG.)

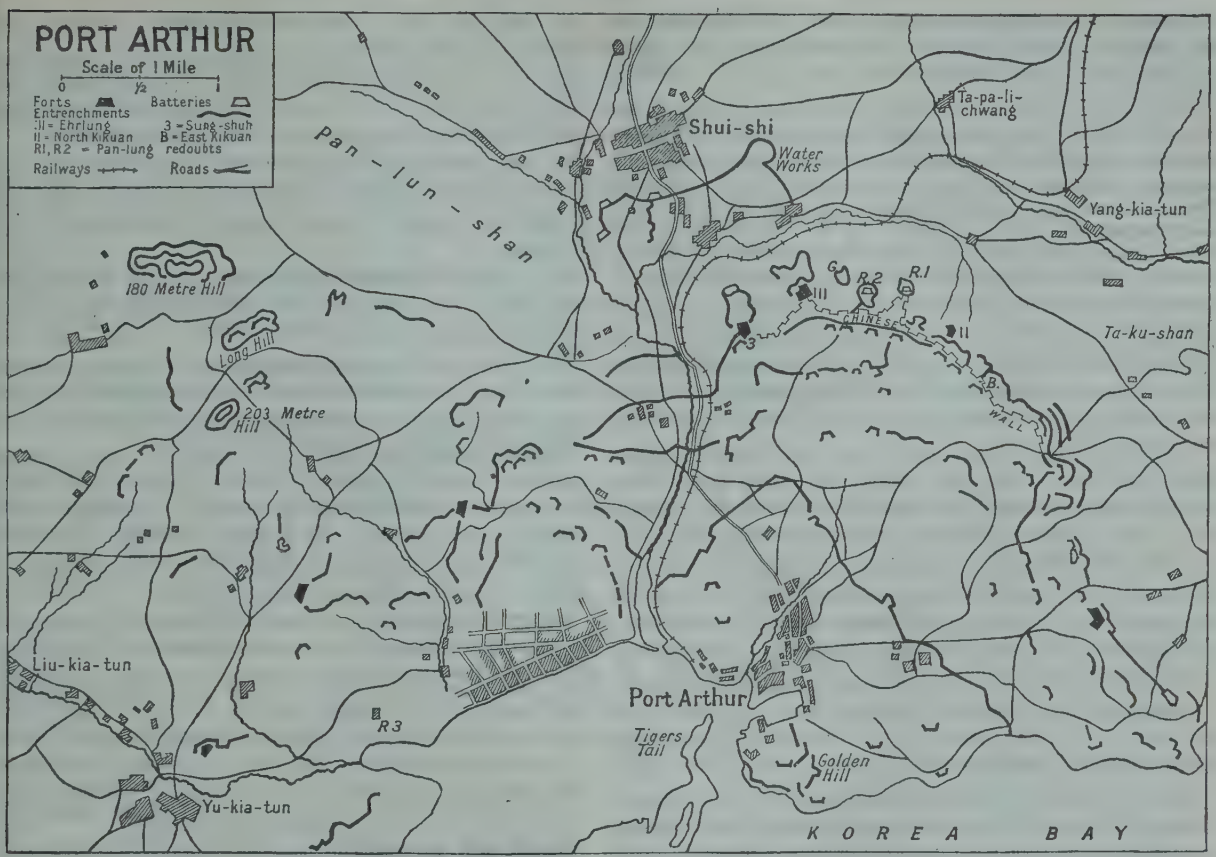
SIEGE OF PORT ARTHUR, 1904

While the fortunes of the siege of Port Arthur had undoubtedly a considerable influence on the outcome of the Russo-Japanese war (*q.v.*), its execution was separated both in space and design from the main operations of the field armies. The first clash of the armies took place on the Yalu on May 1, 1904, and five days later, Gen. Oku's 2nd Army, which had been waiting at Chinampo for the ice to melt, landed near Pitszewo. By storming Nanshan Hill, he gained command of the isthmus which connected the Port Arthur peninsula with the mainland. This mission was a prelude to the siege, and to the 2nd Army's advance northward, its place being taken by the 3rd Army under Gen. Nogi.

Nogi landed on June 1, and his army (1st and 11th Divisions) gradually separated itself from Oku's and got into position for the advance on Port Arthur. Dalny, the commercial harbour, was seized without fighting, and a month was spent in preparing a base there. But so far from retiring within his fort-line, the Russian commander, Gen. Stössel took up a strong position outside. Dislodged from this on June 26, the Russians checked Nogi's further advance on July 3–4, by a fierce, though unsuccessful, counter-stroke. Having been reinforced by the 9th Division and two extra brigades of infantry, Nogi advanced again on the 26th. The Russians, having had a month wherein to intrench themselves, held out all along the line; but after two days and one night of fighting amongst rocks and on precipitous hill-sides, the Japanese broke through on the night of July 27–28. Stössel then withdrew in good order into Port Arthur, which, in the two months he had gained by his fighting manoeuvre, had been considerably strengthened. Nogi had already lost 8,000 men.

The defences of Port Arthur, as designed by the Russians in 1900, and owing to the meagre allotment of funds only partially carried out before the war, had some tincture, but no more, of modern continental ideas. The main line of defence followed the outer edge of the amphitheatre of hills surrounding the harbour. These hills had their greatest development on the north-east side, their outer crests being some 4,000yd. from the Old Town. Running south-west and south back to the coast, the line gradually drew in quite close to the south-west end of the harbour. The total length from sea to sea was some 12 miles. Its most obvious weakness was that 5,000yd. N.W. of the harbour and New Town, the now famous "203-Metre Hill" overlooked both. Here it had been intended to construct permanent works, but consideration of expenditure had caused this to be deferred.

The permanent works along the main line were supplemented before the siege began by a prodigious development of semi-permanent works and trenches. Every knoll had its redoubt or battery, and the trenches were arranged line behind line, to give supporting, cross and enfilade fire in every direction. On the north-west front, 203-Metre Hill, in advance of the main line, was occupied by strong, semi-permanent works, with trenches and redoubts on either flank. Wire entanglements were disposed in repeated lines in front of the defences, but they were not of a strong



type. The Russians, with the resources of the fleet at their disposal (just as at Sevastopol, in the Crimean War), used great numbers of machine guns and electric lights, and the available garrison at first was probably, including sailors, 47,000 men.

Such were the defences that the Japanese attacked, with a force at the outset (July 30) barely superior in numbers to the defenders, and an entirely inadequate siege train (18 6-in. howitzers, 60 4·7-in. guns and howitzers, and about 200 field and mountain guns). They were imperfectly informed of the strength of the garrison and the nature of the defences. Recollections of their easy triumph in 1894 and perhaps thoughts of Sevastopol, German theories of the "brusque attack," the fiery ardour of the army, and above all the need of rapidly crushing or expelling the squadron in harbour, combined to suggest a bombardment and general assault. The bombardment began on Aug. 19 and continued for three days, while the infantry was spreading along the front and gaining ground where it could. The real assault was made on the night of the 21st on the two Pan-Lung forts (semi-permanent) on the centre of the north-eastern front. Although the stormers captured the two forts they were unable to make any further progress under the fire of the permanent forts Erh-Lung and Chi-Kuan on either side of, and the Wan-tai fort behind, Pan-Lung. Every attempt to bring up support to the captured positions failed. On the night of the 23rd–24th, just as the assault was being renewed, Stössel delivered a fierce counter-attack against the lost positions, and the result of an all-night battle was that though the forts were not recaptured, the assault was repulsed with over 5,000 casualties, and the Japanese in Pan-Lung were isolated. This sortie raised the spirits of the Russians to the highest pitch. They seemed, indeed, to have broken the spell of defeat. On the Japanese side 15,000 men had been killed and wounded in three weeks, and their army had now to resign itself to a methodical siege. Small sorties, partial attacks[1] and duels between the Japanese guns and the generally more powerful ordnance of the fortress continued. The siege approaches were first directed against the Temple-Waterworks group, which was stormed on Sept. 19 and 20. Pan-Lung was connected with the Japanese lines by covered ways, approaches were begun towards several of the eastern forts, and on Sept. 20, 180-Metre Hill was stormed, though the crest was untenable under the fire from 203-Metre Hill. Further progress on the western side of the fortress was foiled after hard fighting, and the eastern forts remained the principal objective. Heavier howitzers had been sent for from Japan and on Oct. 1 the first batteries of 28-centimetre (11in.) howitzers came into action. They fired a shell weighing 485 lb. On the 12th, the Japanese took the trenches between the Waterworks Redoubt and the Erh-Lung, and from this time forward there was a desperate struggle at the sap-heads on the north front.[2] A lodgement on the counterscarp of Sung-Shu prepared the way for mining. On Nov. 17, seven mines were exploded.

On Nov. 26, another assault was made on the same lines as the earlier ones. By this time the besiegers were sapping under the escarps of the northern forts, and it would have been better to delay. But the situation was serious in the extreme. In Manchuria Kuropatkin's army had reasserted itself. From Europe Rozhestvenski's squadron was just setting sail for the Far East. Marshal Oyama sent his principal staff officers to stimulate Nogi to fresh efforts, and some exhausted units of the besieging army were replaced by fresh troops from Japan. With 100,000 men and this urgent need of immediate victory, Nogi and the marshal's staff officers felt bound to make a third general assault. The siege works had, indeed, made considerable progress. The ditches of

[1]A feature of these constant night-fights was the effective use of the defenders' searchlight, both to show up the enemy and to blind him.

[2]Hand grenades and extemporized trench mortars were used on both sides with very great effect. The Japanese hand grenades consisted of about 1-lb. of high explosive in a tin case; the Russian cases were all sorts, including old Chinese shell. The Japanese employed wire-netting screens to stop the Russian grenades. Various means were tried for the destruction of entanglements. Eventually it was found that the best plan was to sap through them.

Sung-Shu and Erh-Lung were partially filled. They held most of the ditch of Chi-Kuan Fort and were cutting down the escarp, and two parallels had been made only 30 yd. from the Chinese Wall at Pan-Lung.

The general attack was made at one o'clock in the afternoon. At Sung-Shu the stormers got into the fort, but suffered much from the artillery on the western side of the Lun-ho valley, and were beaten out of it again in 20 min.; 2,000 men tried in vain to get up the Lun-ho valley to take Sung-Shu in rear. At Erh-Lung they could not get over the outer parapet. At "G" they took a portion of the Chinese Wall and lost it again, other trenches with a cross fire being behind. At Pan-Lung the machine guns on the wall prevented them from leaving the parallel. At Chi-Kuan Fort the *terreplein* of the fort had been covered with entanglements defended by machine guns on the gorge parapets, and the Japanese could make no way. Briefly, there was a furious fight all along the line, and nothing gained. On Nov. 27, after losing 12,000 men, the assault was abandoned. On the north front the Japanese returned to mining.

But so urgent was the necessity of speedy victory that the fighting had to continue elsewhere. And at last, after every other point had been attempted, the weight of the attack was directed on 203-Metre Hill. A battery of 11-in. howitzers was established only one mile away. On Nov. 28 and 30, assaults were made and failed. On Dec. 1, there was a fresh bombardment by the big howitzers, which obliged the Russians to take shelter in the rear of the ruined works. On Dec. 2, the Russians tried a counterattack. During the next two days the artillery was busy. The engineers tapped up to the ruins of the western work, saw the shelters on the reverse slope and directed artillery fire by telephone. Thirty-six guns swept the ground with shrapnel. Finally, on Dec. 5, the Japanese attacked successfully. Their losses in the last 10 days at 203-Metre Hill had been probably over 10,000. Those of the Russians were about 5,000, chiefly from artillery fire.

This was the turning point of the siege. At once the 11-in. howitzers, assisted by telephone from 203-Metre Hill, opened upon the Russian ships; a few days later these were wholly *hors de combat,* and at the capitulation only a few destroyers were in a condition to escape. The siege was now pressed with vigour by the construction of batteries at and around 203-Metre Hill, by an infantry advance against the main western defenses, and by renewed operations against the eastern forts. The escarp of Chi-Kuan was blown up, and at the cost of 800 men, General Samereda (11th division), personally leading his stormers, captured the great fort on Dec. 19. The escarp of Ehr-Lung was also blown up, and the ruins of the fort were stormed by the 9th division on Dec. 28, though a mere handful of the defenders prolonged the fighting for eight hours and the assailants lost 1,000 men. Sung-Shu suffered a worse fate on Dec. 31, the greater part of the fort and its defenders being blown up, and on this day the whole defense of the eastern front collapsed. The Japanese 7th and 1st divisions were now advancing on the western main line; the soul of the defense, the brave and capable General Kondratenko, had been killed on Dec. 15, and though food and ammunition were by no means exhausted, Anatoli M. Stössel surrendered on Jan. 2, 1905, with 24,000 effective and slightly wounded and 15,000 wounded and sick men, the remnant of his original 47,000. The total losses of the 3rd Japanese army during the siege were about 92,000 men (58,000 casualties and 34,000 sick).

PORT ARTHUR, a city of Jefferson county, Tex., U.S., in the southeastern part of the state, on the west shore of Sabine lake at the head of the Port Arthur canal, which leads to the Port Arthur docks (at the mouth of Taylors Bayou, 7 mi. S.E.), and on the route of the intracoastal waterway from New Orleans, La., to Corpus Christi, Tex. It is served by the Kansas City Southern and the Southern Pacific railways and by steamship lines.

The population was 22,251 in 1920, 76% native white, 6.4% foreign-born white and 17.6% Negroes, and was, in 1950, 57,530.

Selected as the site for a rail and shipping centre by Arthur Edward Stilwell, of the Kansas City, Pittsburg and Gulf railroad, which later became the Kansas City Southern railroad, the town was surveyed in 1895; Stilwell named it Port Arthur after his first name. In 1898 it was incorporated, and in 1908 the city became a full port of entry.

By 1899 Stilwell required financial help in his widespread enterprises in Port Arthur. John "Bet-a-Million" Gates, a well-known financier and promoter who had sold barbed wire in Texas, bought stock in the various companies and soon controlled them.

In 1932, under a locally drafted home rule charter, the city adopted the council-manager form of government. In 1901 the *News,* which had a daily circulation of 21,542 in Sept. 1951, was founded, and in 1930 St. Mary's Hospital, Gates Memorial, was established.

In 1938 the Port Arthur-Orange bridge, 5 mi. E. of the city on state route 87 over the Neches river, was opened to traffic. With a length of 7,700 ft. and a clearance of 176 ft., the bridge cost $2,750,000.

Port Arthur is a great oil-refining centre. The commerce of the port in 1949 amounted to 23,998,095 tons, valued at $4,180,000, of which about 90% was petroleum and petroleum products. Port Arthur is a salt-water sport fishing centre.

PORTATIVE ORGAN, a small mediaeval organ, not to be confounded with the positive (or portable) organ (*q.v.*). These miniature organs, used during the 14th and 15th centuries, were revivals of those used by the Romans, of which a specimen excavated at Pompeii in 1876 is preserved in the museum at Naples. The case measures 14½ in. by 9¾ in. and contains nine pipes, of which the longest measures but 9¾ in.

PORT AUGUSTA, at the head of Spencer gulf, an arm of the sea which penetrates far toward the interior of South Australia. This position lends Port Augusta a potential importance which, however, is somewhat impaired by a shallow approach and a channel which requires dredging. It is the natural port for the wheat-growing areas to the east, and for the pastoral areas to the north and northwest. Since the construction of the east to west transcontinental line (Perth-Brisbane), Port Augusta has become a break-of-gauge station. Pop. 4,351 (1947). The rainfall (9½″) is too low for crops in the immediate vicinity.

PORT AU PRINCE (originally L'Hôpital, and for brief periods Port Henri and Port Républicain), the capital of the Republic of Haiti, West Indies, situated about 1,400 mi. S. of New York city in 18° 33′ N. and 74° 47′ W. at the apex of the Gulf of La Gonaive which strikes inland for about 100 mi. between the two great peninsulas of the west coast, with its upper recesses protected by the beautiful island of Gonaive (30 mi. long and 2 mi. broad). Pop. (1950 census) 142,840, predominantly Afro-American. The University of Haiti, with a student body of several thousand in its various faculties, and a number of secondary schools, public and private, are in the capital.

Communication with the interior is maintained by two railway lines, by highways, and by telephone and telegraph connections. The excellent harbour serves as a port of call for both American and European vessels participating in the West Indian trade. The city was first laid out in 1749, and its bicentenary was commemorated in 1949 by an international exposition. In 1751, and again in 1770, it was destroyed by earthquakes; in subsequent years the city was ravaged frequently by fire. (*See* HAITI.) (C. E. MC.)

PORT AUTHORITY. For Great Britain the discussion of the constitution and powers of the different port authorities will be found in the articles on the various ports, *e.g.*, London, Liverpool, etc. The U.S. port authority, in many respects peculiar, calls for special discussion. The American Association of Port Authorities issued a port authorities directory for North America which indicated the adoption by an increasing number of American ports of some modification of the form of government established at European ports, notably at London and Liverpool.

Ownership of all facilities on the San Francisco, Calif., waterfront was acquired by the state of California and operated by the board of state harbour commissioners, the state guaranteeing the bonds issued, the principal and interest of which are payable from harbour revenue. No funds were to be raised by taxation and the harbour was self-supporting from its inception.

Under the 1925 charter for the city of Los Angeles, Calif., the board of harbour commissioners obtained possession and control

of the entire waterfront. It might collect rates or charges for the use of facilities in connection with commerce and navigation, might acquire and operate such facilities and secured power to regulate and control the construction, maintenance, operation or use of any such facility.

An act approved on March 14, 1911, authorized the establishment of port districts in the various counties of the state of Washington, and the port of Seattle came into existence under this act —a municipal corporation with power to levy taxes and to issue bonds. It might acquire lands, etc., and exercise the right of eminent domain. Commissioners are elected.

The port of Portland, Ore., was established and incorporated by the laws of 1891. It acquired broad powers, among them full control of the Willamette and Columbia rivers between Portland and the sea to the extent of the state's control, the right of eminent domain, the power to levy regular and special taxes on the property within the district and to bond the district to provide funds for carrying on its operations.

Operation of the port of Houston, Tex., was entrusted to the navigation and canal commission controlling the commercial activities of the port and the maintenance and construction of the terminal facilities. The board of commissioners of the port of New Orleans was created by a Louisiana statute enacted in 1896 to administer the public wharf system, construct and operate a public cotton warehouse, public grain elevator, public coal and bulk commodity handling plant and the great inner harbour navigation canal. The Virginia assembly in 1926 created the state port authority of Virginia, superseding the Hampton Roads port commission.

The board of harbour commissioners for the city of Wilmington, Del., an agency of the mayor and council of Wilmington, was created in 1917 by an act of the general assembly, which act was amended in 1921 and 1925. The board was given authority to fix rates and charges for wharfage and other services rendered in the loading and unloading of vessels, as well as warehouse and storage charges.

The Albany, N.Y., port district commission was created by the legislature of New York in 1925, with broad powers to lease or construct and maintain and operate port facilities, to acquire real property, to contract with municipalities for the construction of port facilities, issue bonds, fix rates, charges and wharfage for the use of all port facilities and collect charges for facilities owned by the district. Provision for tax in the several municipalities in the port district was made. (J. H. Co.; X.)

The Port of New York is unusual in that it lies within the boundaries of two states, New York and New Jersey, each an independent sovereignty. As early as 1834 the two states found it necessary to enter into a treaty settling the jurisdiction of each over the harbour's waters.

In 1917, in its decision in the New York harbour case involving freight rates and other points of conflict between the harbour's New York and New Jersey sides, the Interstate Commerce commission held that "historically, geographically and commercially New York and the industrial district in the northern part of the State of New Jersey constitute a single community" and recommended that immediate steps be taken to reorganize and coordinate the terminal facilities at the port. In 1920 the New York-New Jersey Port and Harbor Development commission, organized to study the problem, recommended creation of a port authority and a port district. This was accomplished when, on April 30, 1921, the two states entered into a compact or treaty. The consent of congress was given by joint resolution approved Aug. 23, 1921.

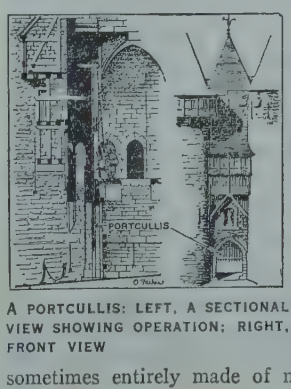
By the compact, which supplemented the treaty of 1834, the two states pledged, "each to the other, faithful cooperation in the future planning and development of the Port of New York." The port authority operates under the direction of 12 unsalaried commissioners, 6 from each state, appointed by the governors for overlapping terms of 6 years. It has full authority to purchase, construct, lease and operate any terminal or transportation facility within the port district; to own, hold, lease and operate real or personal property; to borrow money and secure it by bonds or by mortgage on any property held or to be held by it. It has no powers of taxation and must be entirely self-supporting. No property held by any municipality within the port district, or by either state, may be taken by the port authority without the owner's consent. In 1922 the legislatures of both states adopted a plan for the comprehensive development of the port, as provided for in the compact, and this was approved by congress. Under these and subsequent statutes, the two states authorized the construction or operation of additional transportation and terminal facilities, beginning with the Goethals bridge and Outerbridge crossing across the Arthur Kill between Staten Island and New Jersey, opened to traffic in 1928. Within the next 25 years there were added to port authority operations four more interstate crossings: the Bayonne, N.J., bridge across the Kill van Kull between Staten Island and New Jersey, and the George Washington bridge and Holland and Lincoln tunnels across the Hudson river between Manhattan and New Jersey; two air terminals, La Guardia airport and New York International airport in New York city and two in New Jersey, Newark airport and Teterboro airport; two union motor truck terminals, one in New York city and one in Newark, N.J.; a less-than-carload railroad freight terminal and a union bus terminal in Manhattan; the city of Newark's seaport; and a grain terminal in Brooklyn.

To finance its extensive operations the port authority had issued $711,701,258 in revenue bonds by 1952, including numerous refunding issues. The debt outstanding on March 31, 1952, was $228,172,000. The port authority's credit had improved so that the interest costs on long-term bonds had dropped from 5¼% to 2%. The port authority's actual investment and commitment in facilities as of March 31, 1952, totalled $395,395,396. Retirement of bonds was provided for out of revenues from the vehicular crossings and terminals.

The building and operation of transportation and terminal facilities represents only part of the port authority's work. It is charged by statute with the protection of port commerce and appears before such regulatory bodies as the Interstate Commerce commission, the Civil Aeronautics board and the Federal Maritime board in the interest of the welfare of the unified port area. It established branch offices in Washington, D.C., Chicago, Ill., Cleveland, O., and Rio de Janeiro, Braz., to promote commerce through the Port of New York. (L. K. J.)

PORT BLAIR, capital of the Andaman Islands (*q.v.*), in the Indian ocean, and headquarters of its penal settlement; on the S.E. shore of the South Andaman island, in 11° 42′ N., 93° E. It was occupied in 1789 by Capt. Archibald Blair, R.N., who named it Port Cornwallis; in 1791 the settlement with its name was transferred to the northeast of the island, only to be abandoned in 1796. The original site was again occupied in 1857 when it was named Port Blair. It possesses one of the finest harbours in Asia.

PORT CHESTER, a village of Westchester county, N.Y., U.S., on Long Island sound, at the mouth of Byram river, 26 mi. N.E. of Grand Central station in New York city. It is on federal highway 1, and is served by the New York, New Haven and Hartford railroad, interurban motorbus and truck lines. The population was 23,970 in 1950 and was 23,073 in 1940 and 22,662 in 1930 by the federal census. Port Chester is a residential suburb and has various industries, manufacturing electric shavers, candy, hardware, shoes, wire, pumps, generators and chemicals.



A PORTCULLIS: LEFT, A SECTIONAL VIEW SHOWING OPERATION; RIGHT, FRONT VIEW

During the Revolution the village was frequently occupied by American troops. Until 1837 Port Chester was known as Saw Pit. It was incorporated in 1868.

PORTCULLIS, a strong framed grating of wood, the lower points shod with iron, and sometimes entirely made of metal, counterbalanced, and hung

so as to slide up and down in grooves, and intended to protect the gateways of castles, city gates, etc. The defenders, having opened the gates and lowered the portcullis, could send arrows and darts through the gratings. The Romans used the portcullis in the defense of gateways. It was called *cataracta* from the Gr. καταρράκτης, a waterfall (καταρρήγνυσθαι, to fall down). Vegetius (*De re milit.* iv. 4) speaks of it as an old means of defense. Remains of a *cataracta* are clearly seen in the gateway of Pompeii.

PORTE, THE SUBLIME, the name once given to the Turkish government, derived from the high gate giving access to the building in Constantinople where the offices of the principal state departments were situated.

PORT ELIZABETH, a seaport 436 mi. by sea E. of Capetown, Cape of Good Hope, Union of South Africa, in 33° 58′ S., 25° 37′ E. The white population increased from 26,303 in 1921 to 53,461 in 1936; in 1938 the total population including suburbs was 124,714, of whom 56,250 were Europeans, 35,948 natives, 29,996 "coloured" (mixed), 2,520 Asiatics.

Port Elizabeth is the third port of South Africa, and is on the shores of Algoa bay, to the east of Cape Recife. Four distinct parts may be recognized: (1) the harbour and business quarter; (2) the "Hill," largely a residential part on the tableland overlooking the bay; (3) the "Valley," formed by the Baaken's river; and (4) the "South Hill," east of the river. Other suburbs have also grown up further from the town, such as Humewood, 1¾ mi. along the shore.

The Harbour.—Extensive harbour works were completed to transform Port Elizabeth from an open roadstead to a sheltered enclosed harbour with a water area of 314 ac. Additional quays can be built when required. The depth alongside no. 1 quay (3,540 ft. long) and no. 2 (1,700 ft. long) is 36 ft. L.W.O.S.T. There are three wharves with depths alongside varying from 13 to 24 ft. The hinterland of Port Elizabeth for imports extends to Rhodesia. Its exports are mainly the products of the eastern part of the Cape Province, the most important being wool and mohair, and, until World War I, ostrich feathers. There is a growing export of fresh and tinned fruits.

History.—Algoa bay was discovered by Bartholomew Diaz in 1488. In 1754 the Dutch settlements at the Cape were extended eastward to this point. In 1799 Colonel Vandeleur, after the British occupation of the Cape, built a small fort on the hill, west of the Baaken's river. By 1820, in addition to the troops, the civilian population had grown to 35. In April of that year arrived the first of the 1820 settlers. (*See* CAPE PROVINCE: *History.*) Under the supervision of Sir Rufane Donkin, a town was laid out at the foot of the hills. The real development of the port started when railways were constructed leading to the interior, Kimberley and the Witwatersrand. This work was begun in 1873, at the same time as the building of the existing jetties. Port Elizabeth is largely a British town.

PORTEOUS, JOHN (d. 1736), captain of the city guard of Edinburgh, whose name is associated with the riots of 1736, was the son of an Edinburgh tailor. Having served in the army, he was employed in 1715 to drill the city guard for the defense of Edinburgh in anticipation of a Jacobite rising, and was promoted later to the command of the force. In 1736 a smuggler named Wilson, who had won popularity by helping a companion to escape from the Tolbooth prison, was hanged; and, a disturbance occurring at the execution, the city guard fired on the mob. Porteous, who was said to have fired at the people with his own hand, was brought to trial and sentenced to death. The granting of a reprieve was hotly resented by the people of Edinburgh, and on the night of Sept. 7, 1736, an armed body of men in disguise broke into the prison, seized Porteous, and hanged him on a signpost in the street. It was said that persons of high position were concerned in the crime; but although every effort was made for the apprehension of the perpetrators, no one was ever convicted of participation in the murder.

BIBLIOGRAPHY.—Sir Daniel Wilson, *Memorials of Edinburgh in the Olden Time,* 2 vol. (Edinburgh, 1846–48); *State Trials,* vol. xvii; William Coxe, *Memoirs of the Life of Sir R. Walpole,* 4 vol. (London, 1816); Alexander Carlyle, *Autobiography* (Edinburgh, 1860), which gives the account of an eyewitness of the execution of Wilson; pamphlets (2 vol., in British museum) containing *The Life and Death of Captain John Porteous* and other papers relating to the subject; W. E. H. Lecky, *History of England in the Eighteenth Century,* vol. ii, p. 324, note, 7 vol. (London, 1892). *See* also Sir Walter Scott's notes to *The Heart of Midlothian.*

PORTER, DAVID (1780–1843), U.S. naval officer, was born in Boston, Mass., on Feb. 1, 1780. His father, David, and his uncle, Samuel, commanded American ships in the War of Independence. In 1796 he accompanied his father to the West Indies; on a second and on a third voyage he was impressed on British vessels, but he escaped. He became a midshipman in the U.S. navy in April 1798; served on the "Constellation" and was midshipman of the foretop when the "Constellation" defeated the "Insurgente"; was promoted lieutenant in Oct. 1799, and was in four successful actions with French ships in this year.

In 1803, during the war with Tripoli, he was first lieutenant of the "Philadelphia" when that vessel grounded; he was taken prisoner and was not released until June 1805. He was commissioned master commandant in April 1806; from 1807 to 1810 he served about New Orleans, where he captured several French privateers, and in 1812 was promoted captain. He commanded the frigate "Essex" in her famous voyage (1812–14). In the Atlantic he captured seven brigs, one ship, on Aug. 13, 1812, the sloop "Alert," the first British war vessel taken in the War of 1812. Without orders from his superiors he then (Feb. 1813) rounded Cape Horn, and in the South Pacific captured many British whalers and took formal possession (Nov. 1813) of Nukuhiva, the largest of the Marquesas Islands. The United States, however, never asserting any claim to the island, it was in 1842, with the other Marquesas, annexed by France. During most of February and March 1814 he was blockaded by British frigates in the harbour of Valparaiso, and on March 28 was defeated. Released on parole, he sailed for New York.

He was a member of the new board of naval commissioners from 1815 until 1823, when he commanded a squadron sent to the West Indies to suppress piracy. One of his officers, who landed at Fajardo (or Foxardo), Puerto Rico, in pursuit of a pirate, was imprisoned by the Spanish authorities on the charge of piracy. Porter, without reporting the incident or awaiting instructions, forced the authorities to apologize. He was recalled (Dec. 1824), court-martialled and suspended for six months. In Aug. 1826 he resigned his commission, and until 1829 was commander in chief of the Mexican navy, then fighting Spain. Pres. Andrew Jackson appointed him consul general to Algiers in 1830 and in 1831 created for him the post of chargé d'affaires at Constantinople, where in 1841 he became minister. He died in Pera on March 3, 1843.

He wrote a *Journal of a Cruise made to the Pacific Ocean in the U.S. Frigate "Essex" in 1812–13–14* (1815; 2nd ed., 1822), and *Constantinople and its Environs* (1835), a valuable guidebook. *See* the *Memoir of Commodore David Porter* (1875), by his son, Adm. David D. Porter.

PORTER, DAVID DIXON (1813–1891), U.S. naval officer, son of Capt. David Porter, was born in Chester, Pa., on June 8, 1813. His first voyage, with his father in West Indian waters (1823–24), was terminated by the Fajardo affair (*see* PORTER, DAVID). In April 1826 he entered the Mexican navy, on which his father was commander in chief, and which he left in 1828, after the capture by the Spanish of the "Guerrero," on which he was serving under his cousin, David H. Porter (1804–28), who was killed before the ship's surrender. He became a midshipman in the U.S. navy in 1829, and was in the coast survey (1836–42). In 1839 he married the daughter of Capt. Daniel Tod Patterson (1786–1839), then commandant of the Washington navy yard. Porter became a lieutenant in Feb. 1841; served at the naval observatory from 1845 to 1846, when he was sent to the Dominican Republic to report on conditions there. During the Mexican War he served as lieutenant and then as commanding officer of the "Spitfire," a paddle vessel built for river use, and took part in the bombardment of Veracruz. In 1855 and in 1856 he made trips to the Mediterranean to bring to the U.S. camels for Army use in the southwest. In April 1861, he was assigned to the "Powhatan," and was sent under secret orders from the presi-

dent for the relief of Ft. Pickens, Pensacola. Porter was promoted commander on April 22, and on May 30 was sent to blockade the South-west pass of the Mississippi. Upon his return to New York in November, he urged an expedition against New Orleans (*q.v.*), and recommended the appointment of Commander D. G. Farragut (*q.v.*), his foster-brother, to the chief command.

In the expedition Porter himself commanded the mortar flotilla, which, when Farragut's fleet passed the forts on the early morning of April 24, 1862, covered the passage by a terrific bombardment that neutralized the fire of Ft. Jackson. At Vicksburg Porter's bombardment assisted Farragut to run past the forts (June 28). On July 9, Porter was ordered, with ten mortar boats, to the James river, where McClellan's army was concentrated. On Oct. 15 he took command of the gun-vessels and had a share in the capture of Arkansas Post (Jan. 11, 1863). In the operations for the capture of Vicksburg in 1863 unsuccessful attempts were made by Porter's vessels to penetrate through connecting streams and bayous to the Yazoo river and reach the right rear of the Confederate defences on the bluffs, but the fleet ran past the Vicksburg batteries, mastered the Confederate forts at Grand Gulf, and made it possible for Grant's army to undertake the brilliant campaign which led to the fall of the place (*see* AMERICAN CIVIL WAR and VICKSBURG). Porter received the thanks of Congress for "opening the Mississippi river" and was promoted rear admiral. He co-operated with Maj.-Gen. N. P. Banks in the Red river expeditions in March-May 1864, in which his gun boats, held above Alexandria by shallow water and rapids, narrowly escaped isolation. On Oct. 12, 1864, he assumed command of the North Atlantic blockading squadron, then about to engage in a combined military and naval expedition against Ft. Fisher, N.C. Porter claimed that his guns silenced Ft. Fisher, but Maj.-Gen. B. F. Butler, in command of the land forces, refused to assault, asserting that the fort was practically intact. After Butler's removal, Porter, co-operating with Maj.-Gen. Alfred H. Terry, and commanding the largest fleet assembled at any one point during the war, took the fort on Jan. 15, 1865; for this he again received the thanks of Congress. From 1865 to 1869 he was superintendent of the U.S. Naval academy at Annapolis, which he greatly improved; his most notable change being the introduction of athletics. On July 25 he became vice admiral. From March 9 to June 25, 1869, while Adolph E. Borie (1809–80), of Pennsylvania, was secretary of the Navy in President Grant's cabinet, Porter was virtually in charge of the Navy department. In 1870 he succeeded Farragut in the grade of admiral. He died in Washington (D.C.), Feb. 13, 1891.

Porter wrote a *Life of Commodore David Porter* (1875), gossipy *Incidents and Anecdotes of the Civil War* (1885), a none too accurate *History of the Navy during the War of the Rebellion* (1887), two novels, *Allan Dare* and *Robert le Diable* (1885; dramatized, 1887) and *Harry Marline* (1886), and a short "Romance of Gettysburg," published in *The Criterion* in 1903. *See* J. R. Soley, *Admiral Porter* (1903).

Admiral Porter's three brothers were in the service of the United States: WILLIAM DAVID PORTER (1809–1864) commanded the "Essex" on the Tennessee and the Mississippi in the Civil War, and became commodore in July, 1862; THEODORIC HENRY PORTER (1817–1846) was the first officer of the American Army killed in the Mexican War; and HENRY OGDEN PORTER (1823–1872) resigned from the United States Navy in 1847, after seven years' service, fought under William Walker in Central America, returned to the American Navy, was executive officer of the "Hatteras" when she was sunk by the "Alabama," and received wounds in the action from the effects of which he died several years later.

PORTER, ENDYMION (1587–1649), English royalist, born at Aston-sub-Edge in Gloucestershire, was brought up in Spain—where he had relatives—as page in the household of Olivares. He afterwards entered successively the service of Edward Villiers and of Buckingham, and through the latter's recommendation became groom of the bedchamber to Charles I., who employed him on diplomatic business. During the Civil War Porter remained a faithful servant of the king.

At the end of 1645, when the cause of the king was finally lost, Porter abandoned England, and resided successively in France, Brussels, where he was reduced to great poverty, and the Netherlands. He returned to England in 1649, after the king's death, and was allowed to compound for what remained of his property. He died shortly afterwards, and was buried on Aug. 20, 1649, at St. Martin's-in-the-Fields. Porter had a great reputation in the world of art and letters. He wrote verses, was a generous patron of Davenant, who especially sings his praises, of Dekker, Warmstrey, May, Herrick and Robert Dover, and was included among the 84 "essentials" in Bolton's "Academy Royal." He was a judicious collector of pictures, and as the friend of Rubens, Van Dyck, Mytens and others painters, and as agent for Charles in his purchases abroad he had a considerable share in forming the king's magnificent collection. He was also instrumental in procuring the Arundel pictures from Spain. The authorship of Εἰκὼν πιστή, 1649, a vindication of the Εἰκὼν βασιλική, has been attributed with some reason to Porter.

AUTHORITIES.—*Life and Letters of Endymion Porter*, by D. Townshend (1897); article in the *Dict. of Nat. Biog.*, by C. H. Firth and authorities there cited; *Memoires*, by D. Lloyd (1668), p. 657; Burton's *Hist. of Scotland* (1873), vi. 346–347; *Eng. Hist. Rev.* ii. 531, 692; Waters, *The Chesters of Chichele*, vol. i., 144–149; *Eikon Basilike*, by Ed. Almack, p. 94.

PORTER, FITZ-JOHN (1822–1901), American soldier, was born at Portsmouth (N.H.) on Aug. 31, 1822. He was the son of a naval officer, and nephew of David Porter of the frigate "Essex." He graduated at the U.S. Military academy in 1845; in the Mexican War he won two brevets for gallantry. He served at West Point as instructor and adjutant (1849–55), and at the outbreak of the Civil War in 1861 he was employed on staff duties in the eastern States. He became colonel of a new regiment of regulars on May 14, and soon afterwards brig.-general of volunteers. Under McClellan he commanded a division of infantry in the Peninsular campaign, directed the Union siege operations against Yorktown, and was soon afterwards placed in command of the V. Army Corps. When the Seven Days' battle (*q.v.*) began Porter's corps had to sustain alone the full weight of the Confederate attack, and though defeated in the desperately fought battle of Gaines's Mill (June 27, 1862) the steadiness of his defense was so conspicuous that he was immediately promoted maj.-general of volunteers and brevet brig.-general. His corps, moreover, had the greatest share in the successful battles of Glendale and Malvern Hill. Soon afterwards, the V. Corps was sent to reinforce Pope in central Virginia. Its inaction on the first day of the disastrous second battle of Bull Run (*q.v.*) led to the general's subsequent disgrace; but it made a splendid fight on the second day to save the army from complete rout, and shared in the Antietam campaign.

On the same day on which McClellan was relieved from his command, Porter, his friend and supporter, was suspended and tried by court-martial on charges brought against him by Pope. On Jan. 21, 1863, he was sentenced to be cashiered "and for ever disqualified from holding any office of trust under the Government of the United States." In 1878 Porter's friends succeeded in procuring a revision of the case by a board of distinguished general officers. General Grant had now taken Porter's part, and wrote an article in vol. 135 of the *North American Review* entitled "An Undeserved Stigma." Against much opposition, a relief bill finally passed Congress, and Porter was on Aug. 5, 1886, restored to the United States army as colonel and placed on the retired list, without compensation. After the Civil War he was engaged in business in New York, and held successively many important municipal offices. In 1869 he declined the offer made by the khedive of the chief command of the Egyptian Army. He died on May 21, 1901, at Morristown (N.J.).

See, besides General Grant's art., Cox, *The Second Battle of Bull Run as connected with the Porter Case* (Cincinnati, 1882); Lord, *A Summary of the Case of F. J. Porter* (1883), and papers in vol. ii. of the pub. of the Military Hist. Soc. of Mass.

PORTER, HENRY (*fl.* 1596–1599), English dramatist, author of *The Two Angry Women of Abingdon*, may probably be identified with the Henry Porter who matriculated at Brasenose

College, Oxford, on June 19, 1589. From 1596 to 1599 he was writing plays for Henslowe for the Admiral's Men, and his closest associate seems to have been Henry Chettle. None of the plays mentioned by Henslowe as being written by him are extant, unless, as has been suggested, *Love Prevented* is another name for *The Pleasant History of the Two Angry Women of Abingdon* of which Gayley says: "No play preceding or contemporary yields an easier conversational prose, not even the *Merry Wives.*"

Alexander Dyce edited the *Angry Women* for the Percy Society in 1841; and it is included in W. C. Hazlitt's edition of Dodsley's *Old Plays* (1874). It was edited by Havelock Ellis in *Nero and other plays* (1888, "Mermaid Series,") and in *Representative English Comedies* (1903), with an introduction by the general editor, Professor C. M. Gayley.

PORTER, HORACE (1837–1921), American diplomatist and soldier, was born in Huntingdon, Pa., on April 15, 1837; son of David Rittenhouse Porter (1788–1867), governor of Pennsylvania in 1839–45. During the Civil War he served in the Army of the Potomac until after Antietam; took part in the battles of Chickamauga and Chattanooga; and in April, 1864, became aide-de-camp to Gen. Grant, in which position he served until March 1869. From Aug. 1867 to Jan. 1868, while Gen. Grant was secretary of war *ad interim,* Porter was an assistant secretary, and from March 1869 to Jan. 1873, when Grant was president, Porter was his executive secretary. He resigned from the army in Dec. 1873, when he became vice president of the Pullman Palace Car Company and held other business positions. From March 1897 to May 1905 he was United States ambassador to France. At his personal expense he conducted (1899–1905) a successful search for the body of John Paul Jones, who had died in Paris in 1792. For this he received (May 9, 1906) a unanimous vote of thanks of both Houses of Congress. In 1907 he was a member of the American delegation to the Hague Peace conference. He died in New York city on May 29, 1921. His publications include *West Point Life* (1866) and *Campaigning with Grant* (1897).

PORTER, JANE (1776–1850), British novelist, daughter of an army surgeon, was born at Durham in 1776. Her life and reputation are closely linked with those of her sister, ANNA MARIA PORTER (1780–1832), novelist, and her brother, SIR ROBERT KER PORTER (1775–1842), painter and traveller. After their father's death, in 1779, the mother removed from Durham, their birthplace, to Edinburgh, where the children's love of romance was stimulated by their association with Flora Macdonald and the young Walter Scott. Mrs. Porter moved to London, so that her son might study art, and the sisters subsequently resided at Thames Ditton and at Esher with their mother until her death in 1831. Anna Maria Porter published *Artless Tales* in 1793–95, the first of a long series of works of which the more noteworthy are *The Lake of Killarney* (1804), *The Hungarian Brothers* (1807), *Don Sebastian* (1809) and *Barony* (1830).

Jane Porter—whose intellectual power, though slower in development and in expression, was greater than her sister's—had in the meantime gained immediate popularity by her first work, *Thaddeus of Warsaw* (1803), which was translated into several languages and procured her election as canoness of the Teutonic order of St. Joachim. In 1810, four years before the appearance of *Waverley,* she attempted national romance in her *Scottish Chiefs.* The picturesque power of narration displayed by Miss Porter has saved the story from the oblivion which has overtaken the works of most of Scott's predecessors in historical fiction. Her later works included *The Pastor's Fireside* (1815), *Duke Christian of Lüneburg* (1824), *Coming Out* (1828) and *The Field of Forty Footsteps* (1828). In conjunction with her sister she published in 1826 the *Tales round a Winter Hearth.* She also wrote some plays, and frequent contributions to current periodical literature. On Sept. 21, 1832, Anna Maria died, and for the next ten years Jane became "a wanderer" amongst her relations and friends. She died at Bristol on May 24, 1850.

Robert Ker Porter painted altar-pieces and battle-scenes of imposing magnitude. He went to Russia as historical painter to the emperor in 1804, travelled in Finland and Sweden, where he received knighthood from Gustavus IV. in 1806, and accompanied Sir John Moore to Spain in 1808. In 1811 he returned to Russia and married a Russian princess. He was knighted by the Prince Regent in 1813. In 1817 he travelled to Persia by way of St. Petersburg (Leningrad) and the Caucasus, returning through Bagdad and western Asia Minor. He examined the ruins of Persepolis, making many valuable drawings and copying cuneiform inscriptions. In 1826 he became British consul in Venezuela. He died at St. Petersburg on May 4, 1842.

His works include: *Travelling Sketches in Russia and Sweden* (1808), *Letters from Portugal and Spain* (1809), *Narrative of the late Campaign in Russia* (1813), and *Travels in Georgia, Persia, Armenia, Ancient Babylonia, etc., during the years 1817–1820* (1821–22). After leaving Venezuela (1841) he again visited St. Petersburg, and died there on May 4, 1842. Jane Porter, who had joined him in Russia, then returned to England and took up her residence with her eldest brother at Bristol, where she died on May 24, 1850.

PORTER, NOAH (1811–1892), U.S. educationalist and philosophical writer, of Puritan ancestry, was born in Farmington, Conn., on Dec. 14, 1811. He graduated at Yale college in 1831, for two years taught in the New Haven grammar school, was for two years a tutor at Yale, then becoming a Congregational minister. He was elected professor of moral philosophy and metaphysics at Yale in 1846, and from 1871 to 1886 he was president of the college. His best-known work is *The Human Intellect, with an Introduction upon Psychology and the Human Soul* (1868), abridged as *The Elements of Intellectual Science* (1871). He died in New Haven March 4, 1892.

See *Noah Porter, a Memorial,* edited by G. S. Merriam (1893).

PORTER, WILLIAM SYDNEY: *see* HENRY, O.

PORTES GIL, EMILIO (1891–), Mexican statesman and provisional president (Dec. 1, 1928, to Feb. 5, 1930), was born at Ciudad Victoria, Tamaulipas, on Oct. 30, 1891. He studied in the law school of the National university and was graduated in 1915 at the peak of revolutionary disorders. He took a prominent part in the revolutionary movement, serving in a judicial capacity in Sonora during P. E. Calles' administration as governor and in the legal section of the war department while Gen. Alvaro Obregon was secretary of war. In 1919 he worked in favour of the candidacy of Obregon and was imprisoned for a time for his activities. Following the overthrow of V. Carranza in 1920, Portes Gil acted as provisional governor of Tamaulipas and subsequently was elected a deputy from that state for four terms. He took office as elected governor of Tamaulipas in Feb. 1925 and held this post until appointed secretary of the interior and head of the cabinet by President Calles in Aug. 1928. While governor, he worked on behalf of labour legislation. The number of schools in the state was increased from 280 to more than 600, and special attention was given to agricultural and industrial instruction. He also abolished gambling and established partial prohibition.

Portes Gil was elected provisional president of Mexico by a unanimous vote of the Mexican congress (Sept. 25, 1928) to fill a temporary gap caused by the assassination of President-elect Obregon. His selection was supported by President Calles as well as the powerful Agrarian party. His brief administration was marked by a revolt in Veracruz and northern Mexico, and he retired in 1930 after the election of Pascual Ortiz Rubio. In 1931 and 1932 he was minister to France and from 1932 to 1934 attorney-general of Mexico. He was secretary of foreign affairs, 1934–36, and president of the National Athenaeum of Science and Art in 1949.

PORT GLASGOW, a large burgh of Renfrewshire, Scot., on the Firth of Clyde, 20¼ mi. W.N.W. of Glasgow by Scottish Region railway. Pop. (1951) 21,612. Area, 1 sq.mi. It is continuous with Greenock. The industries include large shipbuilding and engineering works and sawmills. The area of the docks, both wet and graving, is 16½ ac. The graving dock (1762) was the first dock of the kind in Scotland. In 1775 Port Glasgow was created a burgh of barony. Adjoining the town are the ruins of Newark castle (16th century).

PORT HARCOURT, second port of Nigeria, West Africa, was founded in 1914 as the rail terminal for a coal field being opened at Enugu. It became an increasing exporter of palm oil

and with extension of the rails the chief outlet for the tin of the Nigerian plateau. Warehouses and coal tipples occupy the wharfside, a narrow foreshore where the deep Bonny river, a distributary of the Niger, flows beneath a bluff about 30 ft. high. The embryo town stands on this well-drained plain. Bonny bar, 41 mi. downstream, is kept dredged to 23 ft. Scheduled boat service connects with Lagos. (D. WH.)

PORT HUDSON, a village in East Baton Rouge parish, La., U.S., on the left bank of the Mississippi, about 135 mi. above New Orleans. At the sharp turn of the Mississippi there the Confederates in 1862 built on the commanding bluffs powerful batteries covering a stretch of about 3 mi., their strongest fortifications along the Mississippi between New Orleans and Vicksburg. On the night of March 14, 1863, Adm. David Farragut, with seven vessels, attempted to run past the batteries, commanded by Brig. Gen. William M. Gardner, but four of his vessels were disabled and forced to turn back, one, the "Mississippi" was destroyed, and only two, the "Hartford" and the "Albatross" got past. Gen. N. P. Banks's land attack on May 27 was unsuccessful, the Union loss, nearly 2,000, being six times that of the Confederates. A second attack on June 14 entailed a further Union loss of about 1,800 men. But on July 9, two days after the news of the surrender of Vicksburg, after a siege of 45 days, Gen. Gardner surrendered the position to Gen. Banks with about 6,400 men, 50 guns, 5,000 small arms and ammunition, and two river steamers. The Union losses during the siege were probably more than 4,000; the Confederate losses about 800. The capture of Vicksburg and Port Hudson secured to the Union the control of the Mississippi.

PORT HURON, a city of southeastern Michigan, U.S., 60 mi. N.N.E. of Detroit, at the lower end of Lake Huron, on the St. Clair river at the mouth of the Black, and opposite Sarnia (Ontario), with which it is connected by a railway tunnel 6,025 ft. long and the Blue Water International bridge; a port of entry and the county seat of St. Clair county. It is on federal highway 25, and is served by the Grand Trunk, Chesapeake and Ohio, and Port Huron and Detroit railways. The population was 35,597 in 1950 (85% native white) and 32,759 in 1940 by the federal census.

Port Huron is the metropolis of the summer-resort region known as the Lake Huron beaches, stretching for 100 mi. along the lake to the north, and of the manufacturing district which borders the St. Clair for 30 mi. to the south. Its water-borne commerce is considerable.

A thick deposit of salt was discovered under the city in 1883, and gas and oil have also been found in the locality. Port Huron is the headquarters of the Women's Benefit association.

In 1686 the French established Ft. St. Joseph within the present limits of Port Huron. It came into the possession of the British in 1761, and in 1814 was occupied by American troops and renamed in honour of Gen. Charles Gratiot (1788–1855). The settlement which grew up around it was organized as a village in 1840, and in 1893 it was annexed to Port Huron. Another settlement (at first called La Rivière de Lude, and after 1828 Desmond) was made near the fort in 1790 by several French families. It was incorporated as the village of Port Huron in 1849 and chartered as a city in 1857.

PORTICI, a town of Campania, Italy, in the province of Naples, 5 mi. S.E. of Naples by rail, on the shores of the bay, and at the foot of Vesuvius. Pop. (1936) 26,049. The palace, erected in 1738, once contained the antiquities from Herculaneum, now removed to Naples (with the exception of some mosaic pavements), and in 1873 it became a government institute of agriculture. Just beyond Portici, on the southeast, is Resina (pop. in 1936, 30,707), on the site of the ancient Herculaneum, with several fine modern villas. The inhabitants are engaged in fishing, silk-growing and silk-weaving. The town was completely destroyed by the eruption of Vesuvius in 1631.

PORTICO, in architecture, a term loosely applied to many types of structure in which columns or colonnades are the most important part. Thus an entrance porch with columns is called a portico, and the colonnade at the end of a classic temple is also so named. In Rome an arcaded and colonnaded building surrounding an open space or temple, and built for a public covered promenade was termed a *porticus,* like the portico of Octavia (built by Augustus and restored by Septimius Severus and Caracalla, 203), of which there are extensive remains.

PORT JACKSON: *see* SYDNEY.

PORT JERVIS, a city of Orange county, New York, U.S., 70 mi. N.W. of New York city, on the Delaware river at the mouth of the Neversink, where New York, New Jersey and Pennsylvania meet. It is on federal highway 6, and is served by the Erie and the New York, Ontario and Western railways. Pop. (1950) 9,348; and in 1940, federal census, 9,749.

Port Jervis is in a region of beautiful mountain scenery, waterfalls, lakes and trout streams. The Erie has extensive shops in Port Jervis, and the city has various other manufacturing industries.

Hydroelectric power is available from a development at Mongaup falls. Port Jervis was laid out in 1826, soon after work began on the Delaware and Hudson canal (now abandoned) and was named for the engineer who constructed the canal, John Bloomfield Jervis (1795–1885). It was incorporated as a village in 1853 and as a city in 1907.

PORT KEMBLA, a harbour and port on the east coast of New South Wales, Australia, in the Illawarra district, distant some 55 mi. S. of Sydney. It exports considerable quantities of coke in addition to coal from Dapto. A large electrolytic refining and smelting works treats ores (chiefly copper) from various parts of the commonwealth (capacity: 47,000 tons refined ore annually), and has fertilizer and metallurgical works (copper wire, cables, etc.) associated with it. More recently Port Kembla was chosen as the site for a steel industry. The Hoskins company (*see* LITHGOW)—which owns a coking-plant at Dapto—in conjunction with two English steel firms and a Melbourne shipping line, erected works with a view to large-scale production, while the New South Wales government improved the inland connections by constructing a line to Moss Vale (on the main Southern line). Port Kembla is the third port of New South Wales.

(*See* also WOLLONGONG.)

PORTLAND, EARL OF, an English title held by the family of Weston from 1633 to 1688, and by the family of Bentinck from 1689 to 1716, when it was merged in that of duke of Portland. Sir Richard Weston (1577–1635), according to Clarendon "a gentleman of very ancient extraction by father and mother," was the son and heir of Sir Jerome Weston (*c.* 1550–1603) of Skreens, in Roxwell, Essex, his grandfather being Richard Weston (d. 1572), justice of the common pleas. He was lord high treasurer from 1628 until his death on March 13, 1635. He received the earldom in 1633.

The title became extinct in 1688. In 1689 it was revived by William III, who bestowed it upon William Bentinck (*see* below).

Sir Richard Weston must be distinguished from a contemporary and namesake, SIR RICHARD WESTON (*c.* 1579–1652), baron of the exchequer. Another SIR RICHARD WESTON (*c.* 1466–1542) was a courtier and a diplomatist under Henry VIII; his son was SIR FRANCIS WESTON (*c.* 1511–1536), who was beheaded for his alleged adultery with Anne Boleyn. This Sir Richard had a brother, SIR WILLIAM WESTON (d. 1540), who distinguished himself at the defense of Rhodes in 1522, and was afterward prior of the Knights of St. John in England. A third SIR RICHARD WESTON (1591–1652), was mainly responsible for introducing locks on the Wey and thus making this river navigable.

Another family of Weston produced Robert Weston (*c.* 1515–1573), lord chancellor of Ireland from 1566 until his death on May 20, 1573.

Much of the earl of Portland's correspondence is in the Public Record Office, London. For his political career *see* S. R. Gardiner, *History of England* (1883–84), and L. von Ranke, *Englische Geschichte* (English trans., Oxford, 1875).

PORTLAND, WILLIAM BENTINCK, EARL OF (*c.* 1645–1709), English statesman, was born, according to the Dutch historian, Groen van Prinsterer, in 1645, although most of the other authorities give the date as 1649. The son of Henry Ben-

tinck of Diepenheim, he was descended from an ancient and noble family of Gelderland. As page of honour and gentleman of the bedchamber to William, prince of Orange, he secured the friendship of William, which he justified by his prudence and ability. In 1677 he was sent to England to solicit for the prince of Orange the hand of Mary, daughter of James, duke of York, afterward James II, and he was again in England in 1683 and in 1685. When, in 1688, William was preparing for his invasion Bentinck went to some of the German princes to secure their support, or at least their neutrality, and he was also a medium of communication between his master and his English friends. He superintended the arrangements for the expedition and sailed to England with the prince.

The revolution accomplished, Bentinck was made groom of the stole, first gentleman of the bedchamber and a privy councillor; and in April 1689 he was created Baron Cirencester, Viscount Woodstock and earl of Portland. He fought at the battle of the Boyne (1690), the battle of Landen and at the siege of Namur, but his main work was of a diplomatic nature. He helped to arrange the peace of Ryswick (1697); he negotiated with Louis XIV for a partition of the Spanish monarchy and, as William's representative, signed the two partition treaties. Jealous of the rising influence of Arnold van Keppel, earl of Albemarle, Portland resigned all his offices in the royal household in 1692, but he did not forfeit the esteem of the king, who continued to trust and employ him. He received 135,000 ac. of land in Ireland, and only the strong opposition of a united house of commons prevented him obtaining a large gift of crown lands in north Wales. For his share in drawing up the partition treaties he was impeached in 1701, but the case against him did not proceed. He was occasionally employed on public business under Anne until his death at his residence, Bulstrode in Buckinghamshire, on Nov. 23, 1709. Portland's eldest son Henry (1680–1724) succeeded as 2nd earl. He was created marquess of Titchfield and duke of Portland in 1716.

See G. Burnet, *History of My Own Time* (Oxford, 1833); Lord Macaulay, *History of England* (1854); L. von Ranke, *Englische Geschichte* (Eng. trans., Oxford, 1875); and especially Onno Klopp, *Der Fall des Hauses Stuart* (Vienna, 1875–88); M. E. Grew, *William Bentinck and William III* (1924). *See* also A. W. Ward's article in vol. iv of the *Dict. Nat. Biog.*

PORTLAND, WILLIAM HENRY CAVENDISH BENTINCK, 3RD DUKE OF (1738–1809), prime minister of England, son of William, 2nd duke (1709–62), and grandson of the 1st duke. He was born on April 14, 1738, and was educated at Oxford. Under the marquess of Rockingham he was, from July 1765 to Dec. 1766, lord chamberlain, and on the return of Rockingham to power in April 1782 he was made lord lieutenant of Ireland. After the short ministry of the earl of Shelburne, succeeding the death of Rockingham, the duke of Portland was selected by Charles Fox and Lord North as a "convenient cipher" to become the head of the coalition ministry, to the formation of which the king was with great reluctance compelled to give his assent. The duke held the premiership from April 5, 1783, until the defeat of the bill for "the just and efficient government of British India" caused his dismissal from office on Dec. 17 following. Under William Pitt he was, from 1794 to 1801, secretary of state for the home department, after which he was, from 1801 to 1805, president of the council. In 1807 he was appointed a second time prime minister and first lord of the treasury. Ill-health caused him to resign in Oct. 1809, and he died on Oct. 30. He owed his political influence chiefly to his rank, his mild disposition and his personal integrity.

He married in 1766 Lady Dorothy Cavendish (1750–94), daughter of the 4th duke of Devonshire, and was succeeded by his son William Henry (1768–1854). The 4th duke married a daughter of the famous gambler, Gen. John Scott. His son, the 5th duke, William John Cavendish Bentinck-Scott (1800–79), died unmarried.

PORTLAND, a city of eastern Indiana, U.S., 80 mi. N.E. of Indianapolis, near the headwaters of the Salamonie river; county seat of Jay county. It is on federal highway 27, and is served by the Nickel Plate and Pennsylvania railways. Pop. (1950) 7,050. Automobile steering wheels are the main industry; other manufactured products include drop forgings, garments, silos, brushes and brooms, dairy equipment and canned goods. There is also a meat-packing plant in the city. Agricultural products include corn, wheat and oats.

Portland has a number of natural gas and oil wells.

Electric generation and distribution and the waterworks are owned and operated by the city. The city is governed by a mayor, who is elected for a term of four years, and five councilmen, who are elected for terms of four years.

Two daily newspapers and one weekly newspaper are published there. Portland's Jay County hospital was established in 1916.

PORTLAND, the largest city of Maine, U.S., a port of entry and the county seat of Cumberland county; on Casco bay, 110 mi. N.E. of Boston. It is on federal highway 1, and is served by the Boston and Maine, the Grand Trunk and the Maine Central railways, by Northeast Airlines and by steamship lines operating to a number of foreign ports. Pop. in 1950 was 77,634; in 1940 it was 73,643; and in 1930, 70,810 by federal census. Its area of 21.6 sq.mi. includes a peninsula three miles long and averaging less than a mile in width (the original town); another peninsula to the east, occupied by the former city of Deering (annexed in 1899); some encircling territory on the mainland; and islands aggregating 2,585 ac.

The eastern promenade (161 ft. above sea level) overlooks beautiful Casco bay and its numerous islands, the shores of Falmouth and Cape Elizabeth, to the open Atlantic ocean beyond. From the western promenade (altitude 169 ft.) the view embraces a broad sweep of country, to the White mountains of New Hampshire. The public buildings are dignified and substantial. In Congress street (the main thoroughfare) is the Portland observatory (rising 227 ft. above tidewater) built in 1807 to sight incoming vessels. Many of the dwellings are in the simple and gracious architectural style of the 18th and early 19th century. Of special interest are the birthplace of Henry Wadsworth Longfellow and his early home in Congress street (now a museum) built by his grandfather Gen. Peleg Wadsworth in 1785–86. The Eastern cemetery (set aside in 1668) contains the graves of many citizens of note. The oldest church building in the city (1825) is that of the First Parish church (Unitarian), established in 1809. In Williston church (Congregational) the Young People's Society of Christian Endeavor was founded in 1881 by the Rev. Francis E. Clark. Portland has a number of hospitals and several special libraries and museums, besides the large public library. In 1923 Portland adopted a council-manager form of government.

The harbour has a water frontage of 8.5 mi. It is protected by a breakwater, and flanked by Forts Preble, Levett, Williams and McKinley. The nearest deepwater U.S. port to Europe, it was the base of the North Atlantic fleet during World War II. Grain, lumber, wood pulp, oil products, coal, minerals and other cargoes are handled in considerable tonnages. South Portland is the terminus of the Portland-Montreal pipe line and after World War II the city became one of the most important fuel and oil depots on the Atlantic coast.

Portland's industries are highly diversified including shipyards, food processing, foundries and printing and publishing. Other products are lumber, paper and pulp, furniture, clothing, industrial machinery, culverts, refrigeration equipment, textile machinery, stoves and marine hardware.

The Indian name for the peninsula which constitutes the heart of Portland was Machegonne. It was first settled by George Cleaves and Richard Tucker in 1632. The early settlement, known by various names, was destroyed by the Indians in 1676, and again by the French and Indians in 1690, after which it remained desolate until 1715. In 1719 the town of Falmouth was organized, including Falmouth Neck (now Portland). On Oct. 18 1775, it was bombarded and burned by a British fleet in punishment for showing its sympathy for the patriotic cause. Falmouth Neck was incorporated in 1786 as the town of Portland. It was the capital of the state from 1820 to 1832, and on April 30, 1832 adopted a city charter. About 200 ac. in the centre of the city were destroyed in 1866 by a fire resulting from a Fourth of July

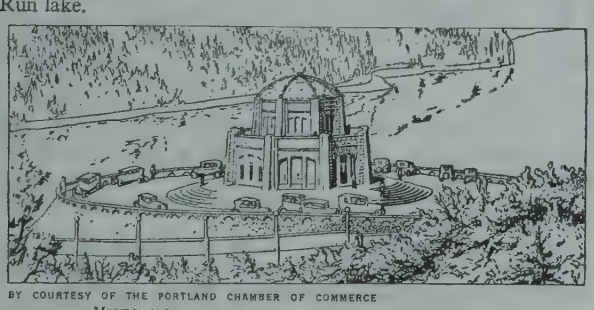
celebration. Portland was the birthplace of Henry Wadsworth Longfellow, Thomas Brackett Reed, Edward Preble, George Henry Preble, Mrs. Parton ("Fanny Fern"), Nathaniel Parker Willis, Seargent Smith Prentiss and Neal Dow, and was the home of William Pitt Fessenden, Theophilus Parsons and Simon Greenleaf.

PORTLAND, the largest city of Oregon, U.S., on the Willamette river, at its confluence with the Columbia, 110 mi. by water from the Pacific ocean, 143 mi. S.S.W. of Seattle, 700 mi. N. of San Francisco and 2,391 mi. from Chicago; a port of entry, the county seat of Multnomah county and the financial, commercial and industrial centre of the vast Columbia river basin. It is at the intersection of the Pacific and the Columbia River highways; is a station on the Pacific coast airway; and is served by the Great Northern, the Northern Pacific, the Southern Pacific, the Union Pacific and the Spokane, Portland and Seattle railways, electric interurban trolley and motor coaches, and more than 50 steamship lines with sailings to all the principal ports of the world. Portland's population was 371,011 in 1950, 305,394 in 1940 and 301,815 in 1930 by federal census.

The city covers 68.27 sq.mi. on both sides of the Willamette river, rising to heights commanding magnificent views of the river valleys and of the snow-clad summits of Mt. Hood, 50 mi. E. by S. (11,245 ft. high), Mt. Jefferson, Mt. Washington, the Three Sisters and other peaks of the Cascade range. The climate is mild and equable, with normal winter temperature 40.9° F., normal summer temperature 65.3°, annual 53.1° and an average annual precipitation of 41.6 in., of which 31.8 in. falls in the winter months. The annual rose festival in June is one of the famous events on the Pacific coast.

The city park system embraces 5,103.2 ac. and includes 54 playgrounds, 3 public golf courses, 64 public tennis courts, 48 softball diamonds, 8 swimming pools and a zoological garden. In one of the parks are the International Rose Test gardens of the American Rose society. Another park also contains an arboretum. There is a public auditorium seating 6,600.

The municipal water supply comes from the Bull Run river and its tributaries, whose main stem heads in Bull Run lake. The basin of the lake is separated from the snow-melt runoff from the summit of Mt. Hood by a drainage divide. The principal reservoir is Lake Ben Morrow, about 14 mi. downstream from Bull Run lake.



BY COURTESY OF THE PORTLAND CHAMBER OF COMMERCE

VISTA HOUSE ON CROWN POINT, NEAR PORTLAND

In 1913 the city adopted a commission form of government. The assessed valuation of property at mid-20th century exceeded $500,000,000.

Portland is the seat of the University of Oregon medical and dental schools, branches of the extension division of the University of Oregon; the Northwestern College of Law, the North Pacific College of Dentistry, Pharmacy and Optometry, the University of Portland, Lewis and Clark college, several private junior colleges and preparatory schools; and Reed college, founded by Simeon G. Reed and his wife (pioneers of 1854) and opened in 1910.

The fine fresh-water harbour has a shore line of 29.5 mi. within the city limits, 6.5 mi. of docks, berthing space for 100 vessels and 65 ac. of cargo space. More than $50,000,000 was invested by federal and municipal governments and private interests in channel improvement and port facilities. Rock jetties at the mouth of the Columbia protect the entrance and the river channel, which accommodates ships of 35 ft. draft at zero stage all the way to Portland. Port facilities are ample and modern. They include three municipal terminals, with cold-storage plants, a 2,053,800-bu. elevator, storage tanks for oil and molasses and efficient handling equipment; 32 lumber, 5 grain and 2 flour, 13 oil, 1 coal, 49 general cargo docks, privately owned. The waterborne commerce amounted to 7,857,118 tons in 1949, valued at $404,825,445. Foreign commerce amounted to 1,291,864 tons valued at $131,312,834.

Outbound cargoes consist largely of lumber, wheat, flour, canned and fresh fruits, paper and paper pulp, scrap iron, doors, furniture and ready-made houses, plywood, box shooks, battery separators, dried prunes and beans, onions and potatoes. Copra, coffee, burlap bags, sugar and bananas are leading articles among the imports. Portland is the leading wheat and lumber shipping port on the Pacific coast.

More than 45% of the manufacturing of the state is concentrated in the Portland metropolitan area. Lumber and lumber products in wide variety (shingles, sash, doors, windows, boxes, staves, shooks, furniture, ready-made houses, portable churches, barns and garages and many smaller articles made of wood) are the leading manufactures. Others of importance are flour, cereals, bran and feeds, meat products, fruits and vegetables, machinery, logging and contractors' equipment, aluminum, structural steel, automatic coal burners or stokers, oil burners, stoves, furnaces, and other metal products; woollen textiles and clothing; paper and paper products; plywood, leather and rubber goods.

Portland was founded in 1845 by Francis W. Pettygrove from Maine and Amos L. Lovejoy from Massachusetts, who owned jointly a government land claim. They tossed a coin to decide whether the site should be named Portland or Boston, and Pettygrove won. By 1849 the new town was a thriving community. The city was chartered in 1851. In the year 1860, just before the Civil War, it had a population of 2,874, which increased to 8,293 in 1870 and (despite a destructive fire in 1873) to 17,577 in 1880. In 1883 railway communication with the east was established by the Northern Pacific, and in 1885 the federal government began to improve the mouth of the Columbia. By 1890 the population was 46,385, and in 1900, after annexations of territory, 90,426. In 1905 an exposition and fair was held in Portland to celebrate the centennial of the expedition of Meriwether Lewis and William Clark to the region.

PORTLAND, ISLE OF, properly a peninsula on the coast of Dorsetshire, England; Chesil bank connects it with the mainland. Pop. of urban district (1938) 12,240. Area 4.5 sq.mi. It is 4 mi. long and nearly 1¾ mi. in extreme breadth, with an area of about 4½ sq.mi. The shores are precipitous, and Portland is inaccessible from the sea except toward the south. The highest point is the Verne hill in the north. A raised beach is seen at Portland Bill. The substratum of the island is Kimmeridge clay, above which rest beds of sand and strata of Oolitic limestone, widely famed as a building stone. In the dirt bed resting upon the Oolitic strata numerous specimens of petrified wood are found, some of great size. The Western Region railway and Southern Region railway have a joint line south from Weymouth to Portland and Easton.

On the isle are the famous prison buildings, now a borstal institution. Portland castle, built by Henry VIII in 1520, is generally occupied by the commander of the engineers or of the regiment stationed on the island. On a rock on the eastern side are remains of a more ancient fortress, Bow and Arrow castle, ascribed to William Rufus. They are in the grounds of Pennsylvania castle, built by John Penn, grandson of William, governor of the Isle of Portland and founder of Pennsylvania.

A harbour of refuge was built by the admiralty, 1847–62. A breakwater stretching northward from the northeast corner of the island partially enclosed a large area of water naturally sheltered on the south and west. An inner arm ran nearly east from the island to a masonry head and fort, and an outer detached arm bent north to a circular fort, a narrow entrance for shipping being left between the two. Two new breakwaters were built after

1895 to close the gap between the end of the outer breakwater and the Bincleaves rocks near Weymouth. The defensive harbour thus completely enclosed has an area of 2,200 ac. to the one-fathom line, of which 1,500 ac. have a depth of not less than 30 ft. at low water.

PORTLAND CEMENT: *see* CEMENT.

PORT MAHON, the capital and principal seaport of Minorca (*q.v.*), in the Spanish province of the Balearic islands. Pop. (1940) 14,301 (mun., 17,459). Port Mahon is on the east coast, at the head of a deep inlet which extends inland for 3½ mi. It is an important harbour. Mahon is the ancient *Portus Magonis,* which under the Romans was a municipium (*Mun. flavium magontanum*), probably including the whole island under its authority. As the name suggests, it had previously been a Carthaginian settlement. The Moors, who occupied Minorca in the 8th century, were expelled by James I of Aragon in 1232. Khair-ed-Din Barbarossa besieged and captured the city in 1535; and in 1558 it was sacked by a corsair called Piali. The British seized the island in 1708, and in 1718 declared Mahon a free port. In 1756 it fell into the hands of the French. Restored to the British in 1762, it was lost again in 1782. In 1802 it was finally ceded to Spain by the treaty of Amiens. Many of the houses date from the British occupation. The King's Island is so called as the landing place of Alphonso III of Aragon in 1287; farther southeast on the shore is the village of Villa Carlos or George Town; and at the mouth of the port, on the same side, are the remains of Fort San Felipe, originally erected by Charles V and twice the scene of the capitulation of British troops. Opposite San Felipe is the easily defended peninsula of La Mola (256 ft. high), which is occupied by extensive Spanish fortifications.

PÔRTO ALEGRE, a city and port of Brazil, capital of the state of Rio Grande do Sul, at the northern extremity of Lagôa dos Patos on the eastern shore of an estuary called Rio Guaíba, about 160 mi. from the port of Rio Grande at the entrance to the lake. Pop. (1950) 381,964 (*município* 401,213). There is a large foreign element, chiefly German and Italian. The city has rail connection with all the main lines in the state. The Rio Guaíba, which is not a river, was once called "Viamão" because its outline is roughly that of the human hand, the rivers entering the estuary at its head corresponding to the fingers. The lower channels of these rivers (the Gravataí, Sinos, Caí, Jacuí and Taquarí) are all navigable. Foreign trade is limited to light-draught steamers able to cross the bar at the entrance to the lake.

The city occupies a tongue of land projecting into the estuary, and extends along its shores. The climate is cool and bracing in winter but hot in summer. The mean annual temperature is slightly less than 69° F., the average maximum being a little more than 82° and the average minimum 59°. The annual rainfall is about 30½ in. The city is laid out with broad streets. It is the chief commercial centre of the state, has shipbuilding yards, and manufactures cotton fabrics, boots and shoes, iron safes and stoves, carriages, furniture, butter and cheese, macaroni, preserves, candles, soap and paper.

Pôrto Alegre was founded in 1742 by immigrants from the Azores and was first known as Pôrto dos Cazaes. It was made a *vila* in 1803, and in 1807 the transfer of the capital from Rio Grande to Pôrto Alegre was officially recognized. In 1822 it was raised to the rank of a city, and in 1841, as a reward for its loyalty in revolutionary wars of that province, it was distinguished by the title of *leal e valorosa* (loyal and valorous). The first German immigrants to settle near Pôrto Alegre arrived in 1825, and much of its prosperity and commercial standing is due to the German element.

PORTO FARINA, a town of Tunisia about 20 mi. E. of Bizerta, on the Ghar-el-Mela, a lagoon, also known as the Lake of Porto Farina, at the mouth of the Mejerda (the ancient Bagradas). Porto Farina was the naval arsenal of the piratical beys of Tunis and was bombarded by the English under Adm. Robert Blake in 1655.

Ruins 10 mi. S.W., near the village of Bu Shater, are identified with the ancient Utica (*q.v.*).

PORTO MAURIZIO: *see* IMPERIA.

PORTO NOVO, a town of India, on the Coromandel coast in the South Arcot district of Madras, 144 mi. from Madras by rail. Pop. (1941) 14,175. It is famous for the battle in July 1781, in which Sir Eyre Coote with 8,000 men defeated Hyder Ali with 60,000 and saved the Madras presidency.

PORT OPERATION. The term "port operation" includes the receiving of ships in harbour, putting them in position to discharge or load their cargoes, the handling of the cargo and its dispatch to or reception from inland destinations. The primary aim of all modern dock operation is to give ships quick dispatch, *i.e.,* to keep down the time in port.

Before the cargo can be distributed it has to be landed, sorted to the various bills of lading, passed by the customs' officers, customs' and port charges paid, and the goods released by the shipowner to the merchant.

The shipper when dispatching goods receives from the master of the ship a bill of lading, which is a negotiable document of title and which he sends to his consignee. While the goods are in the ship they are by law the property of the shipowner, and he has a prior lien on the goods for his freight. This lien is removed by the consignee taking the bill of lading to the shipowner and paying the freight, receiving in exchange a release, which is the authority to the port authority or wharfinger to deliver the goods. But in order that the discharge of the ship shall not be delayed while the consignees are obtaining releases, the discharge of the goods is commenced at once into the transit sheds alongside. These transit sheds are, in the eye of the law, part of the ship. So long as the goods are in the transit shed the shipowner retains his lien for freight, and the port authority cannot allow the goods to leave the transit sheds until a release has been produced.

In the case of goods liable to customs' duty for which it is not desired to pay the duty at once, they are after being released passed under customs' guard into bonded warehouses. In the case of goods of high customs' value, such as wines and tobacco, the goods usually remain in bond until passed into consumption, the owner thus being relieved from the premature payment of heavy duty. Both transit sheds and bonded warehouses have, therefore, to be under double locks of the customs and wharfinger respectively, so that goods can be handled only in the presence of both parties.

To protect the customs, goods can by British law be landed only at duly authorized landing places called "legal quays" and "sufferance wharves," the only difference between these terms being that the first is a permanent licence issued by the treasury, and the second a restricted licence issued by the commissioners of customs. The services of the officers of the customs for watching goods in course of discharge in ordinary hours are paid for by the state, but all overtime is at the cost of the ship, and as customs' hours do not coincide with port hours, a ship working the ordinary hours has to pay at least one hour of customs' overtime, and more if she is herself working overtime.

Rough cargoes such as ores, timber, etc., which do not require shelter, are landed at open quays, and the limitation of the shipowner's lien sometimes gives rise to difficult questions.

In the days before free trade, when nearly all goods were dutiable, it was the British custom to constitute a customs' area of the whole dock estate and to secure it within high walls and massive gates. These will still be found in the older ports, but in modern times it has become the practice to localize the control at sheds and wharves, and transit beyond these limits is free.

Custom of the Port.—A shipowner by his contract of carriage undertakes to deliver to the consignee the goods according to the bill of lading, which implies that he has to separate one man's goods from other people's goods and deliver each in one parcel. But this general rule of law is materially affected by the local custom of the port which varies everywhere and is a cause of much dispute and litigation. In some ports the custom ordains that the ship shall put the goods on the quay indiscriminately and the work of sorting and removal is at the charge of the merchant; in some cases, goods are removed from the crane slings by one party, sometimes by the other, or again shared by the two parties. In some exceptional cases the cost of craning the

goods from the hold is held to be on account of the merchant. For these reasons comparison of the working charges of different ports is always difficult.

The large cargoes now carried and the very mixed nature of the commodities necessitate in most cases landing on the quay for sorting before delivery. This requires much floor area, and has led to the introduction of two or more floor transit sheds to avoid excessive congestion of the cargo when landed. And for the subsequent delivery of these goods by rail or road, special facilities are needed. A single cargo of 8,000 tons of general cargo, if all had to be despatched by rail, would require 1,000 trucks to take it away. These trucks would occupy 3,000 yards of railway, which is some measure of the amount of siding accommodation which has to be provided for the efficient working of a discharging berth and also the great relief obtainable when a large part of the work is done by barge. The movement of these trucks has to be performed without interference with the work at adjacent wharves; hence the proportions which the three methods, barging, railway and road transport, bear to each other must largely affect the design of the shore equipment of a port.

The quick and economical movement of cargo is now largely obtained by the provision of mechanical appliances in substitution for manual labour, and the main staples when arriving or being despatched in whole cargoes, or in large quantities in mixed cargoes, are usually dealt with by special machinery, *e.g.*, for export, coal, and for import, grain, timber, meat and provisions, for all of which specially designed conveying machinery is installed at every port where the tonnage is sufficient to justify the expenditure. Mixed cargoes are discharged either by cranes on the shore or by the ship's gear. Such equipment is usually provided by the port authority.

The Provision of Port Machinery.—But as ships are often required to receive and deliver cargo in the open roadstead or at ports abroad not equipped with shore appliances, they must necessarily be fitted with booms and winches, and it is, therefore, often economical to make use of these appliances even when shore plant is available. In practice, however, competitive reasons compel port authorities to provide cranes, and in many cases more specialized working plant. Coal is shipped by means of (a) tips or hoists in which the wagon is lifted to a height above the ship's deck and the contents tipped into a shute to fall into the hold, (b) staithes, when the configuration of the ground permits, where the wagon is pushed to above deck level and the contents tipped into the hold, and (c) conveyors in which case the wagon at quay level is discharged on to a conveying band to the hatch. The last method is coming into increasing use. Grain is now mostly imported in bulk and is discharged by means of elevators which lift it in a continuous stream from the hold, convey it to the quay, and there deposit it on to conveying bands which carry it to silos where it is either stored or delivered by gravity into sacks for inland transport. These elevators are of either the bucket or the pneumatic type. When grain is imported in sacks the modern practice is to cut the bags in the ship and "start" the contents into bulk for discharge by this more economical method. Grain elevators may be either fixed on the quay or mounted on floating pontoons. The latter, though more costly, has the advantage of greater mobility. Grain discharging machinery has been passing through many stages of evolution during the last twenty years, and the pneumatic type seems to be gradually getting established. For inland transport in England and on the Continent (in contrast to all countries in America) the uneconomic method of carriage in sacks is still prevalent, but a small beginning has been made with bulk transport by rail.

Ores are now generally discharged by grab cranes which are self-filling and save the labour of loading into tubs. Iron is largely discharged by means of an electrified block on a crane which attracts the iron and when over the selected site releases by cutting off the current. Petroleum is usually discharged through pipe lines from the shore storage to the quays. This pipe is connected by means of a flexible hose to the ship's tank and pumped to the storage tanks. The same method is employed for vegetable oils and for molasses where the volume of trade is sufficient to justify the cost of the installation.

With free trade and the removal of customs restrictions, the tendency is increasing for the importing merchant to sell his goods "ex ship," and for goods to pass at once on discharge into consumption, but raw materials are still largely stored in dock warehouses or in adjacent warehouses of private owners for later consumption. Such deliveries are largely of a retail nature, and many of the chief ports have provided elaborate facilities for the storage, sampling, handling and accounting of warehoused goods. This branch of activity prevails in British and in some American ports more than on the Continent of Europe.

Rail Terminals and Docks.—At ports where barging is not the predominant method of handling cargo and at all modern ports to a greater or less degree, the railway facilities are an important feature as affecting the cost of distribution. There is great variety of method. At some railway-owned ports the docks are treated as a terminal goods station under main line control. At others, the railway working is self-contained under the docks superintendent. This affects the design of the railway system and the methods of working. In non-railway docks in some cases the railway company is given running powers to the quays, in others the port authority conducts its own railway operation. As in every properly conducted dock the first and principal aim is to give the ship despatch and with that object to avoid, by its rapid removal, the congestion of cargo at the ship's side, modern practice is to confide the control to the authority responsible for the despatch of the ship, providing an area away from the ship where the traffic is interchanged with the main line railway. In the United Kingdom this area is called the "exchange sidings"; in America the "belt line." One or more such points of interchange may be provided in accordance with the physical conditions of the main railways serving the port.

The post-war development of road transport has imported a new problem into the question of dock layout, and the need for providing facilities for economical loading to road vehicles in docks equipped only for loading to barge and rail requires many modifications of design.

Port Ownership.—The several descriptions of port ownership and operation may be classified under the following heads—(1) National ownership, (2) Trust ownership, (3) Municipal ownership, (4) Railway ownership, (5) Private ownership.

(1) *Examples of National Ownership Are*:—Rotterdam, and all the larger French ports. None are to be found in the United Kingdom except naval dockyards which do not come within the scope of this article.

(2) *Examples of Trust Ownership Are:*—In England, London and Liverpool; in Canada, Montreal and Vancouver; in United States, New York and New Orleans; in Australia, Sydney and Melbourne.

(3) *Examples of Municipal Ownership Are*:—In England, Bristol and Preston; on the Continent, Hamburg, which is the property of the Free City of Hamburg, and might perhaps be classed under national ownership; and Antwerp, the financing of which is divided between the State and the City.

(4) *Railway Ownership.*—Before the amalgamation of the railways of Great Britain in 1921 a number of docks were railway-owned, some having been acquired by railways when they had difficulty to maintain themselves as independent authorities, examples—Southampton, Hull; and others had been constructed by companies which, though nominally railway companies, were mainly ports (examples Cardiff and Newport), to serve the surrounding coal fields. Abroad the outstanding example is South Africa where all the ports are worked as part of the State owned railways. A few examples may be found in the United States, but the tendency in that country is to separate the port and railway ownership.

(5) *Private Ownership.*—In the United Kingdom few ports are to be found in this class, but the Manchester ship canal and the Gloucester Docks and Canal Company may be instanced.

The acceptance as a national liability of a larger or smaller proportion of the cost of construction, maintenance and working of a port prevails on the Continent much more largely than in

the United Kingdom. For example, at Rotterdam and Antwerp the construction, dredging and maintenance of the harbour up to quay level are carried out by the State, as a national charge against the general revenues of the country, the super-structure above water level only being provided by the municipality and being the only portion of the charges to be recovered from the trade passing through the port. This is a potent cause of the lower charges prevailing on the Continent as compared with the United Kingdom. Under the policy which has generally prevailed in the United Kingdom of non-intervention by the State, economic forces have been allowed free play.

Public Ownership.—In the British dominions the policy of state or national ownership is almost universal, but the methods differ widely. In Australia the ports are financed by State loans and administered by nominated commissioners under the control of the Minister for Public Works; in South Africa, they are combined with the State owned railways under the general manager of the latter; in New Zealand and in India the ports finance themselves, but with the Government guarantee behind them, and are administered by a State appointed chief commissioner assisted by commissioners elected by the users of the port with, in some cases, representatives of the local inhabitants. In Canada ownership and administration are with the several States through the agency of nominated commissioners.

Port trusts are statutory bodies not working for a profit but they are obliged, in order to keep themselves solvent, to levy charges high enough to cover all their outgoings. The capital account has to bear all the cost of construction and equipping the port, and the revenue account has to bear the interest and sinking fund on such capital expenditure. Charges, therefore, have to be fixed so as to bring in sufficient revenue to pay this interest and sinking fund in addition to current working expenses. Surplus revenue is applied either to improving the facilities or reducing the charges of the port.

Municipal ports can, if the owners so desire as a matter of policy, be subsidized out of the general rates of the city, and in England these are the nearest analogy to the national ports of the Continent. As port works from their nature take a long time to construct, and as new trade offering naturally cannot wait while facilities are being provided, it is necessary if a port is to maintain its position to provide facilities in advance of the current demand. It is, therefore, in the power of a municipality, if it is prepared to accept a present burden upon its rates in the hope of being eventually recouped, to provide for the future to an extent which private enterprise cannot afford. In some cities of the United States the practice prevails of levying a specific rate on houses and property in aid of port improvements, and an early example in England is the case of Bristol, the largest municipally owned port, which from 1849 to 1897 levied a rate of £4,000 a year on houses for port purposes. Since the last date this levy has been merged in the general rate-in-aid to balance the revenue account which, however, for many years has been less than the annual contribution towards the sinking fund for the extinction of the capital.

Railway-owned docks also can, subject to certain provisions of the Railways Act of 1921 under which all the railways and their ports were amalgamated into four grouped systems, similarly meet any shortage of earnings of the port out of their general revenues, and this power similarly enables them to indulge in a more generous provision of facilities beyond the immediate needs of the trade in order to provide for future development.

Private Ownership.—In the case of the fifth class of ports, the property of private companies, the same end can only be obtained by the shareholders foregoing their dividends during a long fructifying period, which has actually been the experience of both the ports named above. In fact, in the case of the Manchester Ship Canal Company, now the outstanding example of a successful company port, the period of fruition was so long delayed that its capital and credit were exhausted and the Corporation of Manchester had to come to its aid by the provision of additional capital on which it had for a period to forego interest, and in consideration of which it was entitled to representation on the board of directors. But as the management is still with the company's directors, the classification of the undertaking here adopted remains correct.

The decadence of so many English ports under private ownership may be traced to this natural law. Ports constantly tend to become out of date owing to the increasing size of ships, and are faced with the alternative of seeing their present trade depart or of undertaking expenditure on which the return must be far distant, and which often proves to be beyond their unaided resources. London and Bristol, Southampton and Hull are examples of company owned undertakings which were becoming derelict when they obtained outside aid—the first absorbed by a powerful trust under the direct aegis of Government, the second by the local authority, and both have become self-supporting. The last two, though returning large profits to the railway companies which own them, have never directly given a commensurate return on their cost. Immingham and Fishguard, both railway owned from the beginning, have never been remunerative undertakings to their owners, or any great advantage to the trade of the country. The relation between the several classes of ports in the United Kingdom has been largely affected by the Railways Act of 1921 under which the great railway systems have become great port proprietors in competition with others dependent on their own resources. This implies a combination of the two systems of extraneous subsidy and self-containment, each of which has been applied successfully in some countries, but never before both in the same country, and it will be some years before the result can be determined.

Functions of Port Authority.—The functions of a port authority may be classified as conservancy and dock-ownership. The first head comprises all operations connected with making the port available for shipping, maintenance of navigation channels, surveying the same, buoying and lighting, removal of wrecks, signal service, pilotage service, supervision of foreshore to prevent interference with navigation channels.

The conservancy boundaries of a port are laid down in its Acts of Parliament, or in the case of ancient ports may be derived from Royal Charters, and if any portion of those waters form a highway to other ports, the lighting and charting of that portion is usually undertaken by the State, *e.g.*, Trinity House for English waters, and the Scottish Board of Lights for Scottish.

As dock owners the authority provides the equipment necessary for the accommodation of ships, their loading and discharging and the movement of their cargoes, including the provision of transit sheds, cranes and other cargo working machinery, power plants, railway lines and roads, etc.: "facilities," as working of lock gates (if any), lighting, berthing masters and everything necessary to enable a ship to get with safety to a position to discharge and load its cargo, and "services" which include everything connected with the handling of cargo, discharging or loading, receiving, sorting, despatching and storing. "Facilities" are necessarily provided by the dock owner. In regard to the rendering of "services," the practice varies within wide limits. In some ports these are rendered by the dock owners in whole, or in part. In others, the policy is to leave the services to private enterprise. The Port of Manchester is the only example in the United Kingdom of a statutory monopoly of all the services within the dock area, but all ports have power under their acts to provide services and to make "reasonable" charges therefor. The policy however, differs materially in the various ports, some encouraging departmental working, and others favouring separate private enterprise. The principle of a complete monopoly of all services within the port limits is more prevalent in foreign ports.

The growing tendency to provide large scale equipment for handling staple commodities makes it seem possible that in the future, despite the objection that it would deprive the ship owners of the advantage of competition, economic reasons will force the more general undertaking of services by dock owners and the acceptance of the position by ship owners. In the case of Manchester the powers giving the authority the exclusive right are coupled with the proviso that their charges to their customers must not provide more than a ten per cen

profit, and it is a generally accepted principle of port finance that the several departments, viz., conservancy, facilities and services should each be separately self-supporting, though many exceptions to this rule may be found.

In some cases the two functions of conservancy and dock ownership are combined in one authority; in others, they are under separate ownership and administration. There is considerable difference of opinion as to which is the better system, but it is perhaps more generally held that more satisfactory co-ordination can be secured, and therefore better efficiency and economy obtained when both functions are combined in the same authority. This is the case in most of the larger authorities of the United Kingdom, *e.g.*, London and Liverpool. Examples of ports where the conservancy authority is separate from the dock-owning authority are Southampton, Glasgow, Newport. There are cases also of which the following are examples—the East Coast rivers, the Tees, Tyne, Tay and Southampton—where the conservancy authority owns some docks, but other docks to a greater or less extent are provided either by the local railway company or by the local corporation. This entails a division of responsibility which it is sometimes complained leads to the neglect of the needs of trade.

Port Revenues.—The revenues of port authorities are principally obtained under the following heads: as conservancy authority, light dues, pilotage dues, and sometimes tonnage dues levied entirely on the shipping; as dock authority, dues on shipping calculated on the net register ton, import and export dues on the cargoes. Subsidiary, but sometimes very important, items of revenue are:—profits on the handling of cargo, warehousing, railway working round the docks, and rents of lands.

Most ports endeavour to obtain sufficient land to establish industries in the immediate neighbourhood of the docks, and owing to the high cost of inland transport, and the fact that with most commodities the finished article weighs less than the raw material required to produce it, the tendency is continually to move industries more and more from inland centres to the coast in the immediate neighbourhood of the great ports, and when possible to obtain the economic advantage of establishment within the dock area to avoid the cost of intermediate railway or road haulage.

A problem in port economics which has always been the subject of much difference of opinion is the proper distribution of the burden as between the ships and the goods they carry. The principle generally accepted is that the burden should be divided as equally as can be between the two, but this has many exceptions. Some ports adopt the policy of making the charges on shipping very light with a view that thereby freights will be kept low, greater cargoes obtained, and the revenue recouped from the tonnage of those cargoes. Other ports hold the view that the incidence of the port charges on the total expenses of a voyage is so small that it cannot affect the freight, and low charges on goods encourage manufacturers and merchants to use the port. This is the policy of all the railway-owned ports whose dues on goods are not only fixed on a low basis but who frequently render services for less than cost, recouping the cost from the profits on railway haulage.

An important factor affecting the quantum of port and harbour dues is the nature and the cost of the works necessary under the particular physical conditions of each harbour. In the United Kingdom, owing to the great variation of tides, it is in most cases necessary for the efficient working of ships to maintain a constant level in the docks by impounding the water within lock gates (a notable exception is Southampton, which has been favoured by nature with four tides in the 24 hours, reducing the difference between high and low water to a few feet). The Pacific and Indian oceans and the Mediterranean sea on the other hand, with their low rise and fall of tide, enable their ports to dispense with such expensive equipment, and the great ports of these oceans, Sydney, San Francisco, Singapore, Marseilles, etc., are examples where the features of the port as left by nature have been almost entirely retained. For this reason the capital cost, as measured by the accommodation afforded, is much lower and is reflected in the lower scale of dues which can be imposed.

The working expenses of a port are for the greater part of the nature of fixed charges, *e.g.*, interest and depreciation on the capital cost of the accommodation, working of the entrances which are the same whether they lead to few or to many berths, and whether the berths are occupied or not, and those expenses have to be distributed, as a rate per ton, over the shipping using the port. Hence economy of port charges can be obtained by concentrating the trade of a country into a few ports. But this may involve a longer and more expensive carriage to point of origin or destination, and there is constant play of these contending forces. England is a small island with a comparatively large number of ports. On the Continent of Europe, on the other hand, the area of distribution or collection runs into many thousands of square miles served in almost all cases by waterways concentrating in the mouths of a few great rivers. The number of ports is, therefore, fewer and the tonnage concentrated in each much greater than in Great Britain allowing of lower dues per ton to obtain the necessary revenue.

In England, again, the inland transport has mainly to be made by road or rail. On the Continent of Europe the goods are carried for the most part on waterways of a width and depth to take barges sometimes nearly as large as ocean-going ships.

Comparison is frequently made of the charges in English and Continental ports to the disadvantage of the former. The explanation can be found in the foregoing paragraphs, and may be summarized as—

(a) Substantial national expenditure not brought on to the port's accounts.

(b) Concentration of a greater tonnage over which to spread the fixed charges and

(c) The larger units and therefore the lower cost of transfer from ocean to land transport. (D. R.-J.)

IN THE UNITED STATES

The outline in the preceding article with respect to port operation in the United Kingdom is generally the operation found in the United States. The obligation of the steamship owner or the master, the method of cargo handling, customs regulation, provisions for customs custody and protection, are practically the same. The placing of all American port facilities under customs protection, however, depends upon the magnitude of the port's trade and the facilities with which the trade subject to customs supervision, operates. Ports commonly have all piers, or certain sections, supplied by supervisory customs agencies for the protection of customs and to facilitate the movement and clearing of merchandise. Likewise, bonded warehouses or bonded transit sheds have grown up, and the general system of providing customs facilities is similar to that of the United Kingdom.

Berthing Facilities.—A principal difference between English and American operation is in the type of facilities. In the quay system, generally adopted in European ports, the berthing structure runs parallel to the shore line and retards expansion because of the cost of land. However, this system probably provides the cheapest form of transfer from ship to shore, and is widely used. Newly created American ports have adopted, where possible in view of the cost of the necessary land and the saving in the cost of construction, the quay system. Generally, this development in America has been limited to ports built up a stream on rivers because of current conditions, lack of space and the difficulty of projecting piers at right angle to the shore line out into the stream.

The ports which avail themselves, for development purposes, of natural coast-line harbours such as Boston, New York and Newport have all adopted the pier system: the building of the structure out into the stream perpendicular to the shore line. The advantages of pier construction are: (1) increased berthing space, (2) building of facilities without interruption to the navigation of the stream itself, (3) less land per pier is required than that which would be used for a quay capable of berthing the same number of ships. A pier, suitable to accommodate four average ocean freight steamers, can be erected using only approximately 400 ft. of shore land whereas a similar structure built on the quay system

would use approximately 2,500 ft. of shore front. The pier system has led to a somewhat different method of operation both respecting the loading and discharging of cargo as well as to the general port operation with respect to supporting warehouses and transferring facilities.

Mechanical Handling.—A great difference in the operation of ports in the United States and those of other countries is the absence of so-called mechanical appliances on American piers. The mechanical appliances required on the piers or quays to assist or to totally load and discharge cargoes is dependent upon the class of ships being handled. The steamships operating between American ports and other parts of the world are fully equipped to handle freight from and to the ship and the pier. No necessity has existed therefore for the installation of handling appliances on berthing structures such as are commonly seen in foreign ports.

Berthing Charges.—Another difference in European and American port operation is in business methods. Under the American system the steamship company assumes the entire charge for the berthing of the ship—paying for its berthing as well as its pier space which it uses to discharge or assemble its cargo. The shipper generally does not have imposed upon him any additional or auxiliary charges other than the freight rate which the ocean craft makes for the ocean movement or the flat rate which the inland railroad may charge for the movement to and from the port and to and from the particular pier at which a ship awaiting or discharging the cargo may be berthed.

With no progressive ocean freight or inland freight charge there is no inducement to the merchant, the shipper or consignee, to move his merchandise in any particular fashion which might reduce the cost of such movement, except where speed may be a factor. Moreover, because of the length of time which the merchant is given to move his material and because of certain local customs, the merchant prefers to have all of the merchandise discharged to the dock, sorted out and there held, availing himself of the opportunity of selling direct from the dock or holding in case of a lower market. Thus the American system of handling merchandise at ports respecting international trade, involving the co-ordination of the inland system of transportation with the ocean system of transportation, is carried on in a relatively expensive manner. This being true, and the expenses being borne by not more than two parties—the owner of the steamship or the inland system of transportation—has caused the erroneous statement to be made that the cost of handling freight in American ports is lower per ton than in European ports.

Location and Development of Ports.—A tendency to develop greater inland ports has been noticed in recent years. Notable instances are the Canadian port of Montreal, and, in the United States, the artificially created port of Houston, Texas, also the agitation for the St. Lawrence waterway development. This latter is an effort to make ocean ports out of strictly lake ports and other interior points. Location of American ports near the coast-line generally has been possible because of favourable geographical advantages. Illustrating the advantages in this respect are the ports of New York, Norfolk, Newport News and Boston. Competition in sections of the United States for the creation of port facilities has caused some States to create ports artificially and to take other means than the general development of that of the older and more important ports on the Atlantic coast. This has sometimes led to the erection by public agencies of facilities operated at a loss in order to attract tonnage from the more important and older ports.

Until quite recently all port development in the United States has been of a private character while that of many other countries has been carried on by sovereign authority, either national, State or municipal and in many instances by a combination of the three, or through the activity of railroad companies. In 1928, however, there was a tendency to establish the development of ports by quasi-public bodies. The reason for this change of attitude is the increased importance placed on ports which the conduct of governmental operations under emergencies of war brought vividly before all public officers and public bodies. Moreover the development of ports situated in adjoining States has been of such great value to industrial progress, that the building of "outports" or smaller ports is being vigorously prosecuted. Thus due to the difficulty of development by private interests of a system of public control, the construction and operation of ports by the creation of "port authorities" is rapidly spreading.

The recently established American port authorities follow, in many respects, the fundamentals and basic organization of the port authorities of other countries. The water-front facilities have become so important to the place at which they exist that it has become a matter of police power of the sovereignty to see that public rights are protected. However, with the conflicts which exist in the legislation of some 48 States, there is no single method of port authority control in the United States. Some port authorities are organized without actual power to purchase, construct or operate port facilities but have police power. Others are formed with police power and with an indirect authority to purchase, construct, manage and operate port facilities on the basis of issuance of bonds, but without the credit of the State pledged to such bonds. Such port authorities have advantage of the low interest rates of sovereignty which creates it. In this respect alone, such authorities have an advantage in the matter of development not within the power of the private enterprise. The port authority is generally not subject to real estate taxes and other taxes which the private enterprise must bear. With this advantage, a development is more easily originated and carried to conclusion by a sovereign power operating through its agency of the port authority than might be expected for a development of the same facility by private capital.

Some of these adventures by quasi or public agencies representing a sovereign power have been attended by marked success, but the value of this phase has not been fully demonstrated to the degree of ownership, control, management and operations such as similar institutions in other countries have demonstrated. Federal regulation of ports rests with two departments of the Government. The War Department has exercised its power through the Corps of Engineers of the U.S. army. Since the World War, legislation has been passed which has placed in the hands of the War Department the duty of assisting in the matter of the development of ports and protection of ports to a greater degree than heretofore existed. Legislation creating the U.S. Shipping Board, likewise instituted a control jurisdiction over ports in certain respects by this body, comparable to that which the Interstate Commerce Commission exercises over the interstate commerce of the country by railways. (P. L. G.)

PORTO-RICHE, GEORGES DE (1849–1930), French dramatist, born on May 20, 1849, at Bordeaux. In 1873 his pieces in verse began to be produced at the Parisian theatres; he also wrote some books of verse which met with a favourable reception, but these early works were not reprinted. In 1898 he published *Théâtre d'amour*, which contained four of his best pieces, *La Chance de Françoise* (1888), *L'Infidèle* (1890), *Amoureuse* (1891) and *Le Passé* (1897). The title given to this collection indicates the difference between the plays of Porto-Riche and the political or sociological pieces of many of his contemporaries. In Germaine, the passionate and exacting heroine of *Amoureuse*, Mme. Réjane found one of her best parts. In *Les Malefilâtre* (Odéon, 1904), also a drama of passion, the characters are drawn from the working classes. Later plays are *Le vieil homme* (1911) and *Le Marchand d'Estampes* (1914). He published in 1920, under the title *Anatomie sentimentale*, extracts from his works which well illustrates his sense of the inevitableness of the continual duel between men and women. He was a member of the French academy, and director of the Bibliothèque Mazarine. He died Sept. 5, 1930.

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PORTO RICO or PUERTO RICO (second spelling restored by the U.S. congress in 1932) is an island dependency of the United States. It is the most easterly of the Greater Antilles situated between 17° 50′ and 18° 30′ N., and 65° 30′ and 67° 15′ W. Its northern boundary is the Atlantic ocean, its southern the

Caribbean sea, its western the Mona passage, its eastern the Virgin passage. It is situated about 70 mi. E. of the island of Haiti, and about 40 mi. W. of the island of St. Thomas, one of the Virgin Islands, and about 1,400 mi. S.E. of New York city. It is nearly rectangular, with an average length from east to west of about 100 mi. and a width of 35 mi. to 40 mi. Its approximate area is 3,435 sq.mi.

Topography.—The island is the eastern extremity of a chain extending east and west more than 1,000 mi. and the northern extremity of a chain of smaller islands more than 600 mi. in length reaching to the northern coast of South America. These islands are the summits of submerged mountain ranges. The deep-sea soundings north of Puerto Rico disclose one of the most profound chasms on the globe, known as Brownsons Deep. It measures more than 27,000 ft. The surface of Puerto Rico consists of plains from the mountains to the sea, while the interior and much the larger portion of the area consists of an irregular series of mountain ranges, the highest rising to an altitude of more than 4,000 ft. These ranges extend from east to west across the island, but are broken in formation, with intervening valleys of surpassing fertility and beauty. The rivers are not navigable except for a short distance from the coast, but afford an abundance of water power and a supply of water for irrigation of the coastal plains and for the towns. The coastal plains are narrow on the southern slope. The principal mountain ranges are of the same geological period and of similar origin. They are of mixed volcanic and sedimentary formation, consisting chiefly of hornblende, gneiss and tuff, embedded in which, at the higher altitudes, are masses of blue limestone of the Cretaceous period. There is much underground drainage, the rivers often disappearing in chasms to reappear at a distance. Many of the mountains are honeycombed with caves, in some of which are found interesting Indian relics.

Gold mines were worked in the mountain regions and in the beds of the streams for several years in the first century of the Spanish conquest. According to official statistics, 2,700 lb. of gold were shipped to Spain from 1509 to 1536. This was probably the part belonging to the crown of Spain, being one-fifth only of the amount secured. Some is still to be obtained by washing in the streams, but regular work has long been abandoned. Silver, lead and copper in small quantities were also discovered. Magnetic iron is found in some places. Marble deposits of the highest quality can be found. Granite suitable for building is also found. Limestone, gypsum, clays suitable for brick, tile and rough ceramics are abundant. Kaolin suitable for the manufacture of porcelain is also found. No coal nor oil has so far been discovered. For the most part the mountain ranges are covered by erosion deposits forming a soil of deep, reddish clay loams and tenacious red clays.

Climate.—Puerto Rico is situated just within the torrid zone, but its climate is hardly tropical. The mean January temperature for the island as a whole is 73° F., and the mean July temperature is 79°, a range of only 6°. The highest afternoon temperature is 86° and the lowest night temperature 68°. In the city of San Juan the highest temperature recorded was 94° and the lowest 62°. The mean annual temperature for Puerto Rico is 76.5°. In the higher interior regions the mean temperature varies from 70° to 76°, according to the elevation above sea level. The diurnal change in temperature from day to night is from 6° to 7°.

The average rainfall is 70 in. For the north coastal region it is about 60 in., for the south about 30 in., and for the central mountain portion about 100 in. This uneven distribution has been in part overcome by the irrigation systems. Winter rains are comparatively light, with a slight increase from February to May; thereafter the general average is maintained throughout the summer months. The rainfall is generally heaviest from September to November. The rains are sometimes heavy, but are usually of short duration. The average humidity during the day is about 70%, and during the night about 85%.

The trade winds, aided by the daily recurrence along the coasts of the cool, invigorating sea breeze, constitute a most beneficient provision in the tropics. This is especially true in Puerto Rico. It is situated far out in the Atlantic ocean, nearly 1,000 mi. from the mainland. Thus it receives in full measure the trade winds which blow almost constantly from the northeast, veering sometimes to the east and southeast.

Puerto Rico is in the storm belt of the Caribbean region and is subject to occasional visits from the West Indies hurricanes. Fortunately these visits have been rare. Most of these storms occur from July to October.

Fauna and Flora.—Most of the domestic animals are now found in Puerto Rico. Bats, dolphins and manatees are the only indigenous mammals. Thus far 162 species and subspecies are recorded for Puerto Rico and the neighbouring islands. Birds of prey are rare. There is but one species of snake and specimens are rarely seen and are harmless. There are several types of the lizard group, feeding mostly on insects. They are harmless, and beneficial to plant life. There are five species of turtles, both of the small and large varieties. There are 291 species of fish.

The physical conformation of Puerto Rico, rising as it does from low coastal plains to mountains sometimes with altitudes of 4,400 ft., covered in most places with a generous and productive soil, is such as to furnish an astounding variety of plant life. The National Forest reserve at Luquillo is a typical tropical forest with original growths of all kinds almost jungle-like in density and variety of tree, vine and shrub life. Compared with this the carefully cultivated orchards of the fruit-growers afford a contrast most striking and interesting.

It is probable that before the coming of the Spaniards the entire island was densely wooded. Now little of the original forest growths remain; but there are coffee plantations, coconut groves, fruit farms and ornamental flowering trees and shrubs both indigenous and imported. There is a long list of what might be considered the common useful trees, among which are the bamboo, palm, cedar, ebony, calabash, whitewood, lancewood, boxwood and logwood. Among the fruit-bearing trees and shrubs are the avocado or alligator pear, orange, lemon, lime, grapefruit, almond, cacao, coffee, coconut, nispero, pomegranate, gooseberry, raspberry, guava, banana, *plátano,* breadfruit, mango and papaya. Almost all the food plants are grown in Puerto Rico. Among the medicinal, useful and rare plants may be noted chicory, indigo, vanilla, castor, plumbago, ginger, sisal, mallow, patchouli, salvia, elder and aloe.

History.—Puerto Rico was discovered by Columbus on his second voyage to the new world, Nov. 19, 1493. He landed on the western coast and took possession of the island in the name of Ferdinand and Isabella of Spain. This landing was the first and only time the feet of Columbus trod the soil of what is now United States territory. After replenishing his supply of water Columbus proceeded to Santo Domingo, first naming the island San Juan Bautista in honour of Prince Juan, heir to the Spanish throne. Occasional visits for supplies were made subsequent to the discovery, but no attempt was made to establish a colony until many years later. There was a marked difference between Columbus' first and second voyages. After months of trial he had at last been able by favour of the queen to equip his three small craft and collect a nondescript crew of 90 men to set sail on an unknown sea westward to an unknown destination. But when he returned, giving undoubted proofs of his discovery, he at once became a hero. On his second voyage 17 ships and several smaller craft and more than 1,500 men joined in the venture. Among the hidalgos and persons of rank who were eager to share with Columbus the expected glories and riches of the voyage was Juan Ponce de León. After a stay in Santo Domingo of about 15 years, during which time he rendered valuable service to the colony, Ponce de León persuaded the governor to supply him with ships and men to make an exploration of the island which Columbus had named San Juan Bautista. With these he sailed in 1508 and landed first at the point he had visited with Columbus. Pursuing his voyage along the north coast toward the east he discovered the bay which afterward became the harbour of San Juan. Because of its excellence the explorer gave it the name of Puerto Rico or Rich Port. By a strange inversion the bay and capital city became San Juan and the island became Puerto

Rico. Being favourably impressed, Ponce de León secured colonists and supplies in Santo Domingo and founded a settlement, known as Caparra, near the harbour in an almost inaccessible location among the foothills. The situation was unfortunate and the colony moved to the island in the harbour on which is now located the city of San Juan. In 1510 Ponce de León became governor by order of King Ferdinand. Explorations were made with a view of finding gold but without much success, and the future did not seem promising for the colony. Trouble with the Indians threatened owing to the efforts made by the colonists to force them to work and dig for gold.

When discovered by Columbus Puerto Rico was peopled by a tribe of Indians known as Borinqueños. These Indians were a peaceful agricultural people who had developed some progressive tendencies. The social organization was similar to that of the Indians on the northern continent; the unit was the clan and the chief was called the cacique. The cacique lived in a larger house than the others, which always contained the zemi, or idol of the clan; his powers were supreme, and his wives were many. The Indians were not used to hard work, having led an Arcadian existence which required little labour to maintain. When forced to dig in the hills or wash for gold in the streams all day under a tropical sun they succumbed or fled to the mountains to escape. The original number of the natives is difficult to ascertain; estimates vary from a few thousand to 600,000. By a system of allotment the whole population was gradually enslaved, and under this treatment the race was in a short time exterminated. In 1582 it was officially reported that none were left; most had died from ill usage or disease or had successfully escaped to other islands.

During these early years of colonization the island did not prosper. While considerable gold was secured the supply was soon practically exhausted. By the enforced labour of the Indians, and then by the labour of thousands of Negroes brought from Africa, the gold digging continued until it became so unprofitable that it was abandoned. Its evil influence seemed to bring bad luck, and disaster followed disaster. The Caribs, a savage, warlike tribe inhabiting the southern islands of the West Indian group, made frequent incursions, carrying away what food and property were found and murdering the defenseless inhabitants. Hurricanes destroyed homes and crops. The people began to leave the island whenever opportunity offered. Then followed the attacks of the pirates and the French, Dutch and English freebooters, which brought the record of calamities to a climax. San Germán, the most important town after San Juan, was completely destroyed by the French in 1554.

Conditions were so bad that petitions and delegations clamoured for protection. Spain was finally made to see that it would be necessary either to abandon or fortify its possessions. In 1533 the building of La Fortaleza was commenced. Its site was ill chosen and it was never completed as a fort but was converted into the governor's palace and has since been so occupied. The high point at the entrance of the harbour was then covered by an excellently built and massive fortress which is still well preserved and is known as Morro castle. San Cristóbal, a larger and stronger fortress, was also constructed on the Atlantic side of the city. Several other points were fortified and the entire city was enclosed in a strong stone wall, two sides of which are still well preserved. These defensive works made the city of San Juan well-nigh impregnable to attack from the sea. Sir Francis Drake attempted its capture in 1595, but the defense was so effective that the attack failed and his fleet retired. Later Lord George Cumberland entered the city by a land attack, but did not capture the fortifications and soon retired. In 1625 the Dutch also attacked and took the city, but did not capture Morro, and after partially burning the city they too retired. For many years, during which the European nations were striving for supremacy, the islands of the Caribbean region became the prizes for which the maritime powers contested; but Puerto Rico was never subjugated and remained a Spanish possession until 1898.

End of Spanish Rule.—The Spanish-American War (*q.v.*) began on April 21 and closed on Aug. 13, 1898. In May of that year Adm. W. T. Sampson, in search of Adm. Pascual Cervera y Topete Cervera's fleet, bombarded Morro for a short time without serious results and then retired. Gen. Nelson A. Miles, commander in chief of the U.S. forces, landed his troops on the southern coast of Puerto Rico on July 25. A short campaign followed, but the defensive Spanish forces were weak and retired before the advancing Americans. The people of Puerto Rico refused to join with the Spanish forces in defense of the island, and welcomed rather than resisted the coming of the Americans. When the news of the surrender was received, hostilities ceased and the U.S. occupancy began.

U.S. Administration.—On Oct. 18, 1898, the island was turned over to the U.S. forces and Gen. John R. Brooke became military governor. In the work of policing the country, in the accompanying tasks of sanitation, construction of highways and other public works, accounting for the expenditure of public funds and establishing a system of public education the military control which lasted until May 1, 1900, proved effective in bridging over the period of transfer from the control of Spain to the system under the U.S. civil government. But it was hardly adapted to teach a people utterly without political experience the essential elements of self-government. To meet this problem the U.S. congress passed the Foraker act, under which civil government was instituted in May 1900. Under this act the U.S. element exercised the controlling power; this, however, having proved distasteful to many Puerto Ricans, the Organic law was subsequently amended to give a wider native participation in the government. The Olmsted act, approved by congress on July 15, 1909, placed the supervision of Puerto Rican affairs in the jurisdiction of an executive department to be designated by the president. He subsequently selected the war department. The people, however, demanded a larger measure of local control. The majority also asked for U.S. citizenship and many other changes. As a result, congress passed a new Organic act (the Jones act), which came into effect on March 2, 1917. Under its terms Puerto Rico became a territory of the United States "organized but unincorporated," and citizenship of the United States was conferred collectively on Puerto Ricans, allowing the right to retain the old status if preferred. Only 288 persons so declared.

Means of transport, educational facilities and labour conditions improved after U.S. occupancy. Chief among the laws bettering conditions of labour were the following: regulating working hours in public works; providing for the sale of public lands to labourers; determining the procedure of claims for wages; fixing the duties of employers in case of strikes; establishing workmen's settlements in the principal cities; providing a free dispensary with facilities for minor surgery in shops and factories; regulating the weights to be carried by labourers; providing for the settlement of strikes and lockouts; establishing a minimum wage for women and for labourers on public works; regulating the work of women and children and protecting them from dangerous occupations; creating a homestead commission; regulating the employment of minors and providing for the compulsory attendance of children in schools; regulating contracts for wages; providing workmen's accident, sickness and death compensation; creating a general employment agency. But these welfare measures failed to solve the problems of the increasingly overpopulated island with its agrarian economy. Recurring hurricanes, of 1928 and 1932, joined with declining exports to aggravate the economic distress of the depression. The quota limitations on sugar and the application of the Fair Labor Standards act to Puerto Rico caused a critical condition of unemployment principally among farm workers and needleworkers. The island shared in federal relief and rehabilitation expenditures. Rural resettlement and electrification, reforestation and rural and urban housing projects were completed.

The decade of the 1930s clearly indicated the inability of the island's agricultural industries to absorb the annual increase in the labour force. The latter had been increasing at a rate of more than 10,000 a year, but agricultural employment was even less than it had been in 1910. This situation emphasized the urgent need for finding new sources of employment and income in the island. The problems of the period forced attention to the

question of political status. It seemed clear that any change in status that might worsen the already precarious economic situation was unpracticable. In this situation a significant political reorientation began, which took effect after World War II.

The military fortification of Puerto Rico began in 1939 with the approach of World War II. Airfields and roads were built in various parts of the island, and San Juan's defenses were strengthened. Puerto Ricans served in all branches of the U.S. armed forces, and about 60,000 saw service overseas.

In 1947 the 80th U.S. congress amended the Organic act of Puerto Rico to provide that the governor be elected by popular vote for a term of four years, and that he should appoint the heads of the executive departments with the advice and consent of the Puerto Rican senate. The first native governor, Luis Muñoz Marín, was elected Nov. 2, 1948, and took office the following January.

Government.—From 1493, the date of the discovery of Puerto Rico by Columbus, to 1898, when the first military governor was appointed by the president of the United States, 142 governors ruled the island for Spain, the first being Juan Ponce de León. Nearly all were army officers. By these officers Puerto Rico was governed practically on the same plan as other Spanish colonial possessions. The governor was supreme in military affairs, and practically so in civil. The executive, legislative and judicial functions were for most of the time vested in the captain general. Whatever offices, boards or tribunals existed were used merely for the transactions of routine business. The captain general's authority was not limited except in a general way by the laws of the Indies and by royal decrees. This condition existed until 1870, when under a liberal government Puerto Rico was made a province of Spain and given representation by deputies, elected by the people, in the Spanish *Cortes*. This lasted only four years when the provincial deputation was abolished and the island returned to its old status. In 1877 the deputation was reestablished, and in 1897 Puerto Rico was given an autonomous government, but it never became operative because of the Spanish-American War and the consequent occupation of Puerto Rico by the U.S. army in 1898. The military government of Puerto Rico by the United States was from Oct. 18, 1898, to May 1, 1900. In April 1900 congress provided for a civil government in what was known as the Foraker act, and on May 1 Charles H. Allen was inaugurated the first civil governor.

The first Organic act served a useful purpose, but the limitations on the exercise of self-government were unsatisfactory. As a result congress passed a new Organic act, which came into effect on March 2, 1917. Under its provisions the governor's term was made dependent on the pleasure of the president. Six executive departments were created: justice, finance, interior, education, agriculture and labour and health. Of these, the heads of the departments of education and justice were appointed by the president, the others by the governor. The president also appointed the auditor and the members of the supreme court. The legislature under the act was to consist of 19 senators and 39 representatives, all elected by the people. A resident commissioner to the United States, paid by the federal government, was elected by popular vote for a term of four years; he represented the island in the U.S. house of representatives, with a voice but without vote, and was recognized by all departments in Washington, D.C. There are four political organizations in the island—Statehood, Socialist, Independent and Popular Democratic.

Elections are held every four years and suffrage is universal. Public law 362 of the U.S. congress amended the Organic act of Puerto Rico in 1947 by extending to the island the right to elect its own governor; the first took office in Jan. 1949. The only insular officials still appointed by the U.S. president thereafter were the auditor and the justices of the supreme court. Puerto Rico became virtually self-governing.

Production.—The products of Puerto Rico are principally agricultural. Sugar cane is grown and sugar is manufactured at the centrals or sugar factories. Tobacco is grown and there are cigar and cigarette factories. The principal products are sugar, tobacco, coffee and fruits. In 1941 the government launched an economic development program to broaden, diversify and raise the productivity of the industrial base of the insular economy. The government entered fields of business that had been neglected by private capital, and at the same time encouraged private industry with a series of legislative acts beneficial to new industries.

Sugar.—It is said that in 1548 a rude sugar mill operated by oxen began the production of sugar in Puerto Rico. Eleven mills were in operation in 1581 producing 187 tons annually. With varying rates of progress the amount produced reached 56,064 tons by 1850, and by 1899 it was 66,000 tons. By the time of the U.S. occupancy, almost all the lands suitable for the production of cane had been brought under cultivation. While the cane lands had reached the limit so far as area was concerned, the product was small and the cost of production large. The causes were lack of fertilization and proper cultivation, and antiquated mills and methods of operation. After U.S. capital was invested in sugar production, progress was rapid. In the southern part of the island irrigation brought some new land under profitable cultivation; otherwise the area remained almost stationary, but the production was greatly increased.

By the beginning of the 20th century, sugar was by far the most important Puerto Rican export. In 1901 sugar exports had a value of $4,700,000, representing 54.9% of all exports. The value of sugar export and its importance as a percentage of total exports in later years was as follows: 1921, $72,400,000—69.5% of exports; 1931, $54,300,000—55.2%; 1941, $58,600,000—66.7%; 1949, $128,500,000—62.9%. The highest return for sugar exported was in 1919–20, amounting to $98,900,000 and representing 65.6% of all exports. The amount and value of Puerto Rico's sugar exports were influenced by the several acts of the United States congress setting production and marketing quotas for areas supplying the United States. In 1948 established quotas for the five-year period 1948–52 were set at 910,000 short tons.

Puerto Rico came to sell all its export sugar in the mainland. In the period 1931–51 it supplied from 10% to 15% of the sugar consumed in the United States.

Tobacco.—Tobacco was first produced for market in 1614, when by royal decree the colonists were permitted to plant and sell the crop. Small progress was made until 1870, when Cuban tobacco rose to great prominence and demand. Under U.S. administration the United States tobacco industry entered Puerto Rico and undertook production of tobacco and manufacture of cigars, and the industry enjoyed a growing prosperity.

During the decade 1939–49 tobacco acreage, production and average price per pound received by farmers fluctuated as shown in Table I. Restrictions on the acreage of tobacco after World War II held production almost constant and prices remained stable. In 1941 the total export value of tobacco and tobacco products was $7,800,000, representing 8.91% of all exports. During World War II exports of cigars remained extremely low, but exports of unmanufactured tobacco held up well, averaging $7,000,000 per year. In 1946 all tobacco exports rose to $21,400,000, then steadily fell to $11,800,000 in 1949.

TABLE I.—*Tobacco Production in Puerto Rico*

Crop year	Acreage	Production, green weight (in pounds)	Average price (in cents per pound)
1939	18,688	13,800,000	16.8
1943	12,360	9,400,000	35.0
1947	31,334	23,000,000	25.0
1949	32,500	27,000,000	28.0

Coffee.—While sugar production is limited mostly to the low coastal plains and tobacco to the valleys, coffee is best produced in the higher altitudes, from 600 ft. to 2,500 ft. In the higher valleys of the interior mountain ranges the coffee trees are principally grown. The trees are from 6 ft. to 20 ft. high, with permanent leaves, a beautiful white blossom and a small flexible trunk only a few inches in diameter. Until World War I the industry enjoyed a growing prosperity. Its markets were mainly European, however, and these were never fully regained after the war. During the 1920s shipments decreased but the product commanded a high price. Destructive hurricanes in 1928 and 1932 still further depressed the industry.

The coffee crop for 1949 was 24,000,000 lb., and for 1950 it was 19,900,000 lb. Even under favourable weather conditions, the Puerto Rican production of coffee is barely sufficient to supply local markets. However, coffee emerged again in 1950 as an export commodity because of favourable export prices.

Fruits.—About the only fruits grown in Puerto Rico of which account was made prior to the U.S. occupancy were oranges, bananas and coconuts. The principal fruits now exported are grapefruit and pineapples. Grapefruit and pineapples are also canned extensively. Bananas and plantains are the largest fruit crops, although little exported. These are principal articles of food and are grown everywhere. Breadfruit is also extensively grown. Exports of prepared grapefruit were negligible during World War II, but had some recovery later, reaching a value of $264,000 in 1946. Export of prepared pineapples, which had an export value of only $48,000 in 1921, increased with some fluctuation to more than $2,000,000 in 1946, with exports of $1,300,000 in 1944 and $1,700,000 in 1945. In 1949, 1,250,000 crates of pineapples were produced on 4,000 ac.

Other Products.—After the end of prohibition, the manufacture of rum grew rapidly, 1,137,235 gal. valued at $5,567,765 being exported by 1940. Upland rice is also produced. Beans are a profitable crop. Corn is grown quite extensively in the higher altitudes. As rice, corn and beans are the habitual foods of the people and are principally imported, every effort is made to encourage their production. Blackstrap molasses was produced to the amount of 49,522,486 gal. in 1949–50; much of this is also used in the manufacture of commercial alcohol.

Needlework and apparel accessories are the most important manufacturing industries in the insular economy. Needlework made up roughly 60% of manufacturing employment at mid-20th century, and accounted for 22% of the export value in 1950. Between 1931 and 1940 exports of this product averaged $14,800,000. During World War II exports were curtailed sharply but recovered to $25,500,000 in 1946 and $33,800,000 in 1949, representing 16.5% of the total value of exports.

Other commodities exported from Puerto Rico to the United States include beeswax, cattle hides and goat skins, honey, bay rum, straw or fibre hats, pearl or shell buttons and unmanufactured cotton.

In 1941 the insular government launched an economic development program for Puerto Rico. The goal was to increase production, reduce unemployment and attain a higher standard of living. By Sept. 1950, 86 new enterprises were established, employing about 15,000 workers. The program was financed mostly from treasury surpluses attained during World War II. Investment of these new enterprises in Aug. 1950 totalled $32,200,000. Together with the industrialization program the government embarked on a capital improvement for which it had appropriated $172,300,000 up to Dec. 1949.

Finance.—The revenues and other receipts (cash receipts—revenue and nonrevenue items) during 1949–50 for all funds amounted to $218,626,003 plus a carried forward balance of $85,600,000. Over-all expenditures and disbursements for all funds were $203,654,357, leaving a cash balance as of June 30, 1950, of $100,600,000. Of the total revenues and other receipts, $122,400,000 was spent for public services (general fund) such as: general government, $12,200,000; protection and correction, $7,800,000; public works, $13,300,000; agriculture and commerce, $2,300,000; labour, $1,300,000; health and welfare, $13,200,000; educational and related services, $27,600,000; war emergency program, $5,100,000; grants, subsidies and awards, $30,900,000; and other, $8,500,000. These governmental expenditures and disbursements were met through the levy of taxes and from other sources. The most important sources of recurrent revenue for 1949–50 were: income taxes, $28,000,000; excise taxes on alcoholic beverages, tobacco products, petroleum products and other, $42,800,000; property taxes, $5,400,000; motor vehicle and drivers' licences, $2,200,000; revenue from lottery, $3,700,000; and other, $7,300,000. Total revenue collected from these sources in 1949–50 was $107,000,000, the first time since the abnormal years of World War II that it had surpassed the $100,000,000 mark.

The outstanding debt was $31,030,000 on June 30, 1950, compared with $12,800,000 the year before. The increase was the result of the placement of $18,000,000 of bonds for long-term investment in public works and income-generating projects. No default had ever been made in the payment of principal or interest of the insular debt. A sinking fund is provided for the payment of outstanding bonds, principal and interest at maturity. The limit of insular indebtedness was placed by the Organic act at not more than 10% of the aggregate tax valuation of its property, which amounted to $437,500,000 in 1949. A reassessment of all real property was begun in Jan. 1949, the first reassessment of real property since 1916; it was expected to equalize taxes among property owners and to enlarge the tax base.

In March 1950 seven locally chartered banks, owning more than 99% of the banking assets of the island, were admitted as members of the Federal Deposit Insurance corporation. Banks are regulated by a comprehensive law, providing for government supervision, investigation and reports. On June 30, 1950, capital paid in, surplus and undivided profits totalled $37,992,981, deposits amounted to $251,124,364 and total assets were $326,080,924.

Commerce and Transportation.—For the fiscal year 1949–50 the external trade was as shown in Table II. Foodstuffs and beverages constituted 32% of the total tonnage. Imports were valued at $16,600,000 in 1900 and at $199,400,000 in 1940. More than 90% of the

TABLE II.—*External Trade of Puerto Rico, 1949–50*

Imports and exports	Value	Shipping weight (in pounds)
Imports		
United States	$317,954,000	3,159,000,000
Other countries	26,758,000	1,039,800,000
Total	$344,772,000	4,198,800,000
Exports		
United States	$210,057,000	2,801,200,000
Other countries	25,148,000	745,300,000
Total	$235,205,000	3,546,500,000

island's commerce is with the United States, with which it has free trade. Exports as well as imports showed a rising trend after 1940, with sugar by far the most important component of exports. In 1948 sugar made up 58% of total export value and 59% in 1950. Needlework products exported showed a substantial increase after 1940. The export value of newly established industries was $18,600,000 in 1950.

During 1950 import surplus of goods and services declined to $23,500,000, a reduction of $61,400,000 from the peak year 1947–48. The number of vessels that arrived during 1947–48 was 3,130 (2,447 U.S., 683 other) with an aggregate tonnage of 9,916,700. Facilities for handling freight and passengers are provided in 11 ports, including protected harbours and open bays. Ocean transportation is important; San Juan is about 1,400 mi. S.E. of New York city, the principal market for Puerto Rican products.

Two principal steamship lines serve Puerto Rico, carrying both passengers and freight. San Juan has air passenger, mail and express service by scheduled certificated air lines and nonscheduled carriers with the U.S. mainland, the West Indies and the east and west coasts of South America. Three commercial cables extend from Puerto Rico, and there is government and commercial wireless service. A railroad following the coastal plains extends almost around the island. There were approximately 2,200 mi. of public roads in 1951, reaching all the cities and towns of the island and all parts of the interior. Hundreds of thousands of tons of freight are carried inland from the ports by motor truck, and everywhere there are motor vehicle and passenger services. Automobiles totalled 34,570 in 1949, and there were 22,688 other motor vehicles operating in the island. Tourism is a small factor in the island's economy but its importance increased greatly after World War II.

Population.—Puerto Ricans are descendants of the Spaniards who conquered and settled the island. According to a census taken in 1899, shortly after the island was ceded to the United States, population was 953,243; in 1920 it had grown to 1,229,809, in 1940 to 1,869,255 and in April 1950 to 2,210,703. The count for 1950 represented an increase of 18.3% over the 1940 population. For the calendar year 1949 the total number of births was 85,287, with a birth rate of 39.1 per 1,000 population.

The total number of deaths was 23,395, with a death rate of 10.7. The population density per square mile was 646 in 1950, a rise of 99 since 1940 and one of the highest population densities in the world. Of the 1950 population, 40.5% was classified urban and 59.5% rural. The colour line is much less sharply drawn in Puerto Rico than in continental United States.

The census returns placed 76.6% of the 1940 population in the white classification. Almost all of the nonwhite population is Negro or mulatto. The population of the island and its principal cities is summarized in Table III.

TABLE III.—*Population of Puerto Rico and Its Principal Municipalities*

Area	Population		Per cent of increase 1940–50
	1950	1940	
The territory	2,210,703	1,869,255	18.3
Urban	894,813	566,357	58.0
Rural	1,315,890	1,302,898	1.0
Per cent urban	40.5	30.3	11.9
Principal municipalities:			
San Juan	224,767	169,247	32.8
Río Piedras	143,989	68,290	110.8
Ponce	126,810	105,116	20.6
Mayagüez	87,038	76,487	14.1
Caguas	60,132	53,356	12.7

Education.—There were probably no schools outside the cities of San Juan and San Germán as late as 1799. Some increase was made in private schools where instruction was paid for, but it was not until 1845 that any public primary schools were provided. In 1899 it was reported that only 15% of the population could read or write. The total number in all schools at that time was 22,265, or about 2% of the population. Of these, 15,108 were boys.

The principal objective of the educational policy in Puerto Rico at mid-20th century was to bring the schools into closer touch with the social and economic realities of the island. The public-school system

of Puerto Rico is headed by a commissioner of education, appointed by the governor and confirmed by the insular senate. Responsible to him are assistants charged with enforcement of the educational policy and with administration. The island in 1951 was divided into 73 school districts, each headed by a superintendent who was the local representative of the commissioner of education. The public-school system is organized on a six-three-three plan; that is, there is an elementary school of six years; an urban junior high school or a rural second unit of three years; and a senior high school of three years. There are also vocational schools, school for adults and summer and evening schools. The over-all resources available to the department of education for 1949–50 were $33,500,000 ($7,200,000 from federal funds), of which $20,500,000 were for school operation, $8,000,000 for school lunchroom programs, and $2,400,000 for a veterans' education program.

The administrative and teaching personnel in public schools totalled 9,452; 1,996 were males and 7,456 females. There were 8,865 teachers in service with public schools and 1,067 with private schools. With few exceptions, all were Puerto Ricans.

TABLE IV.—*School Enrolment in Puerto Rico, 1949–50*

Schools	Urban	Rural	Total
Public day schools			
Elementary (1–6)	135,191	181,967	317,158
Junior high school (7–9)	45,803	16,052	61,855
Senior high school (10–12)	29,115	—	29,115
Total public day schools			408,128
Accredited private schools			22,595
Vocational and evening schools			14,000
Total enrolment			444,723

Enrolment in schools for 1949–50 is shown in Table IV. In 1950 there were 3,077 school buildings with a total of 7,564 classrooms. All new construction is of reinforced concrete. During 1950, 72 concrete school buildings with 340 classrooms were completed. The expenditure per student in public day schools for 1949–50 was $63.18. It was estimated that 105,591 children from 6 to 12 years of age were not attending school during 1949–50, although schooling is free and compulsory for children. There was a total of 2,066 public schools (1,739 elementary, 93 junior high, 66 senior high, 168 second units and vocational) and 95 private schools. Private schools operate under the supervision of and standards prescribed by the department of education. A total of 32,373,770 free school lunches were served to about 197,000 children during 1949–50; there were 1,504 lunchrooms in operation at a cost of $7,600,000 in this period. There are adult-adolescent schools for illiterate, English and special students, evening high and eighth-grade schools. The percentage of illiteracy was reduced from 31.2% in 1940 to 20.0% in 1950.

The University of Puerto Rico was established by the government in 1903. It was later entirely reorganized and is conducted as are the state universities of the United States. It is a fully recognized institution with three campuses housing colleges of general studies, humanities, natural sciences, social science (including department of social work and public administration), business administration, education (including home economics department and extramural service), law, pharmacy and agriculture and mechanic arts and a school of medicine. Enrolment for 1949–50 was 11,337, excluding 5,000 schoolteachers who attend summer classes.

A federal grant in 1935 made possible the construction of several buildings, among them an auditorium, air conditioned and seating 2,100. Students from the United States who desire special training for service in Central and South American countries, and students from those countries who desire special preparation for service in the United States and other English-speaking countries, may receive it at the University of Puerto Rico, where work in the schools and colleges is conducted in both Spanish and English.

In 1950 the university engaged in an investigation in the field of electronic radiation of cosmic rays under the auspices of the U.S. Atomic Energy commission. The school of medicine was inaugurated in Aug. 1950, and absorbed the school of tropical medicine of the University of Puerto Rico which had been operating since 1925. The school of tropical medicine, established in conjunction with Columbia university, became pre-eminent in postgraduate teaching in the fields of tropical medicine and public health. The school of medicine offers the degree of doctor in medicine, and gives advanced degrees and certificates in professional fields allied to medicine and public health. There are also the Polytechnic institute, the University of Santa María and other private corporations offering undergraduate studies.

Customs and Habits.—The sugar factories and the larger tobacco and coffee plantations employ large numbers of men and women. There was a great change in the manners and customs of the people after U.S. occupancy. The bankers, merchants and other businessmen developed U.S. methods and customs. The lawyers, physicians and chief government officials for the most part received their professional training in the United States. The English language is taught in the schools and is used largely in business and trade. However, the language of the people is still Spanish and most of the periodicals are printed in Spanish.

The native rural citizen, born on the soil, clings to it tenaciously. After four centuries he still retains much of his Andalusian ancestry. He is rather small in stature and dark. He is unambitious but a good and obedient worker. He is rarely a landowner, but, for the most part, both a tenant and a farm hand. Wages are low by mainland standards.

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PORT PHILLIP: *see* MELBOURNE.

PORT PIRIE, a seaport of South Australia situated near the northeastern extremity of Spencer Gulf. The harbour is poor, and Pirie won its place as the second port of the state because it is the nearest convenient maritime outlet for Broken Hill (*q.v.*), 205 miles inland (northeast). At Pirie the Broken Hill ores are smelted with coal from Newcastle (New South Wales), the smelters (which were burned down in 1920) being on a large scale.

The town is also the centre of an important wheat-growing area and wheat and minerals (zinc and silver concentrates and pig lead) constitute the bulk of the exports. (Pop., 1933: 11,677.) In 1938–39 the total cargoes shipped overseas weighed 408,000 tons, while interstate traffic accounted for 157,000 tons.

PORTRAIT PAINTING. A portrait is a work of art representing an individual. It has been called a materialization of an individual soul. The pleasure we derive from the contemplation of a portrait is due to its value as a likeness as well as to its aesthetic qualities.

A cast taken from life is not a portrait, nor is a photograph, nor any painting, drawing or sculpture which does not possess the harmony of line and colour which alone can give it aesthetic value.

A composer who wishes to give the impression of the song of birds does not imitate the notes of real birds, but invents notes which harmonize with his music. When heard alone they would have no meaning, but as part of the composition they convey to us the sensation of hearing birds sing. So the colours and lines of a picture gain significance only through their relation to each other. As in a poem not one word can be changed, so in a portrait not a touch can be added without unbalancing the whole. But whatsoever the aesthetic quality of a picture may be, it cannot be called a portrait unless it awakens in us the feeling that we are facing an individual with his physical and mental characteristics.

HISTORY

When the ancient Egyptians buried their dead they enclosed in the tombs statues representing the dead so that the Ka might find its earthly habitat in them. For this reason the statues of the ancient empire, and again of the Saïte epoch were of amazing realism: true portraits because they were at the same time superb examples of decorative sculpture. But as far as we know, Egyptian painting remained a mere colouring of figures which had to conform to rigid formulae dictated by the priests.

The encaustic portraits found in Egyptian tombs of the Roman period are of small artistic value. As yet no fine examples of Greek or Roman painting have been unearthed. But from contemporary writers we learn so much about them that we have reason to believe that they were equal in quality to the sculpture. Inferior copies, such as the copy in mosaic of a painting representing Alexander the Great in the Battle of Issos, give us some idea of their style and colouring. The paintings of Pompeii and Her-

culaneum show that the Roman artists had an impressionistic method of indicating form and dividing colour.

As early as 1326 B.C. portraiture is mentioned by the Chinese. In accordance with the doctrine of filial piety, Confucius, in the 6th and 5th centuries B.C., taught that portraits of great men should furnish to the coming generation stimulating and ennobling examples. In temples some portraits of the best period have been preserved. Limited to line, the painters succeeded in producing the sensation of perfect modelling with mere contour. The primary condition of such a picture is to decorate a flat wall; the spaces covered are flat spaces. The artist invents a harmony of colour which intensifies and gives added charm to the harmony of line.

In Europe, for more than ten centuries, the Catholic Church placed restrictions on artists similar to those of the Egyptian priests. In A.D. 325 the Council of Nicaea proclaimed that the "composition of pictures should not be the invention of the artist but the rules and traditions of the church." In the 7th century St. Gregory the pope wrote, "Let the churches be filled with paintings that they who do not know their letters may be able to read on the walls what they cannot read in the manuscripts." It goes without saying that portraiture could not flourish under these conditions, since individualization was prohibited.

In Italy in the 13th century, Giotto was the first to introduce into his frescos of religious subjects groups of spectators for which his friends posed. Thus we have in a group of citizens on the fresco "Paradise" in the chapel of Bargello, in Florence, a portrait of Dante. Filippino Lippi (1457–1504) paints himself with Botticelli and Pollaiolo in the Brancacci chapel. Ghirlandajo (1449–1494) places himself and his family and the donors on the fresco in the Capella Tornabuoni.

Fresco painting developed in the Italian artists the ability to work very rapidly and therefore, very broadly, to ignore all possible detail. In Flanders the damp climate was so unfavourable for its use the artists perfected the more durable process of oil painting, which permitted them to work on panels with the same attention to detail which they had devoted to the miniatures of the manuscripts.

In spite of the rules of the church, the Gothic sculptors and illuminators had developed an astonishing degree of realism in their work, the realism which culminates in the painting of the Van Eycks.

In his portraits, which have never been surpassed, Jan Van Eyck (1385?–1441) shows us people of solid flesh and bone, on whose faces life has traced its story, and because they are real, we see their souls. He gives poetry to reality.

Rogier Van der Weyden and Hans Memling prepare the way for Italianism.

The Flemish love for detail was often carried to an excess by German artists. However, two men of genius, Holbein and Dürer, knew how to subordinate this detail and make of it a powerful aid in characterization. Just as an orchestra brings out a soloist, so the backgrounds and accessories in their portraits evoke sensations which make the impression of the figure all the stronger. As a thinker Dürer ranks with Leonardo and Michelangelo; as an objective painter of portraits Holbein equals Rembrandt and Velasquez. His portrait drawings are the most striking examples of individualization. Never have lines expressed more powerful modelling, profound psychology, rhythm and harmony. When Germany was torn by religious strife he found at the court of Henry VIII. in England the right field for his work. Lucas Cranach (1472–1553) was an independent, positive artist. Antonello da Messina (*c.* 1414–*c.* 1493), who is said to have studied in Flanders and to have introduced the technique of oil painting into Italy, combined Flemish love of realism with his Italian sense of beauty.

The classic traditions had never quite died out in Italy, and were revived by the study of antique examples. The result was a magnificent school of portraiture which brought out the finest qualities of the sitter and artist. The Renaissance worshipped beautiful aristocratic types and the artists delighted in painting them at their best, accentuating their nobility of character by harmonious composition and colouring, ignoring all disturbing detail. If Waetzoldt has compared a portrait to a lyric poem, we are reminded by these Italian portraits of Shelley's definition of poetry:

"Poetry is the record of the best and happiest moments of the highest and best minds. . . . Poetry thus makes immortal all that is best and most beautiful in the world. . . . Poetry redeems from decay the visitation of the divinity in man."

The artists were pioneers and delighted in solving new problems.

Many of the great painters of religious subjects excelled in portraiture. Leonardo da Vinci (1452–1519), in his search for greater truth, sacrificed the pure colouring and line of the primitives, enveloping his modelling, giving depth to his shadows. Raffaello Santi (1483–1520), Andrea del Sarto (1486–1531), Andrea del Castagno, Benozzo Gozzoli (1420–98), Pontormo (1494–1557) and Bronzino (1502–72) were masters in portrait painting. The Venetian, Giambattista Moroni (1510–78) was, however, the first artist to devote himself exclusively to portraiture.

In Venice conditions were favourable to the development of a brilliant school of portraiture with Bellini and Giorgione as leaders. There were fewer religious restrictions and the general atmosphere was one of wealth and splendour, of gaiety and moral and physical health. This reflects itself in the masterpieces of Titian Vecelli, whose rich colouring and profound insight into human nature places him among the greatest portrait painters. Sir Joshua Reynolds speaks of "the unaffected air of the portraits of Titian, where dignity, seeming to be natural and inherent, draws spontaneous reverence." Tintoretto, Sebastiano del Piombo, Paolo Veronese and Lorenzo Lotto have left us portraits of great strength and beauty. When the joy of blazing new trails was over and Italian painters settled down to inventing formulas for giving their sitters the aristocratic appearance they desired, the art degenerated into mannerism.

In Holland the reformation triumphed after a struggle of 80 years against the Spanish yoke. In 1579 the seven Dutch provinces had formed a republic which developed into the most civilized State of the times. Tolerance attracted to it those who were persecuted for their advanced ideas in other countries. Wise laws raised the standard of the people and a vast trade brought contacts with all countries of the world. General wealth and culture was the result. The Dutch burghers, who had accomplished so much, did not desire to ape aristocracy. Their success had given them self-respect and they wanted portraits which showed them as they were. This gave their great artists a most ideal opportunity. Their knowledge of composition had free rein in great group paintings ordered by societies and guilds to adorn their meeting halls and so perpetuate the memory of the men and women who had rendered services to their country. Little wonder that painting became the highest developed form of Dutch art. The painters reflected the love of independence in their work. They saw with their own eyes.

Rembrandt van Rijn (1607–69) and Frans Hals (1580–1666) are the great portrait painters. Each looked at life from an entirely different angle and treated what he saw with entirely different methods. Hals is known as the painter of laughter, but it is not only the laughter of merrymakers; it is also the smile of the man of the world too proud to show emotion—laughing so as not to weep. His amazing knowledge of anatomy permitted him to treat these fleeting expressions with an assurance and breadth of touch which fascinates.

Rembrandt was a profound student of human nature for whom every form, condition and action had its significance. Character and soulfulness interested him more than perfection of form. He saw with the eye of a lover, a lover of humanity, revealing beauty where it is least expected. What Holbein accomplished with line Rembrandt obtained with colour, with his golden light and luminous shadows. His etcher's point has left us portraits which are the classics of etching. (See DRYPOINT: *Portrait of Arnold Tholinx.*)

Among the numerous Dutch painters who devoted themselves to portraiture must be mentioned Bartolommeo Van der Helst and Jan Steen. As with all other schools, decadence began when the Dutch tried to reduce the methods of the masters to formulae.

Spanish artists always remained very free from academic tendencies. Their portraits are therefore unusually fine.

Dominico Theotocopuli, called El Greco, a Greek, born in Crete, settled in Spain after working in Titian's studio. His early influences were doubtless Byzantine. He owes perhaps to Tintoretto his impressionistic handling. Through Ribera (1588–1656) Caravaggio became the inspiration of most of the Spanish artists. Zurbaran (1598–?1669) excelled where most of the masters failed: in portraits of children.

It is difficult to trace the influences which might have affected Velasquez (1599–1660), so completely did he see with his own eyes. Even his technique was a new departure. He was the first to use oil as a sole medium in order to paint directly on his canvas without preparatory underpainting. This made possible the accurate values which give depth and air to his pictures. Although as a court painter to Philip IV. he was forced to repeat the same subjects many times, his sincerity and interest in the pictorial qualities of his sitters kept his vision keen. There was so much to fascinate him in light, colour and atmosphere besides the personality of his models, that his portraits are perhaps the most real ever painted. There is no evidence of preoccupation with technical problems. His palette was simple and his brush responded to his mind like the instrument of a great musician. His portraits make their appeal through truthfulness, refinement and reserve. Elie Faure compares him to Beethoven, because he possessed the supreme virtue—heroic simplicity.

Goya y Lucientes (1746–1828) kept alive the best Spanish tradition when in other countries artists had forgotten how to paint, and has had a great influence on modern art.

The wealth and wholesome vigour of Flanders which in the 17th century enjoyed the advantages of commerce with all parts of the world, found an interpreter in Petrus Paulus Rubens (1577–1640). The portraits of his family, especially of Helena Fourment, his second wife, are the best examples of his art and reflect his joy in life, his health and vitality. His pupil, Anthony Van Dyck, although brilliant when he painted his early portraits, as court painter to Charles I. of England, was so overwhelmed with work that he rarely painted more than the head himself, leaving the rest to assistants. The hands were painted from models and this, more than anything else, weakened the character of his portraits. He also used landscape backgrounds which shock our modern taste accustomed to the reflections and colour shadows of outdoor painting.

These insincere methods were unfortunately adopted by the English portrait painters of the 18th century. England had imported her portrait painters, Holbein, Rubens and Van Dyck, without developing any native talent except for some miniaturists such as Isaac Oliver and Samuel Cooper. (*See* MINIATURE PAINTING.)

Puritanism brought all art to a standstill. Under the reign of Charles II. other foreigners became the vogue—Sir Peter Lely (Dutch) and Sir Godfrey Kneller (German). William Hogarth (1697–1764) was the first native English painter of real merit. He rebelled against the prevailing insincerity in art and wrote of his "contempt of the portraits by native and foreign impostors who puffed and flattered themselves into fashion. By this inundation of folly and fuss I was much disgusted and determined to try if by any means I could stem the current and by opposing, end it." The few portraits he painted are of a high order, too true, perhaps, to make him popular.

It is a curious phenomenon that England in the 18th century should of a sudden develop a group of important portrait painters, such as Sir Joshua Reynolds, Thomas Gainsborough, George Romney, Allan Ramsay, John Opie, Hoppner, Sir Thomas Lawrence and Sir Henry Raeburn. Demand undoubtedly had a great deal to do with it. Their work reflects a refined, healthy, self-contented atmosphere that makes one feel as if one were moving in the best society. This, perhaps, explains the popularity of these pictures. Healthy complexions and beautiful clothes gave the artists an opportunity to make colourful pictures but there is little research into character. Shop methods prevailed. Like Van Dyck, Reynolds painted only the head. In this way he was able to paint about 150 portraits a year for several years.

Gainsborough's was the most artistic nature but he was more interested in a silk gown than in the sitter. Only an extravagant wife kept him from abandoning lucrative portraiture for landscape painting which he loved. (F. T. W.)

France.—Jean Fouquet (1415–1485), is the first of the great French portrait painters. Without departing from the technique of the miniature painters, with their gold background and attention to minute detail, he none the less treats the face and costume more broadly.

Jean and François Clouet (their dates are, approximately, Jean, 1485–1541?; François, 1510–72), attached to the court of Francis I. and his three successors, have bequeathed to us the physiognomy of these princes and their counsellors. Sharing in the Italianism which dominated manners at the period of the Renaissance and representing the old feudal order on which they rested their claims, these men are at once subtle and fierce; their sparkling glances, their flashing or gloomy eyes, their humble or haughty characters, their brilliant or sober costumes, all are studied with scrupulous detail, all speak to us of their hates, their fears, or their hopes. We look at their paintings like historical documents whose truth heightens their pictorial value.

Antoine Lenain (1598–1648), along with his brother Louis (1593–1648), are two portrait painters of high rank. The period which they represent is less violent; the power of royalty has triumphed over feudalism. But the realistic tradition of the Middle Ages still survives and resists the more decorative and more impersonal academic tendencies.

Philippe de Champaigne (1602–74), portrait painter of Louis XIII. and Richelieu, introduces a new element—the pomp of courts and the fashion of the official portraits. He portrays the majesty of royalty, flattering his models a bit in the way of nobility and dignity, and he paints the glowing colours of their royal vestments. Mignard (1610–95), and after him Tocqué (1696–1772), in his great portrait of Marie Leczinska, amplify and enrich the opulent style of the official portrait.

The sweeping lines of materials in rich folds become still more decorative in the eighteenth century. They give an air of awkwardness to the persons set off by them. Rigaud (1659–1743) less cold and simpler in his art, one of the fine talents of the end of the 17th century, is surpassed in brilliance by Nattier (1685–1766), whose famous "blue" has become celebrated; and especially by Largillière (1656–1746).

The latter returns to the naturalistic tradition with all the opulence of a palette worthy of Rubens at the service of a rather subtle understanding of the human soul. He defines the features clearly, he selects the characteristic detail to mark a momentary state of soul. He has left us a considerable number of magnificent portraits. His portraits of women have all the charm, all the grace and all the sumptuousness of that delightful century. The stiff school of Mignard is definitely vanquished by charm and light. It is not yet the famous "rayon rose" of Boucher. It is simply the harmonious balance of all, the joy of painting materials and beautiful flesh. Largillière, like Oudry, is often influenced by Snyders and he knows how to enliven a portrait with a remarkable bit of still life, without going contrary to the spirit of the composition.

Charles Vanloo (1705–1765), in the portrait of Louis XV. at the Chase, introduces the element of landscape more extensively than ever before in portrait painting. Watteau (1684–1721), Chardin (1699–1779), Boucher (1703–1770), Fragonard (1732–1806), Greuze (1725–1805), are not actual portrait painters, but who would pass them without mention? Their varied palettes, the delicacy of their composition, their expressive design, compel us to note them and to class them among the greatest portrait painters. Perroneau and Latour, most famous of pastel painters, both broke deliberately with the tradition of official portrait painting. Latour is never constrained. All his portraits give the impression of having been fixed on the canvas at the moment when the subtlest smile of the subject is responding to a witty word. Madam Vigée-Lebrun (1755–1842), with her charm and grace, concludes the achievement of this brilliant century and fittingly introduces the next. (C. MAS.)

Already under Louis XV. the classic reaction had begun, due

largely to the influence of the scholar Winckelmann. In 1764 the translation of his *History of Art Among the Ancients* appeared in which he exhorts the artists to take their models from antiquity. Piranesi's prints also served to draw attention to the art of ancient Rome. Philosophers and writers such as Diderot and Caylus attacked artists for their subservience to fashionable tastes. During the Revolution, just as in politics, theorists went to the limit of the absurd declaring that beauty could be obtained only through calculation by knowledge of the antique. Louis David (1748–1825) who became the apostle of this creed painted some truly fine portraits in which, however, reason takes the place of passion. Gérard, Girodet and Gros were not his equals. Prud'hon alone had an artist's vision, but due to the use of bitumen his paintings deteriorated.

The next generation which had grown up during the excitement of the Revolution and of the wars of the Empire rebelled against this art of reason. Géricault who died very young, and his friend, Eugène Delacroix (1798–1863), were inspired by the English landscape painters and introduced their brilliant colours and free methods. Delacroix fought classicism with a "hate of systematic painting," but he, himself, distorted truth. For this reason his portraits are inferior to his compositions. A pupil of David, Jean Baptiste Dominique Ingres (1780–1867), enriched the field of portraiture with admirable pencil drawings. His painted portraits do not possess the same charm. His pupil Flandrin continued his decorative style. The revolt against Ingres and Delacroix was led by Courbet (1819–1877) who introduced the realism of the great Spaniards and Dutch into French art. In his "Funeral of Ornans" every figure is a portrait painted directly from the model. Rebelling against classicism and romanticism alike, he wanted to paint the life of his time in a method which his contemporaries could understand. That is the most important lesson taught by modern art, that beauty is all around us, if we only have eyes to see it.

From now on most of the best French portraits are painted by artists who did not take up portraits as a vocation. Daumier did a striking portrait of Berlioz. Jean Francois Millet's (1814–1875) portraits of his family and friends are as virile and as full of pathos, emotion and tenderness as his compositions. The landscape painter Corot (1796–1875) made a great contribution to modern painting with his exquisite portraits of woman. He sees women as pure nature, without sentimentality, and he is comparable to Jan van der Meer of Delft in the beauty of his colour and the strength of his construction. The portrait is the touchstone of an artist's ability.

Nothing bore richer fruits than the discovery of Japanese art and the influence of the Impressionists. Tired of the harsh, cold studio light, artists began posing their models in the open or in rooms flooded with sunlight. Muddy tones gave way to luminous shadows and reflections. With Edouard Manet (1823–83), Edgar Degas (1834–1917) and, above all, with Auguste Renoir (1841–1919) and Paul Cézanne (1839–1906), a new conception of painting developed. Art is at last free from the nightmare of classicism. The new ideas were applied especially to portrait painting by Anders Zorn in Sweden, Peter Severin Kröyer in Denmark, Sorolla y Bastida in Spain, and by others. It was especially the American-born James McNeill Whistler (1834–1903) who came under the influence of Japanese art. In his writings as well as his painting he focussed attention on the necessity of decorative qualities in a portrait. No one knew better than he the value of the silhouette against a background rendered interesting by discreet arrangement of flat spaces. His compatriot, John Singer Sargent (1856–1925), who, like him, spent most of his life abroad, became one of the most popular portrait painters.

It is significant that both these men made their homes abroad, while in America foreign artists, often inferior ones, were and still are popular. Yet America can boast of many able and talented portrait painters. Most of them had training abroad and their work can hold its own with that of their European contemporaries. It cannot be said, however, that a typically national style has developed. Even George Bellows (1882–1925) and Abbott Thayer (1849–1921) show European influences. The same applies to other American painters. Art has become cosmopolitan.

Fortunately the growing interest of Americans in modern art is creating a demand for colourful portraits, so artists should give their talent freer rein. Perhaps Grant Wood (1892–1942) sounded a new note in his "American Gothic" with its bold colour and uncompromising realism. The portraits of Luigi Lucioni (1900–) combine true decorative qualities with sincere characterization. He says of himself: "I try more and more to create reality with the simplest means and with all essential detail. But I feel that all this should be part of a design, which I believe every canvas must primarily possess." This should be the aim of every true portrait painter.

PROBLEMS AND TECHNIQUE

While the old masters excelled in portraits of men, man's modern attire makes it most difficult for an artist to obtain satisfactory results. The harsh collar, the drab colouring and the standardized cut all unite to ruin the effect of the finest head. Women, on the contrary, have much greater freedom than the women who posed for the old masters, with their rigid garments and their stiff attitudes prescribed by fashion and convention. However, the use of cosmetics is a great drawback. Rouge, lipstick and powder conceal, camouflage so to speak, the fine modelling on which a great portrait depends and they defeat their own purpose by rendering the surface of the skin opaque. The natural skin is semi-translucent and therefore more luminous than anything that can be applied to it. As long as cosmetics are generally used there is little hope that the finest type of portrait will be appreciated. Paint and powder are used to deceive, to produce an artificiality which does not give beauty to commonplace, and which makes common the most beautiful.

For a connoisseur, "the question of portrait painting is a matter of birth, associations and character. In other words, one cannot expect a man born and bred in a low environment and associating with people of his own status to understand the character of a noble sitter; nor can he have any insight into the essence of such a person's nature. Therefore, he cannot paint a portrait of such a one. The grand manner is a question of grand association. If it is mere imitation, it is worthless and shows how spurious it is."

Psychologically different types cannot be expected to understand each other. This must be considered when people offer their criticisms of a portrait. Portraits which are entirely satisfactory to the family of the sitter often displease outsiders. The sitter himself may be unsympathetic to them. For this reason the artist and client must be careful in accepting criticism without making due allowance for difference of temperament and the state of mind which has much to do with opinion. Mood, health, age, sex and eyesight are factors to be counted with. A man's portrait may delight girls and meet with adverse criticism from men. A short-sighted person can never see a portrait as it should be seen. A bilious critic can never be expected to find beauty in anything. From day to day we change our opinions. What we liked yesterday may not appeal to us tomorrow. An artist can class people psychologically by the remarks they make about a portrait; one will see a benevolent smile where another sees a sneer. One notices a frown where another finds thoughtfulness. Then according to the occupation of the beholder certain things attract undue attention. A physician will notice the anatomy, a tailor the clothing. Likeness, the *sine qua non* of the portrait, is after all very relative.

It is curious how blind most people are to the characteristics of those around them. The artist will often reveal traits which are unsuspected—good as well as bad. Any one who wishes a flattering likeness should endeavour to keep his relations with the artist very cordial. Abbott Thayer explains in a letter to Royal Cortissoz the reaction of the artist to his sitter: "The violin, whose strings ring whenever their note is sounded by an outside instrument, is pure symbol of the poet. In the poet cumulative images of every form of beauty begin in earliest infancy to occupy the brain, till, in his early maturity, these have become true touchstones, like the violin string. Let the painter once look upon a person who has, beneath no matter how many surface defects, one dominant greatness—purity at heart and fiery love of truth and beauty—and in his own heart the image of such a person-

VAN DYCK AND REMBRANDT

Top: Anthony Van Dyck (1599–1641), "Children of Charles I.," painted in England in 1635. The original hangs in Windsor Castle

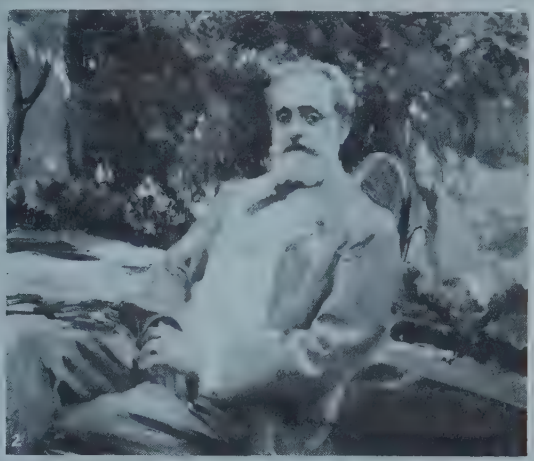
Bottom: Rembrandt Van Rijn (1606–69), "Sortie of the Banning Cock Company," also known as the "Night Watch," 1642. In the Rijks Museum, Amsterdam

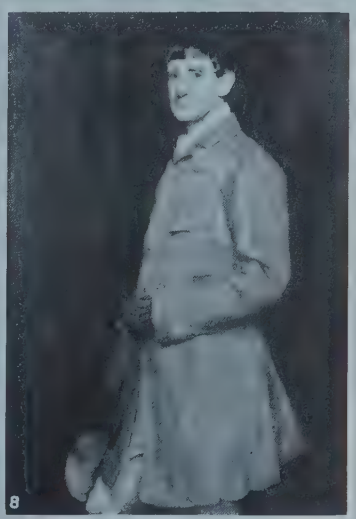
PORTRAIT PAINTING

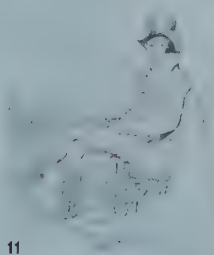
BY COURTESY OF (1) THE NATIONAL GALLERY, LONDON, (9) THE NATIONAL GALLERY, SCOTLAND; PHOTOGRAPHS, (3, 4) ALINARI, (5) BRAUN AND CIE, (7) COLLECTION ARCHIVES PHOTOGRAPHIQUES, (8) ANDERSON

PORTRAITS BY THE OLD MASTERS

1. "Portrait of a Man" by Jan van Eyck (1385–1440). Flemish
2. "Company of St. George" by Frans Hals (1580–1666). Dutch. In the Frans Hals Museum, Haarlem
3. "Portrait of Erasmus" by Holbein (1497–1543). German. In the Louvre
4. "Man with a Glove" by Titian (Tiziano Vecellio, *c.* 1477–1576). Venetian school. In the Louvre
5. "Jan Six" by Rembrandt van Rijn (1606–69). Dutch. In the Six Gallery at Amsterdam
6. "Portrait of a Man" by El Greco (Domenico Theotocopuli, *c.* 1542–1614). Spanish school. In the collection of Col. Michael Friedsam.
7. "Portrait of Mlle. Rivière" by Jean A.D. Ingres (1780–1867). French In the Louvre
8. Detail from "The surrender of Breda," showing the head of General Nassau, by Diego Rodriguez de Silva y Velazquez (1599–1660). Spanish. In the Prado
9. "Mrs. Graham" by Thomas Gainsborough (1727–88). English







BY COURTESY OF (1) FREDERICK T. WEBER, (2) THE HISPANIC SOCIETY OF AMERICA. (3) THE PHILLIPS ACADEMY, (10) NY CARLSBERG GLYPTOTHEK; PHOTOGRAPHS, (4) BERNHEIM JEUNE ET CIE, (6, 7) COLLECTION ARCHIVES PHOTOGRAPHIQUES, (9) BRAUN AND CIE, (11) GIRAUDON

16TH CENTURY PORTRAIT AND EXAMPLES OF MODERN WORK

1. "Mother and Daughter," by Frederick T. Weber (1883–), American
2. "Don Raimundo de Madrazo y Garreta," Joaquin Sorolla y Bastida (1863–1923), Spanish
3. "Woman in Green Velvet," by Abbott H. Thayer (1849–1921), American
4. "Portrait of the Painter," by Paul Cézanne (1839–1906), French
5. "Lady Orpen," by Sir William Orpen (1878–1931), English. In the Tate Gallery, London
6. "Portrait de Jeune Fille," by Hilaire Germain Edgar Degas (1834–1917), French
7. "Portrait de Mme. Charpentier," by Pierre Auguste Renoir (1841–1919), French
8. "Phil May," by Sir J. J. Shannon (1862–1923), English. In the Tate Gallery, London
9. "Portrait of a Man in a Broad Brimmed Hat," by Hans Holbein (1497–1543), German
10. "Members of the Committee for the French exhibition of Fine Arts at Copenhagen," by P. S. Kroyer (1851–1909), Danish
11. A pencil portrait, by Jean A. D. Ingres (1780–1867), French

PORTRAIT PAINTING

BY COURTESY OF (TOP) THE METROPOLITAN MUSEUM OF ART, NEW YORK, (BOTTOM) THE DEPARTMENT OF FINE ARTS, BROOKLYN MUSEUM

AN OIL PORTRAIT AND TWO WATER COLOURS BY SARGENT

"The Wyndham Sisters," painted in 1900 by John Singer Sargent (1856–1925), an important example of Sargent's portraiture, the type of work for which he was most widely known. He was equally a master of the technique of water colours, of which two examples are reproduced. Left "In a Levantine Port." Right "Santa Maria della Salute, Venice"

ality wakes into brilliant ringing clearness and takes the helm, saying: 'Watch this being! Thou wilt surely see, now and then, the being she really is (it's now a she!) come forth and be fully in sight. Watch, then, and take in how she looks, for in those aroused moments she dominates the whole face and body, ruling all their details into her heavenly form.'" Breaking appointments, coming too late to sittings, bargaining over the price, making remarks about the portrait before the artist asks for criticism, can mar the spirit that should reign during the pose. Hatred and contempt can find their way into the portrait. We have examples of this in Goya's portraits of the Bourbons and in some of Sargent's portraits; and often when artists paint from models of a race they dislike.

The artist owes the greatest consideration to his sitter and should avoid fatiguing him. A comfortable position is necessary if the expression is to be natural and the sitting should be a delightful experience to both the artist and the sitter. Van Dyck realized this and would often invite his sitters to dine with him so that he could study their expression when they were at their ease. Most people will be self-conscious and stiff at first but after some time will fall into natural poses. It is therefore wise to make small preliminary colour sketches until a good pose is found. This method has the added advantage that it gives the client an opportunity to express his opinion before the real work begins. An artist can do many different portraits of the same person. They may be all good and yet the client will have his decided preference for one.

It is the duty of the artist to find out what his client wants. Far from being a hindrance this may lead him to new ideas, just as the restriction of rhyme can suggest new thoughts to a poet. The greater the artist the more willing he will be to put his faculties to a test. Of course, this does not mean that he should do anything against his better knowledge. Holbein painted Erasmus in many different poses but the profile in the Louvre alone gives us the impression of greatness. Often the profile is the only advantageous view of a head and yet there seems to be a prejudice against it. Some people think it is easier to do. It is said that some of the men who had their portraits done by Rembrandt in large groups refused to pay him because he did not show their full face. Needless to say, it requires just as much knowledge to build up the modelling of the side face as it does to paint any other view of the head. From a decorative standpoint a profile is certainly the most advantageous. It predominated in the early Italian portraits.

Lighting presents many difficulties and so much depends on it that it requires the greatest attention. We have seen how largely the effects of the old masters depended on lighting. Holbein, Clouet and other early painters posed their sitters in full light which cast as few shadows as possible. Leonardo let the light fall from above to accentuate modelling. Rembrandt evidently used a small window which concentrated the light on one part. Ribera and his followers are known for their harsh light effects. It is evident that by manipulating the light different characteristics can be brought out or suppressed. The old masters generally posed women facing the light; while with men they let shadows accentuate the features.

The pose of the body and hands can be a great aid in obtaining a likeness but if too much emphasis is laid on action the attention can be diverted from the head. For the ancient Greeks the body had as much significance as the head; now after ages of neglect, it is coming to its own again, and the modern artist should make the most of this opportunity. The choice of costume is of the greatest importance. As every woman knows, different dresses bring out different qualities in their face. Often when an artist is unable to obtain the desired expression he finds that changing the dress is all that is necessary. The lines of the costume react on the lines of the face just as in music a note has its overtones. This is why artists are always glad to use scarfs, furs or anything they can arrange themselves on their sitters.

One of the most difficult problems is that of the background, which is just as important as any other part of the portrait. It can be compared to the accompaniment in music, strengthening by relative values the illusion of colour and form in the figure.

Each portrait presents its own individual problem. The surest way to fail is to try to develop a formula. It is impossible to paint two subjects with the same methods. For this reason great artists often have stage-fright before beginning a portrait. The brush work which makes the work of Rembrandt, Hals and Velasquez so astonishing was certainly not planned in advance but dictated by the inspiration of the moment and the vividness of the impression made on the artist. This does not mean that the artist should make experiments on his clients. He should not accept a commission to paint a portrait before he has solved all technical problems on portraits of friends or of hired models. It is one thing to paint from a hired model, accustomed to sit for many hours and indifferent about the results, and another to deal with a client easily fatigued, pressed for time and entitled to have a word in the proceedings.

A portrait painter can rarely put his canvas aside, forget about it and take it up again after months, when his vision is fresh. For this reason he must depend on comments made by the client and his friends, trying to glean from them where the trouble lies. It is rarely where the layman thinks but with experience and a little psychology the artist can profit by learning how the portrait reacts on different people. However, remarks offered before he is ready for them can be very harmful. It is difficult for the layman to realize that a portrait cannot be a perfect likeness until it is entirely finished; nor that the artist must work up all parts of the picture simultaneously in order to make a harmonious whole. He cannot finish the head and then progress to the body and hands any more than an architect can finish one room in a building before the roof is on. Each colour, each line, in a picture affects all others. It is their relative value alone which gives the illusion of form.

Modern artists as a rule paint directly, trying to place the right tone in its right place immediately. Charles Hopkinson recommends the process probably used by many of the old masters. Over a monochrome under-painting he models carefully with red, black, white and blue, mixing the lights with red and white; the shadows with red and black. These simple tones permit him to devote his full attention to the form. When this under-painting has dried he glazes with the bright colours, the yellows, bright reds, greens, etc. Rich, luminous transparent tones are obtained in this manner and by contrasting transparent flesh tones with opaque touches in accessories a great variety of texture is obtained. Both processes have their advantages and their disadvantages. Glazes do not permit a very sincere study of colours in relation to other colours and they can endanger the durability of the painting. Many of Reynolds' canvases faded, cracked and pealed off during his life-time. The direct method is very durable if it is not retouched too soon, but many of Sargent's portraits covered with cracks are sad examples of what happens when paintings are worked upon before they are thoroughly dry. Titian and Rembrandt are said to have let their work dry for months, but few modern people would be able to let their sittings cover so long a period.

The frame should be chosen before the portrait is finished and the final work on the canvas should be done after it is framed. The frame can be toned and antiqued so that the whole is harmonious. An unsuitable frame can affect the likeness and cause great trouble to the artist. It is well for the artist to know beforehand where the portrait is to be hung. He can then arrange his colouring and lighting to harmonize with the surroundings. Some people decorate their rooms to bring out a picture. The illusion of form is more vivid if the portrait is hung with the light falling from the direction of the light in the picture. The client should live with the portrait for some time before requesting changes. Often he becomes reconciled to the artist's vision and does not wish changes made which generally impair the beauty of the whole for the sake of some detail.

The opinion seems to prevail that different subjects require different mediums. Oils are supposed to be best for men, pastels and crayons for women and children. But we must remember that Holbein's magnificent drawings of men are equal, if not superior, to any painting. Latour could render in pastel the strength

of men as well as the delicacy of women and the portraits of women and children by the great English painters, or by Renoir, prove that with oil paints the most subtle qualities can be obtained. However, the lighter mediums permit the artist to abandon and take up his work at will, an important factor where capricious women and children are concerned. Oil painting requires longer sittings.

It is wise for an artist to change his medium now and then. Nothing freshens up his colour sense better than a water-colour or pastel and etchings stimulate his interest in line. Sculpture is the greatest tonic a painter can use. Most of the great masters devoted themselves to other subjects besides portraits. It is needless to mention the religious paintings of the old masters, the landscapes of Rembrandt, Rubens, Gainsborough, Whistler and Sargent. When tired of the sickly court Velasquez would take as models robust peasants. No artist can paint day after day the same type of picture without lessening the keen interest which is necessary for success. The joy which the artist takes in his work is communicated to the beholder.

It is difficult to form an opinion about contemporary portrait painting, as some of the best portraits are never exhibited. There are sincere, conscientious artists who with the right encouragement would be able to leave important work, but there are also many of the kind Hogarth attacked: those who impose on an ignorant public by painting from photographs; those who hide their ignorance and lack of talent behind all sorts of theories, claiming that likeness is not necessary; those who are more interested in paint and in clever brush work than in their sitter.

The sincere modernist in his effort to give to painting the emotional quality of music, finds in likeness as yet an obstacle, although his idols, the Orientals, Egyptians and primitives, made of it a powerful aid. He is governed by taboos and prejudices as bad as those of the academy, but rigid as are the rules and laws laid down by the modernist, they are "subject to change without notice." He is quick to admit an error in his arguments as in the case of cubism. There is an increasing number of cultured people who know what a fine portrait is, and who have pride and standing enough to wish to be painted as they are. (*See* also PAINTING; OIL PAINTING, TECHNIQUE OF; MINIATURE PAINTING.)

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(F. T. W.)

PORT RICHMOND, a community of the borough of Richmond in New York city, on the north shore of Staten island and on the Kill van Kull channel. It is one of the leading business areas of Staten island. Among its places of historic interest are the Dutch Reformed church, which is the direct successor of the church established at the Voorlezer's house (still standing) at Richmondtown, Staten island, about 1695; and the Daniel Mesereau house, built about 1787. In this house Aaron Burr spent the last years of his life, dying there on Sept. 14, 1836.

PORT ROYAL, an island in Beaufort county, South Carolina, U.S.A., at the head of Port Royal sound, about 16 mi. from the Atlantic coast, and about 50 mi. southwest of Charleston. It is about 13 mi. long and 7 mi. wide, generally flat, and with much marshland in its southern part and along the northeastern shore. The principal town is Beaufort (pop. 1950, 5,081), a port of entry and the county seat of Beaufort county. It is served by the Charleston and Western Carolina railway, has inland water communication with Savannah, Ga., and one of the best harbours on the Atlantic coast. In the vicinity cattle and cotton, rice, potatoes and other vegetables are raised, and there are groves of yellow pine and cypress. About 5 mi. south of Beaufort is the town of Port Royal (pop. 1950, 793). The island was named by Jean Ribaut (1520–65) who in May 1562 entered the harbour with a shipload of Huguenot colonists from France. Fort Charles (situated on Parris Island) was built and 29 volunteers under Captain de la Pierria were left as the first garrison. Soon afterward they mutinied, killed Pierria, put to sea in an insufficiently equipped vessel (first ocean-going vessel built by white men in North America) from which they were rescued by an English ship and carried to England. In 1683 a settlement of Scottish families led by Henry Erskine, third Lord Cardross, was established; but three years later most of the settlers were murdered by Spaniards from Florida and the remainder fled to Charleston. In 1710, after the lords proprietors had issued directions for "the building of a town to be called Beaufort Town" in honour of Henry Somerset, duke of Beaufort, the first permanent settlement on the island was established. In Jan. 1779, during the American Revolution, the British attempted to occupy the island but were defeated in February by Col. William Moultrie. In the Civil War, Confederate forts on Hilton Head and Bay Point were reduced by the bombardment of a northern naval expedition, after which Port Royal harbour became a federal coaling, repair and supply station.

PORT ROYAL, a celebrated Cistercian abbey, occupied a low and marshy site in the thickly wooded valley of the Yvette, at what is now known as Les Hameaux near Marly, a few miles southwest of Paris. It was founded in 1204 by Mahaut de Garlande, wife of Mathieu de Montmorenci-Marli in 1204; the church was built in 1229. During the three succeeding centuries its discipline became relaxed; reform was only attempted when Angélique Arnauld (*q.v.*) was appointed coadjutor to the abbess in 1598. Angélique's reforming energy soon brought her into contact with Jean du Vergier (*q.v.*) abbot of Saint Cyran, and chief apostle in France of the Jansenist revival.

In 1626 ague drove the nuns to Paris; they settled at Port Royal de Paris, at the end of the Faubourg Saint Jacques. The deserted buildings of Port Royal des Champs were presently occupied by "hermits," laymen, mostly relatives of the abbess, who wished for a semimonastic existence, though without taking formal vows. In 1648, however, some of the nuns returned, and the hermits retreated a short distance from the abbey. Here they set up a "little school" for the sons of Jansenist parents; and here Racine received his education. But in 1653 Innocent X condemned Jansenism and in 1656 "the hermitage" and school were broken up, and the nuns forbidden to receive new members.

In 1660 Louis XIV condemned the order and, between 1664 and 1669, the archbishop of Paris laid under an interdict those nuns who refused to subscribe to the papal censure on Jansen. In 1669, however, came the so-called "Peace of Clement IX," when the Jansenists generally were admitted to grace, and the interdict was removed from Port Royal, though the authorities broke up the convent into two distinct communities. The conformist nuns were gathered together at Port Royal de Paris, under an independent abbess, their Jansenist sisters at the original building in the country. Thereupon followed ten years of peace, through the protection of the king's cousin, Mme. de Longueville. But in 1679 she died, and Louis at once ordered the nuns to send away their novices and boarders and to receive no others. Finally, in 1705, he got from Clement XI a new condemnation of the Jansenists, which the few remaining nuns, all of whom were over sixty, refused to sign; and on the 29th of October 1709 they were forcibly removed from Port Royal by the police, and distributed among various conformist convents. In the

next year the buildings were pulled down. The land on which the convent had stood was made over to Mme. de Maintenon's college of St. Cyr; in 1825 it was bought by some descendants of Jansenist families, who have done their best to restore the grounds to their original appearance, and have built a museum rich in Jansenist relics. Port Royal de Paris was secularized at the French Revolution, and is now a maternity hospital.

For a classified list of the chief books, ancient and modern, dealing with Port Royal, *see* the *Abrégé de l'histoire de Port Royal*, by Jean Racine, ed. E. Gazier (Paris, 1908). *See* also C. A. Sainte-Beuve, *Port Royal* (6 vols. and index, Paris, 1882); Charles Beard, *Port Royal* (2 vols., London, 1861); H. Reuchlin, *Geschichte von Port Royal* (2 vols., Hamburg, 1839–44), and the books recommended under the articles ARNAULD, JANSENISM and PASCAL.

PORTRUSH, an urban district and seaside resort of Co. Antrim, Northern Ireland; the terminus of a branch of the Northern Counties (L.M.S.) railway. Pop. (1937) 3,386. Area, .8 sq.mi. It is situated on the basaltic peninsula of Ramore head, with a deep bay on either side, and a harbour protected by the natural breakwater known as the Skerries. It is the tourist centre for the Giants' Causeway, with which it is connected by an electric railway. The extensive ruins of Dunluce castle, between Portrush and Bushmills, stand on a rock separated from the mainland by a chasm spanned by a bridge. Portrush has a salmon trade.

PORT SAID (sah'ĕd), a seaport of Egypt, at the entrance of the Suez Canal, in 31° 15′ 35″ N., 32° 19′ 20″ E., and 145 mi. by rail N.E. of Cairo, pop. (1937) 124,749, lies on the western side of the canal on the low, narrow and treeless strip of land which separates the Mediterranean from Lake Menzala, the land at this point being raised and its area increased by the draining of part of the lake and by the excavation of the inner harbour. The outer harbour is formed by two breakwaters which protect the entrance to the canal; altogether the harbour covers about 570 acres and accommodates ships drawing 28 ft. The port possesses a floating dock 295 ft. long, 85 ft. broad and 18 ft. deep, capable of lifting 3,500 tons, and a patent slip taking 300 tons and ships drawing 9 ft. 9 in. of water. On the western breakwater is a colossal statue of Ferdinand de Lesseps by E. Fremiet, unveiled in 1899, and a lighthouse 174 ft. high. Among the few buildings of note in the town are the offices of the Suez Canal Company and the British barracks, the last having been built by Prince Henry of the Netherlands (d. 1879) as a dépôt for Dutch trade.

Port Said dates from 1859. Originally it depended entirely upon the traffic of the canal, being the chief coaling station of all ships passing through and becoming the largest coaling station in the world. In 1902, however, a new industry was added in the export of cotton from the eastern provinces of the Delta, the cotton being brought from Mataria by boat across Lake Menzala. In 1904 the opening of a standard gauge railway to Cairo placed Port Said in a position to compete with Alexandria for the external trade of Egypt generally, besides making it a tourist route to the capital from Europe.

PORTSMOUTH, EARLS OF. In 1743 John Wallop (1690–1762) of Farley Wallop in Hampshire was created earl of Portsmouth. He belonged to an old Hampshire family and had been a lord of the treasury from 1717 to 1720, when he was created Baron Wallop. The earldom has since been held by his descendants. Gerard Vernon Wallop (b. 1898) became the 9th earl in 1943; he was a member of parliament, 1929–34, and author of several books, including *Alternative to Death* (1943).

PORTSMOUTH, LOUISE DE KÉROUALLE, DUCHESS OF (1649–1734), mistress of the English king Charles II., was placed early in life in the household of Henriette, duchess of Orleans, sister of Charles II. In 1670 she accompanied the duchess on a visit to Charles II. at Dover. The king placed her among the queen's ladies-in-waiting. Her intrigue with Charles was vigorously pushed by the French ambassador, Colbert de Croissy, aided by the secretary of state, Lord Arlington, and his wife. Louise, who concealed great cleverness and a strong will under an appearance of languor and a rather childish beauty (Evelyn the diarist speaks of her "baby face"), yielded only when she had already established a strong hold on the king's affections. Her son, ancestor of the dukes of Richmond, was born in 1672.

The support she received from the French envoy was given on the understanding that she should serve the interests of her native sovereign. The bargain was confirmed by gifts and honours from Louis XIV., and was loyally carried out by Louise. The hatred openly avowed for her in England was due as much to her own activity in the interest of France as to her notorious rapacity. The titles of Baroness Petersfield, countess of Fareham and duchess of Portsmouth were granted her for life in 1673. Her pensions and money allowances of various kinds were enormous. In 1677 alone she received £27,300. Soon after the king's death she retired to France, where, except for one short visit to England during the reign of James II., she remained. Her emoluments were lost in her later years, which were spent at Aubigny, but she was protected from her creditors by Louis XIV. She died in Paris on Nov. 14, 1734.

See H. Forneron, *Louise de Kéroualle* (Paris, 1886).

PORTSMOUTH, a city, county and parliamentary borough, and seaport of Hampshire, England, 74 mi. S.W. from London, on the S.R. Pop. (est. 1938) 258,400. Area 14.4 sq.mi. The city suffered heavy air raids during World War II. About 93% of the houses were damaged, though many were repairable, but the gild hall (1890), both the main shopping centres and many public buildings were gutted.

Portsmouth owes its origin to the retreat of the sea from Porchester. No town existed there until the 12th century, when its strategical advantage induced Richard I to build one. The borough is governed by a charter granted by Charles I in 1627, modified by the municipal acts of the 19th century. The market, dating from 1194, is held on Tuesday and Saturday.

The naval station and arsenal is an aggregate of four towns, Portsmouth, Portsea, Landport and Southsea, and occupies the southwestern part of Portsea island, which lies between Portsmouth harbour and Langstone harbour, two inlets of the English Channel. Portsmouth harbour opens into Spithead, one of the arms of the Channel separating the Isle of Wight from the mainland. The harbour widens inwards in bottle form, Portsmouth lying on the east shore of the neck, with Gosport opposite to it on the west side. Portsmouth proper may be distinguished as the garrison town; Portsea as the naval station with the dockyards; Landport is occupied chiefly by the houses of artisans; and Southsea is a residential quarter and a watering-place. There is a modern Roman Catholic cathedral. The church of St. Thomas of Canterbury, a cruciform building, dates from about 1180. It was restored in 1904, and in 1935 a scheme of enlargement was begun. In 1924 the foundation of a new diocese of Portsmouth and the Isle of Wight, taken from that of Winchester, was approved, and St. Thomas's was designated as the pro-cathedral. The see was created in 1927. The garrison chapel originally belonged to the hospital of St. Nicholas, a foundation of the 13th century. Passenger steamers from Portsmouth harbour serve Ryde in the Isle of Wight. A ferry and a floating bridge connect with Gosport. The parliamentary borough was divided into central, north, and south divisions in 1918, each returning one member. The county borough was created in 1888 and raised to the dignity of a city (1926) with a lord mayor in 1928.

Nelson's flagship, H.M.S. *Victory*, on which he met his death at Trafalgar in 1805, is in dry-dock in Portsmouth; she is the flagship of the admiral of the station. (*See* NELSON.)

The dockyard dates in its earliest form from 1496, though the town was already of importance as a naval station. Its later rise began with the building of one dry and two wet-docks in 1698. In 1848 a steam basin and four new docks were opened, the dockyard ground being extended to 115 ac. In 1865 extension works decided upon included a tidal basin and a deep dock and two locks, in themselves serving as large docks, which lead to three basins and four docks. Subsequent improvements included two new dry docks (1896); the construction of jetties at the entrance to the tidal basin and at the north wall; the establishment of a coal wharf with hydraulic appliances; numerous subsidiary works; and extensive dredging of the harbour to increase the berthing accommodation for the fleet. New locks and a dry dock were completed shortly before World War I. In 1925 the government

decided to reduce the dockyards at Rosyth and Pembroke to a care-and-maintenance basis and to concentrate all admiralty home dock work at Portsmouth, Devonport, Chatham and Sheerness. Portsmouth royal dockyards cover an area of 500 ac. There is a gunnery establishment on Whale Island and barracks, including those of the royal marine artillery at Eastney, beyond Southsea.

PORTSMOUTH, a city of New Hampshire, U.S., the only seaport of the state; on the Piscataqua river, near its entrance into the Atlantic ocean. It is on federal highways 1, 4 and 16 and is served by the Boston and Maine railroad and by air and bus lines. It is connected with Maine by two bridges, the Memorial bridge (1923) and the $3,000,000 Interstate bridge (1940). The population in 1950 was 18,830; in 1940 it was 14,821 by the federal census. On Fernald's and Seavey's Islands, opposite the city (but in the town of Kittery, Me.), is the Portsmouth navy yard (established 1800), one of the largest in the country, and the principal yard for building, fitting out and overhauling submarines. The treaty ending the Russo-Japanese War was negotiated there in 1905. During the Spanish-American War, Adm. Pascual Cervera y Tópete and other Spanish officers and sailors were imprisoned on Seavey's Island, where later a large naval prison was built. Portsmouth is the seat also of a naval hospital (1891).

At New Castle (2 mi. S.E.), guarding the entrance to Portsmouth harbour, is Ft. Constitution, on the site of Ft. William and Mary (1630); and across the river, on Kittery Point, is Ft. McClary, a colonial blockhouse. Portsmouth is rich in historic associations and in beautiful buildings of the 18th and early 19th centuries, many of which are open to the public. The two oldest houses in the city were built in 1664 and 1668. Among fine examples of colonial architecture are the Wentworth-Gardner house (1760), and the Tobias Lear house (1740) both recently renovated; the Moffatt-Ladd house (1753); the mansion built by Gov. Benning Wentworth in 1750; the house occupied by John Paul Jones in 1779 (built in 1758), now the home of the Portsmouth Historical society; the William Pitt tavern (before 1767); the Gov. John Langdon house (1784); the Warner house (1716); and the Assembly house, a dance hall built in 1750 and described by George Washington as one of the finest in the United States. The Athenaeum, a valuable library established by a society organized in 1817, occupies a building erected in 1803. Portsmouth was the birthplace of Governors Benning Wentworth, John Wentworth and John Langdon; Thomas Bailey Aldrich (whose home is now a museum), Gen. Fitz John Porter and Celia Thaxter.

In 1623 David Thomson, with a small company from Plymouth, Eng., established a fishing and trading station at Little Harbor (now Odiorne's Point in the town of Rye); and in 1630 another band, sent over by the Laconia company, occupied Thomson's house and Great Island (New Castle), and built the "Great house" on what is now Marcy street, in Portsmouth. The settlement was known as Strawberry Banke until 1653, when it was incorporated by Massachusetts under the name of Portsmouth. It was the capital of New Hampshire from 1679 (when the province was separately constituted) until 1775, and was chartered as a city in 1849. One of the first military exploits of the Revolution took place at New Castle, when the Portsmouth committee of safety, on receiving from Boston (through Paul Revere) a copy of the order prohibiting the exportation of military supplies, organized militia companies and captured Ft. William and Mary (Dec. 14, 1774). During the Civil War the "Kearsarge" and several other war vessels were built at the Portsmouth navy yard, and in the 20th century it became a centre for the construction of submarines.

PORTSMOUTH, a city of southern Ohio, U.S., the county seat of Scioto county; on the Ohio river, at the mouth of the Scioto. It is on federal highways 23 and 52, and is served by the Baltimore and Ohio, the Chesapeake and Ohio, and the Norfolk and Western railways, and by river packets and barges. A highway bridge across the Ohio was opened in 1927. Pop. (1950) 36,798; in 1940 it was 40,466 by the federal census. It has a picturesque site on a bend in the river, protected from high water by a concrete flood wall 77 ft. above normal water stage and 27 ft. higher than the flood stage of the Ohio river. This $10,000,000 works was completed and dedicated in 1950. The Shawnee State forest, a state reservation of 60,000 ac., is near the city; and along the Ohio for 8 mi. extend earthworks of the mound builders, including the Great Serpent mound at Locust Grove (75 mi. W.). Products are iron and steel, shoes, heels and lasts, shoelaces, stoves, gray iron castings, firebrick, coke and by-products, paper boxes. There are large sandstone quarries which have supplied material for the Canadian parliament buildings and many other important structures of America. Settlement in this vicinity began in 1796. In 1799 Thomas Parker, of Alexandria, Va., laid out a village (called Alexandria) below the mouth of the Scioto, but it suffered from floods, and about 1810 the inhabitants moved to Portsmouth, which had been laid out in 1803. Portsmouth was incorporated as a town in 1815, as a city in 1851. The Ohio and Erie canal from Cleveland to Portsmouth was opened in 1832.

PORTSMOUTH, a city of southeastern Virginia, U.S., on the Elizabeth river (an estuary of Hampton Roads) opposite Norfolk; the county seat of Norfolk county, but independent of it. It is on federal highway 17 and is served (either directly or through the industrial belt line which encircles Portsmouth and Norfolk) by the Atlantic Coast Line, the Chesapeake and Ohio, the Norfolk Southern, the Norfolk and Western, the Pennsylvania, the Seaboard Air Line, the Southern Atlantic and Danville and the Virginian railways, and by interurban trolleys, motorbus and truck lines, ferries and steamship lines.

The population of Portsmouth was 80,039 in 1950 and 50,745 by the federal census of 1940 (35% Negroes). On the eastern water front is the Norfolk naval shipyard, the oldest, and one of the most important, in the country. On a promontory about a mile west is the U.S. naval hospital. Trinity church (1762) is the oldest building in the city.

Portsmouth is a shipping point for large quantities of oysters, vegetables and farm produce. Commercially the city is an integral part of the great port of Hampton Roads. (*See* NORFOLK.) The city operates under a commission-manager form of government.

Portsmouth was established in 1752 by act of the Virginia assembly, incorporated as a town in 1852 and chartered as a city in 1858. The navy yard, established by the British shortly before the Revolution, was confiscated by Virginia during the war and in 1801 was sold to the United States. In April 1861 it was burned and abandoned by the Federals, and then for a year was the chief navy yard of the Confederates. They raised the frigate "Merrimac" and transformed her into the ironclad "Virginia" which on March 9, 1862, fought the famous battle with the "Monitor" in Hampton Roads (*q.v.*). Two months later (May 9) the Confederates abandoned the navy yard and evacuated Norfolk and Portsmouth.

PORT SUDAN, a town and harbour on the west coast of the Red sea, in 19° 39′ N. lat. and 37° 14′ E. long., approximately 700 mi. by sea south of Suez and approximately 497 mi. by rail northeast of Khartoum and 295 mi. east of the Nile valley, which the railway joins at Atbara. Pop. (1945) 47,400. It is the port of the Anglo-Egyptian Sudan. The coral reefs fringing the coast are there broken by a straight channel with deep water giving access to the harbour from which a short arm branches off westward close within the entrance. Depth 10 to 14 fathoms; at the main quays 33 ft. On the northeast side of the inlet are the main quays fitted with electric cranes, etc. There are the customs house, import clearance sheds and the warehousing area. The town proper lies on the southwest side of the inlet connected with the main quays by a causeway. Besides government offices, the public buildings include a hospital and schools.

The port dates from 1908. It owes its existence to the desire of the Sudan administration to find a harbour more suitable than Suakin for the commerce of the country. The railway (which has termini both at Port Sudan and Suakin) was opened in Jan. 1906. Port Sudan immediately attracted a large trade and became a regular port of call of British, German, Italian and other steamers. The imports are largely cotton goods, coal, oil, petroleum, provisions, machinery, timber and cement; the exports cotton lint, gum, sesame, durra, ivory, senna, coffee, sheep and goatskins, etc. Eighty miles north of Port Sudan is Mohammed

Gul, the port for the mines of Gebet.

PORT TALBOT, Glamorganshire, Wales, a municipal borough on the Avon, near its mouth in Swansea bay, 11 mi. E.S.E. of Swansea and 170 mi. from London by the Western Region railway. Pop. (1951) 44,024. Area 38.8 sq.mi. A castle once stood at Port Talbot, but, despite its apparent strategic importance, the Normans allowed it to remain in the hands of Welsh chieftains who, from the 13th century on, styled themselves De Avan or D'Avene. A town grew up around the castle; one of its charters was granted in 1372 by Edward le Despenser. During the early industrial period, Cornish pioneers were attracted to the Avon valley by its possibilities as a coal-mining and manufacturing centre. The early tendency was to take the ores to the coal and thus Cwmavon, 1½ mi. N.E. of Aberavon, flourished in the middle of the 19th century, being noted for its copper-smelting works and other metallurgical activities. Copper was brought from Cornwall and discharged at Aberavon, the ships then going to Taibach to load a return cargo of coal from the Morfa collieries. With the increase in coal production for export, the need for better shipping facilities was felt. The river below Aberavon was deflected into an artificial channel, its former mouth blocked and its lower course converted into a dock, which was again extended in 1898. Railway enterprises linked the town with the coal-mining valleys, especially with Cwm Rhondda, and in 1921 the Great Western railway took charge of the docks. With the development of the port, the town took over many of the activities of Cwmavon, coal being brought down to the port to work up imported ores. Consequently, a modern industrial centre sprang up between the old centres of Aberavon and Taibach, and in 1921 the town of Aberavon and the urban district of Margam were amalgamated as Port Talbot. The town suffered severely in the depression of the 1930s, 34.4% of the insured male population being unemployed in May 1934. The establishment of a trading estate resulted in some improvement.

PORTUGAL, a republic of southwestern Europe, forming part of the Iberian peninsula and bounded on the north and east by the Spanish provinces of Galicia, León, Extremadura and Andalusia and on the south and west by the Atlantic ocean. For administrative purposes Portugal includes the Azores (about 700 mi. W. of Lisbon) and the Madeira group of islands. The total population amounted to 7,722,152 in 1940 and to 8,490,455 in 1950; the figures for continental Portugal were 7,185,143 in 1940 and 7,902,590 in 1950. The area of continental Portugal is 34,254 sq.mi., that of the Atlantic islands 1,236 sq.mi. In shape the country is a rough rectangle, its parallel sides running from east to west about 362 mi. apart and its breadth varying from 140 mi. in the north to about 70 mi. in the southern Alentejo.

Portugal's land frontiers are partly defined by mountains and by its four principal rivers. In the northwest the lower course of the Minho divides Portugal from Galicia, but from its middle course to Miranda do Douro the frontier usually follows mountain ranges. From Miranda to Barca de Alva the Douro marks the limit, which then drops raggedly to the level of the Tagus. The frontier follows the Tagus westward for a little way, then cuts across country to the Guadiana. From Mourão southward Portugal extends beyond the Guadiana and there is no natural feature to divide it from Spanish Extremadura. In its lower course the Guadiana again forms the frontier.

The Portuguese seaboard is about 500 mi. long. The only islands near the coast are the dangerous Farilhões and Berlings (Portuguese Berlengas) off Cape Carvoeiro. Most of the Portuguese coast is a series of long and gradual curves, with few indentations. Long sandy beaches are general, but Cape Rock (Cabo da Roca; *i.e.,* the Distaff) and Cape Espichel are rocky headlands north and south of the Tagus where the mountains reach the sea. Sines is another headland, and Cape St. Vincent (Cabo de São Vicente), the southwestern extremity of the country, has rough cliffs. There are sandy islands off the coast of the Algarve. The estuaries of the Tagus and Sado form considerable indentations. The former contains a small inland sea, the Mar da Palha, separated from the ocean by the narrows of the "Lisbon river"; the capital, on the north shore, is also the country's largest port. The Sado estuary lies before the port of Setúbal. The estuary of the Douro contains the great city of Oporto (though the port installations are outside the estuary at Leixões). The Mondego estuary has the small port and resort of Figueira da Foz. A number of other ports scattered round the coast are important for sardine and tunny fishing, but their harbours are almost all suitable only for small ships.

The "Atlantic Islands"—that is the Azores and Madeira (*qq.v.*) but not the Cape Verde Islands—have since 1832 formed part of metropolitan Portugal. The nine islands of the Azores have an area of 888 sq.mi. and a population (1950) of 318,686; the Madeira group, consisting of Madeira itself, Porto Santo and the uninhabited Desertas and Selvagens (Salvages) islands, has an area of 308 sq.mi. and a population of 269,179 (1950).

Physical Features.—The scenery of Portugal is rather diverse in relation to its limited area; both fauna and flora vary considerably within small distances. A broad distinction may be made between the area north of the Tagus, which is hilly (about half of it above 1,300 ft.), and that to the south, which is flat (97% of it below 1,300 ft.) except for the hills of Monchique which divide the Algarve from the Alentejo. Generally speaking, Portugal begins at the western edge of the Spanish *meseta* and shelves away from Spain and down to the Atlantic seaboard.

Northern Portugal comprises the provinces of Minho and Douro Litoral, which form the humid coastal region of pinewoods, maize fields and "green wine" (*vinho verde*), and the more mountainous interior province of Trás-os-Montes e Alto Douro, which includes bare ranges of mountains interspersed by forests of oak and chestnut and valleys in which cereals, olives and root crops are grown. The upper Douro valley where the river has cut through a deep stony gorge forms the celebrated wine country (*pais do vinho*) from which port wine derives its special qualities.

South of the Douro there is a coastal strip, the province of Beira Litoral, similar to the coast farther north, with fields of cereals and root crops and pinewoods; Aveiro, with its salt-water lagoon and canals, has an ancient salt industry. Inland, Beira Alta and the northern part of Beira Baixa share the Serra da Estrêla, the highest range of mountains in Portugal, which falls away in rough scrubby slopes toward the Spanish frontier. The folds of middle Beira form a transition area that produces good wine. The region of Castelo Branco in Beira Baixa is suitable for extensive agriculture with olives and cork trees. The Tagus valley, round which is formed the province of Ribatejo, is a rich alluvial region, and the flat and fertile fields known as *lezírias* bear cereals, fruits, rice and market produce, which form the wealth of the district of Santarém. To the southeast of Ribatejo is Alto Alentejo, where frontier areas of cork oaks and olives are broken by extensive stretches of sparsely inhabited heath. This country gradually merges into the extensively cultivated wheat-growing district of Beja in the province of Baixo Alentejo. The mountains and heath of Monchique divide this area from the seaboard of the Algarve, which partakes rather of the character of Andalusia or northwest Africa, being rich in fruit trees, especially the almond, fig and carob.

As has been mentioned, the highest mountains of Portugal are in the Serra da Estrêla (6,535 ft.), which forms the backbone of Beira. The next highest land is the Transmontane system on the Galician frontier, whose ranges are usually continuations of those in Spanish territory: the Serra do Gerez reaches 5,045 ft.; Larouco, adjoining Gerez, 5,003 ft.; Peneda, overlooking the river Minho, 4,357 ft.; Marão, between the Douro and Tâmega, 4,642 ft.; and Nogueira, near Braganza, 4,324 ft.

Between the Douro and the Mondego, the chief ranges are the Montemuro (4,534 ft.), the Serra da Gralheira (3,661 ft.), the Serra do Caramulo (3,514 ft.) and the Serra da Lapa (3,127 ft.). The Serra da Estrêla is continued in the Serra de Lousã (3,944 ft.). Between Lisbon and the sea rise the charming hills of Cintra (Sintra), which with the Serra da Arrábida (1,637 ft.) form an amphitheatre round the capital, broken by the Tagus valley. South of the Tagus on the Spanish frontier there are several blocks of high land or single ridges, including São Mamede (3,363 ft.), Ossa (3,129 ft.) and Monfurado (1,388 ft.). The Monchique

range in the northern Algarve reaches 2,959 ft.

The rivers of Portugal comprise four large streams, which have their sources in Spain, and a number of shorter ones. The Douro (Spanish Duero), Tagus (Portuguese Tejo, Spanish Tajo), Guadiana and Minho (Spanish Miño) are the main rivers (*see* DOURO; GUADIANA; TAGUS). All four form for part of their courses sections of the frontier, but none of them is navigable in an international sense; Portugal is consequently not the natural port for the wares of western Spain. The Minho, 210 mi. long, can take small coasters for about 20 mi. The Lima (Spanish Limia) rises in Galicia, but its main course is in Portugal; on its estuary is the port of Viana do Castelo. The Cávado and Ave flow into the sea at Espozende and Vila do Conde. South of the Douro, the main rivers are the Vouga, rising in the Serra da Lapa and flowing into the lagoon at Aveiro; the Mondego, 137 mi. long, the longest river wholly in Portuguese territory, which rises in the Serra da Estrêla, runs first northeast, then turns back to flow through the picturesque gorge of Penacova, round the foot of the hill on which Coimbra is built and to the sea at Figueira da Foz. The Zézere, rising north of the Serra da Malcata, is a tributary of the Tagus from the north. The Sorraia flows into the Tagus estuary from the south. South of the Tagus, the Sado rises near Ourique and flows northward into a large bay on which is the port of Setúbal.

Portugal abounds in hot springs, often known as *caldas* (*e.g.*, Caldas da Rainha, Caldas de Monchique, etc.). These springs are used for medicinal purposes, and the resorts are much frequented.

On the Spanish frontier the scenery is rough and somewhat monotonous, rising to grandeur only in the gorge of the Douro and on the heights of Alto Alentejo; but the interior and coast are varied and pleasantly coloured. On the northern coastal area the effects of mist are attractive, and the softness of the light is in contrast with the dazzling summers of the extreme south. Where the soil is good, a wide variety of temperate and semitropical vegetation can be grown, and in Portugal the regions of palm and pine come close together. Although these favoured areas give the impression of a "garden planted by the sea," it is also true that much of the soil is poor and the rocky hillsides are often unproductive.

For the geology of Portugal, as part of the Iberian peninsula, *see* SPAIN.

Climate.—The climate of Portugal is usually mild, equable and temperate. The mean temperatures of the four cities of Lisbon, Oporto, Coimbra and Évora are between 60° F. and 61.5° F., and the daily variation nowhere exceeds 23° F. At Lisbon snow is almost unknown, and the heat of summer is tempered by a breeze which blows every evening (*nortada*). At Oporto the temperatures are a little lower and the whole year is damper, while the Algarve is sufficiently far south to experience considerable heat in August. In the interior the climate is affected by the Spanish *meseta*, and the northern and central frontier zones are hotter in summer than the seaboard and bleaker in winter; the deeper valleys are shielded by the mountains from cool winds and are sometimes oppressively hot in summer, while the summits of the mountains overlooking them remain fresh. The coldest place in Portugal is the high range of the Serra da Estrêla, where the annual mean temperature is less than 45° F. Heavy snowfalls lie on the mountain tops for several months of the year, but perpetual snow is unknown.

Rainfall varies considerably and reaches as much as 110 in. in the Serra da Estrêla and the northern coastal area. In the interior, drought is not uncommon and sometimes seriously affects crops, whose production may consequently vary considerably from year to year. Fog is common off the coast and is sometimes dangerous to shipping. Violent storms are infrequent, but earthquake tremors are felt from time to time. Several severe earthquakes are on record in historic times; by far the most violent was that of Lisbon (*q.v.*) of Nov. 1, 1755.

Fauna and Flora.—For the fauna of the Iberian peninsula as a whole, *see* SPAIN. Wolves are found in the wilder and more mountainous areas, notably the Serra da Estrêla, and wild boars are preserved in certain districts. Bears existed in historic times but have long been extinct. The birds of Portugal are varied, but their distribution is often restricted to certain limited areas and they are rather inadequately protected.

A mixture of temperate and semitropical vegetation is characteristic of Portugal, where many of the plants of northern Europe flourish side by side with others introduced from Africa, the Americas and the east; thus, the slopes of Cintra are covered with pines and familiar deciduous trees, interspersed with specimens of cacti, palms, aloes and tree ferns. This is in contrast with Spain, where the vegetation, though its variety is almost equally great, is divided among zones that are rather severely demarcated. The difference is caused by the higher rainfall of Portugal, which is brought in on winds from the Atlantic and dropped before the Spanish frontier. In a number of places there are fine stretches of forest, among which the woods of Bussaco (*see* BUSSACO, SERRA DO) deserve to be mentioned. North of the Tagus the lime, elm, poplar and pine are common; the chestnut is grown for its fruit, and the Barbary oak (*Quercus bellota*, Portuguese *azenheiro*) for its acorns and charcoal, which is widely used as fuel. The cork oak is widely distributed, and the cork is of great importance in Portugal's export trade; the most important cork-bearing region is the Alentejo. The olive is also widely distributed and of no less economic importance. The carob (*Ceratonia siliqua*, Portuguese *alfarrobeira*) produces edible seed pods. Numerous conifers are grown for their timber and resin; they include the *Cupressus lusitanica*, probably a native of the Azores. Other common trees are the ilex, araucaria, myrtle and magnolia. The Australian eucalyptus flourishes, being remarkable for the rapidity of its growth. Also to be found are the agave, the Mexican opuntia, the American maple, the jacaranda and other witnesses of Portuguese enterprise in the four corners of the earth. Among specialized flora the Serra de Estrêla may be mentioned for its alpines and the lagoon at Aveiro for its aquatic plants.

HISTORY

Portugal has existed as an independent state since the 12th century, when it finally detached itself from León. Possibly even two centuries earlier there was a county of Portugal; but before this the area that is now so called had no consecutive political history independent of Spain's, nor indeed a distinctive name. An account of the common experience of the Iberian peninsula in Roman, Visigothic and Moslem times is given in the article SPAIN, but it should be remembered that the lack of independent administrative records does not disprove the ethnical and geographical dissimilarity of early Portugal from neighbouring territories. The Lusitanians, a tribe of what is now northern Portugal with relatives in adjacent Spain, fiercely resisted the Romans not only in their own tribal territory but as far afield as Andalusia. Their leader Viriatus being killed by treachery, they were subdued; but their name was later given to the westernmost of the three provinces into which M. Vipsanius Agrippa divided the peninsula (27 B.C.). The Roman Lusitania included most of modern Portugal but also spread eastward, its capital being at Mérida in Spain.

After the Germanic invasions (409–418), the Suebi maintained for a time an independent kingdom in the northwest, but this was incorporated into Visigothic Spain in 585. From this time until the Moslem invasion of 711 Portuguese history is undifferentiable from the little that is known of the Visigothic kingdom. With the fall of this power, the whole of Portugal passed under Moslem rule; but there was little Arab or Berber settlement in the north, and within half a century the expansion of the Christian kingdom of Asturias and León put an end to Moslem power north of the Douro.

The County and the Kingdom (to 1383).—It was in this early period of reconquest and resettlement that the phrase *terra portucalis* was first used. Derived from the name of a Roman settlement on the shore of the Douro, Portus Cale, it came to be applied to a wider area from the Douro to the Galician frontier, the Minho. This area became in the 10th century an hereditary county, when the first known governors were Dona Mumadona and her husband Mendo Gonçalves. Half a century later a mem-

ber of this family was tutor and later father-in-law to Alphonso V of León, but under Ferdinand I, "the Great", of Castile and León it appears to have lost its influence. In 1064 Ferdinand carried the reconquest down to the Mondego, capturing Coimbra and appointing a separate governor there.

Under Alphonso VI of León (1065–1109) and Castile (1072–1109), the county of Portugal reappears and incorporates the district of Coimbra, to form the domain of Alphonso's illegitimate daughter Teresa and her husband Henry, brother of Duke Odo (Eudes) I of Burgundy. From 1095, therefore, Count Henry and Queen Teresa, as she sometimes called herself, governed Portugal and held the Coimbra frontier as vassals of León. On the death of Alphonso VI, when León passed to his legitimate daughter Urraca, Henry attempted to invade her domains, but little had been accomplished when he died in 1112. His son Alphonso (Afonso) I, called Henriques, was an infant; and his widow, actuated by jealousy of her half-sister, vainly endeavoured to intervene in the affairs of León and Galicia. Her association with her Galician favourite Fernão Peres, count of Trava, lost her the esteem of the Portuguese nobility and clergy. In 1128, after she had again embroiled Portugal in a futile conflict with León, supporters of her young son defeated her followers in the battle of São Mamede, and she and Fernão Peres were exiled.

Already in 1124 Urraca's son Alfonso VII had armed himself knight and been declared king of León. His cousin Alphonso Henriques similarly armed himself knight (a privilege usually confined to kings) a year later and, on the banishment of his mother, became count of Portugal. During his first years Alphonso Henriques fought vigorously on all frontiers, invading Galicia in the north and repelling the Moslems in the south. On July 25, 1139, he defeated the Moslems in the battle of Ourique (probably not the modern town of the same name). Soon after, he assumed the royal style (1140). In 1143, as a result of his campaigns and of negotiations with his cousin, his independence was admitted by León, and he placed Portugal under the direct protection of the Holy See, promising to pay an annual tribute. In March 1147 he carried the frontiers of Christian Portugal south to the Tagus with the capture of Santarém, and the arrival of a band of English, French, Flemish and German crusaders bound for Palestine enabled him to form a temporary alliance and to undertake the siege of Lisbon, which fell on Oct. 24, 1147. An English crusader, Gilbert of Hastings, became the first bishop of the restored see of Lisbon.

In Alphonso's later years, from 1179 to 1184, the Moslems, stiffened by the African Almohades, regained some ground in the south but failed to take Santarém or Lisbon; and when he died on Dec. 6, 1185, Alphonso had not only gained Portugal's independence but doubled its national territory. The military orders, especially the Templars, but also those of Santiago and Calatrava and later the Hospitallers, assisted in the defense and resettlement of the frontier areas regained from the Moslems, and the Cistercians introduced good agriculture and architecture into central Portugal, making their headquarters at Alcobaça.

Although Alphonso Henriques began to grant charters to new settlements, it was his son Sancho I (1185–1211) who enfranchised many municipalities (*concelhos*), especially in eastern and central Portugal. The privileges of these communities were embodied in charters (*forais*), which attracted settlers from the more feudal north. Even Moslems were enfranchised, though on the other hand many of them were enslaved. Assisted by passing crusaders, Sancho captured Silves in the Algarve (1189); but in the following year an army from Africa advanced as far as the Tagus and, although Lisbon, Santarém and Tomar stood firm, the Moslems recovered Silves in 1191 together with most of the land below the Tagus. In his later years Sancho was involved in a quarrel with the bishop of Oporto and with the papacy; but peace was made before his death, and it was left to his son Alphonso II, "the Fat", (1211–23) to endeavour to strengthen the power of the throne at the expense of the church.

Though Alphonso II himself was an unwarlike king, his followers were beside the Castilians at the great Christian victory of Las Navas de Tolosa in 1212 and, again assisted by crusaders, recovered Alcácer do Sal in 1217. Meanwhile Alphonso repudiated the bequests of large estates made by his father to his brothers and accepted those to his sisters only after a war with León. In the first year of his reign, Alphonso called a meeting of the *cortes* at Coimbra, to which the nobility and prelates were summoned (representatives of the commoners were not to appear till 40 years later). On this occasion the barons and, especially, the clergy obtained important concessions; in fact the position of the church and the orders was now so strong that Alphonso II and his successors were involved in recurrent conflicts with Rome. Alphonso himself instituted *inquirições* or royal commissions to investigate the nature of holdings and recover whatever had been illegally taken from the crown. In his last years Alphonso defied the papacy and was excommunicated, but he was reconciled shortly before his death in 1223.

His son Sancho II (1223–48) succeeded as a boy of 13. Little is known of his reign, but the reconquest of the Alentejo was now completed and much of the Algarve was reduced. On his accession, Sancho found the church in full ascendancy as a result of the agreement made before his father's death. Conflicting reports exist of Sancho's own government, but in his later years the kingdom seems to have slipped into anarchy. At all events his younger brother Alphonso, who had become count of Boulogne by his marriage with the countess Matilda, was granted a papal commission to take over the government, and Sancho was ordered to be deposed by papal bull. When Alphonso reached Lisbon in 1246, he received the support of the church and of the inhabitants of Lisbon and other towns. After a civil war lasting two years, Sancho II retired to Toledo, dying there in Jan. 1248.

On his arrival the count of Boulogne had already declared himself king as Alphonso III, and the death of Sancho without issue gave his usurpation the mantle of legality. He brought together the divided kingdom, completed the reconquest of the Algarve, transferred the capital from Coimbra (*q.v.*) to Lisbon and, fortified by the support of the towns, summoned *cortes* at Leiria at which for the first time commoners representing the municipalities made their appearance (1254). Although still the husband of Matilda of Boulogne, Alphonso married Beatriz de Guzmán, daughter of Alphonso X of Castile, receiving the disputed territory of the Algarve as a fief of Castile. This marriage led to a dispute with the Holy See, in which Alphonso was placed under an interdict. Despite his early connection with Rome, Alphonso refused to give way, and in 1262 the bigamous marriage was legalized and his eldest son, Denis (Diniz), legitimized. Shortly afterward, Alphonso launched *inquirições*, as a result of which the church was deprived of much property. The prelates protested and most of them left the country. Although Alphonso was excommunicated and threatened with deposition, he defied the church until shortly before his death early in 1279.

The achievements of Alphonso's reign—the completion of the reconquest, the assertion of the royal power before the church and the incorporation of the commoners in the *cortes*—indicate important institutional advances. Under his son Denis (1279–1325) Portugal was to come into closer touch with western Europe and to acquire a university, the elements of a national literature and a navy. The chartering of fairs and the increased use of minted money bear witness to the growth of commerce, and the planting of pine forests to hold back the sand dunes near Leiria illustrates Denis' concern for shipbuilding and agriculture. In 1317 Denis engaged a Genoese admiral, Emmanuele di Pezagna (Manoel Pessanha), to build up his navy, having already adopted various measures to stimulate foreign trade. He founded the University of Coimbra (at first in Lisbon) in 1290 and was both a poet and patron of literature. Yet he was especially famed as the "farmer king" (*rei lavrador*) for his interest in the land.

Despite his attachment to the arts of peace, Portugal was several times involved in strife during the reign of Denis. In 1297 the treaty of Alcañices with Castile confirmed Portugal's possession of the Algarve and provided for an alliance between Portugal and Castile. In the later years of his reign, his son, the future Alphonso IV, rebelled more than once, being persuaded to submit by the influence of his mother Isabella, daughter of Peter III of

Aragon. This remarkable woman, later canonized as St. Elizabeth of Portugal and popularly known as "a Rainha-Santa," successfully exercised her influence in favour of peace on several occasions.

Alphonso IV (1325–57) was also involved in various disputes with Castile. Isabella, who had retired to the convent of Santa Clara at Coimbra, continued to intervene in favour of peace; but on her death in 1336 war broke out, and terms were not made till 1340, when Alphonso himself with a Portuguese army joined Alphonso XI of Castile in the great victory over the Moslems on the Salado river in Andalusia. Alphonso IV's son Peter (Pedro) was married to Constance, daughter of the Castilian infante Juan Manuel de Peñafiel, but soon after the marriage he fell in love with one of her ladies, Inez de Castro (*q.v.*), by whom he had two sons. Alphonso IV was persuaded to countenance the assassination of Inez in 1355, and one of Peter I's earliest acts on his accession was to take vengeance on her murderers. During his short reign (1357–67), Peter devoted himself to the dispensation of justice; his judgments, which he executed himself, were severe and often violent, and his iron rule was tempered only by fits of revelling.

Peter's son by Constance, Ferdinand (1367–83), inherited a wealthy throne almost free of external entanglements; but the dispute between Peter the Cruel and Henry of Trastamara for the Castilian throne was raging, and on the murder of the former, several Castilian towns offered their allegiance to Ferdinand, which he was unwise enough to accept. Henry of Trastamara duly invaded Portugal in 1369, and by the peace of Alcoutim (1371) Ferdinand was constrained to renounce his claim and to promise to marry Henry's daughter. However, he instead took a Portuguese, Leonor Teles, although she was already married and in spite of the protests of the commoners of Lisbon. He also made alliance with John of Gaunt, who had married the elder daughter of Peter the Cruel and claimed the Castilian throne. In 1372 Ferdinand provoked Henry of Trastamara, who invaded Portugal and besieged Lisbon. Unable to resist, Ferdinand was forced to repudiate his alliance with John of Gaunt and to act as an ally of Castile, surrendering various castles and persons as hostages. It was only on the death of Henry that Ferdinand dared openly to challenge Castile again. In 1380 the English connection was resumed, and in the following year John of Gaunt's brother, Edmund of Langley (earl of Cambridge and afterward duke of York), took a force to Portugal for the invasion of Castile and betrothed his son Edward to Ferdinand's only child, Beatrice. In mid-campaign Ferdinand came to terms with the enemy (Aug. 1382), agreeing to marry Beatrice to a Castilian prince. She did in effect become the wife of John I of Castile, and when Ferdinand died, prematurely decrepit, Leonor Teles became regent and Castile claimed the Portuguese crown.

Leonor had long been the lover of the Galician João Fernandes Andeiro, count of Ourém, who had intrigued with both England and Castile and whose influence was much resented by Portuguese patriots. Opponents of Castile chose as their leader an illegitimate son of Peter, John, grand master of Avis, who killed Ourém (Dec. 6, 1383) and, being assured of the support of the populace of Lisbon, assumed the title of defender of the realm. The regent fled to Santarém, and the king of Castile sent an army to her aid; Lisbon was besieged for five months, but an outbreak of plague obliged the Castilians to retire.

The House of Avis.—The legitimate male line of Henry of Burgundy came to an end with the death of Ferdinand, and when the *cortes* met at Coimbra in April 1385 John was declared king and became the founder of a new dynasty. This result was not unopposed, for many of the nobility and clergy still considered the queen of Castile the rightful heiress; but popular feeling was strong, and John I had valuable allies in Nuno Álvares Pereira, "the Holy Constable," his military champion, and João das Regras, his chancellor and jurist.

A number of towns and castles still held out for Castile when in Aug. 1385 John I of Castile and a considerable army made their appearance in central Portugal. Although much outnumbered, the Portuguese won the great battle of Aljubarrota (Aug. 15, 1385) in which the Castilian chivalry was dispersed and John of Castile himself barely escaped. The victory, followed by secondary successes won by Nuno Álvares, assured John of Avis of his kingdom and made him a desirable ally. A small force of English archers had been present at Aljubarrota. Now the treaty of Windsor (May 9, 1386) raised the Anglo-Portuguese connection to the status of a firm, binding and permanent alliance between the two crowns. John of Gaunt duly went to the peninsula and attempted an invasion of Castile in conjunction with John of Avis. This was not successful, but the Portuguese king married Gaunt's daughter Philippa of Lancaster (1387), who introduced various English usages into Portugal and became the mother of four princes, the *ínclita geração*. The truce arranged with Castile in 1387 was prolonged at intervals until peace was finally concluded in 1411.

The victory of John of Avis may be regarded as a victory of the national spirit against the feudal attachment to established order. As much of the older nobility had adhered to Castile, John rewarded his followers at their and at the crown's expense. Meanwhile, commerce prospered, and the marriage of John's daughter Isabella to Philip the Good of Burgundy was to be followed by the growth of close trading relations between Portugal and Flanders. With the conclusion of peace with Castile, John found an outlet for the activities of his frontiersmen and of his own sons in the conquest of Ceuta (1415), from which may be dated the great age of Portuguese expansion.

During the short reign of John's eldest son Edward (Duarte), "the Philosopher King" (1433–38), an unsuccessful attempt was made to conquer Tangier in 1437 by Prince Henry the Navigator and his younger brother Ferdinand, "the Constant Prince," who was held by the Moors as a hostage and died, still unransomed, in 1443. On Edward's death his son Alphonso V was still a child, and his brother Peter, duke of Coimbra, had himself made regent instead of the widow, Eleanor of Aragon. But Peter's own regency was later challenged by the powerful Braganza family, descended from John of Avis and Nuno Álvares Pereira. This family continued to set the young king against his uncle, who was forced to resign the regency, driven to take up arms and killed at Alfarrobeira (May 1449). Alphonso V (1438–81) proved unable to resist the demands of the Braganzas, who now came to own about a third of all Portugal. Having married Joan, daughter of Henry IV of Castile, Alphonso laid claim to the neighbouring throne and became involved in a lengthy struggle with Ferdinand and Isabella in the region of Zamora and Toro, where he was defeated in 1476. He sailed to France to entreat the aid of Louis XI, in which he failed, and on his return concluded the treaty of Alcácovas (1479) abandoning the claims of his wife Joan, after which she retired to a convent. Alphonso V, sometimes known as "the African" because of his Moroccan campaigns, never recovered from this reverse, and during his last years his son John administered the kingdom.

John II (1481–95) was as cautious, firm and jealous of the royal power as his father had been openhanded and negligent. At the first *cortes* of his reign he exacted a grovelling oath which displeased his greatest vassals. A suspicion of conspiracy against him enabled him to arrest Ferdinand II, duke of Braganza, and many of his followers; the duke was sentenced to death and executed at Évora, and John himself stabbed James (Diogo), duke of Viseu. In addition to his onslaught on the power of the nobility, John contrived to lessen the effects of the unfavourable treaty with Castile. Calculating and resolute, he received the epithet of "the Perfect."

John II was predeceased by his legitimate son and therefore succeeded by his cousin Manoel, duke of Beja, known as "the Fortunate" (1495–1521). Manoel I, who assumed the title of "lord of the conquest, navigation and commerce of India, Ethiopia, Arabia and Persia," inherited, thanks to the work of John II, a firmly established autocratic monarchy and a rapidly expanding overseas empire. Drawn toward Spain by the common need to defend their overseas interests as defined by the treaty of Tordesillas (*see* below), Manoel nourished the hope of joining the whole peninsula under the house of Avis; he married Mary, eldest daughter of Ferdinand and Isabella, who, however, died in giving birth to a son, Miguel da Paz. This child was recognized as heir to

Portugal, Castile and Aragon but died in infancy.

As a condition of the marriage, Manoel was required to "purify" Portugal of Jews. John II had admitted many Jewish refugees from the persecution instituted by Isabella in Castile and had exacted from them a heavy poll tax, but was also to supply ships for them to leave Portugal within eight months. This was not done, and Manoel now ordered all Jews to leave by Oct. 1497. On their assembly in Lisbon, every effort was made to secure their conversion by promises or by force. Some who resisted were allowed to go, but the rest were "converted" under promise that no inquiry should be made into their beliefs for 20 years. As "Christians" they could not be forced to emigrate, and they were indeed prohibited from leaving Portugal. In April 1506 a large number of these "new Christians" or marranos were massacred during a riot, but Manoel afterward protected them and allowed many to emigrate to Holland, where their experience of Portuguese trade was put at the service of the Dutch. It was only in 1536, again through Spanish pressure, that the Inquisition was established in Portugal; the first auto-da-fé was held in 1540.

If Manoel failed to realize his dream of ruling Spain, his son John III (1521–57) lacked the power to resist Castilian influence. A pious, dull man, he was ruled by his wife, Queen Catherine, sister of the emperor Charles V, and encouraged the installation of the Inquisition and the Society of Jesus, which soon controlled education in Portugal. In 1529 the settlement of the Moluccas dispute removed an obstacle to Portuguese-Spanish understanding, and the line of Tordesillas was matched by a similar line in the Pacific; all the new countries were in theory divided between Spain and Portugal, while the Reformation (as well as the discoveries) had come between the latter and its English ally.

John III was succeeded by his grandson Sebastian (1557–78), then a child of three. As a boy Sebastian became obsessed with the idea of a crusade against Morocco. Fanatically religious, he had no doubts of his own powers and listened only to flatterers. He visited Ceuta and Tangier in 1574 and began in 1576 to prepare a large expedition against Larache (El Araish); this departed in June 1578 and on Aug. 4 was utterly destroyed by the Moors. Sebastian himself was killed, 8,000 of his men are said to have died and 15,000 were captured. Only a handful escaped.

On the news of Sebastian's death, his great-uncle, Cardinal Henry, a brother of John III, became king. His age and celibacy made it certain that the Portuguese throne would soon pass from the direct line of Avis. Philip II of Spain, nephew of John III and husband (by his first marriage) of his daughter Mary, had already made his preparations and, on the death of the cardinal-king (Jan. 31, 1580), summoned the authorities to obey him. An army under the great duke of Alva (*q.v.*) entered Portugal in 1581, the resistance of the prior of Crato (illegitimate son of John III's brother Louis), who was acclaimed as Antonio I at Santarém, was swept aside, and Philip II of Spain became Philip I of Portugal. The claims of the duchess of Braganza (Catherine, daughter of John's brother Edward) were disregarded.

The Discoveries and the Empire.—The idea of expansion into Africa was a logical result of the completion of the reconquest in the peninsula, and the conquest of Ceuta in 1415 may be regarded as the source of the discoveries. The simple idea of fighting the Moslems on their own soil was linked with more complicated motives: the search for a Christian ally, Prester John; the desire to explore in a scientific sense; the hope of finding a way to the rich spice trade of the Indies; and the impulse to spread the Christian faith. These purposes were gradually moulded together into a national enterprise, though at first they represented the hopes and aspirations of one man, Prince Henry (*see* HENRY OF PORTUGAL). The third son of John of Avis and Philippa of Lancaster, known rather inaccurately as "the Navigator" (he himself never went farther afield than Tangier), Henry became master of the Order of Christ, which King Denis had founded on the suppression of the Templars in 1319. The resources of the order were used to draw together skilled geographers and navigators and to provide and equip a series of expeditions that only gradually began to bear fruit. When Prince Henry died in 1460 his explorers were still about 8° short of the equator.

The date of Prince Henry's earliest expedition is not exactly known, but appears to have been about 1418, when Porto Santo was visited; the first call at Madeira probably dates from 1419. An attempt was made to settle in the Canaries, and between 1427 and 1431 the Azores were visited by Portuguese seamen. Both the Azores and Madeira were then uninhabited, and their colonization proceeded fairly rapidly from *c.* 1445. Sugar was exported to Europe and gave the islands great economic importance. Meanwhile, Prince Henry's ships were probing the African coast, passing Cape Bojador in 1434 and Río de Oro (1436). The unsuccessful expedition against Tangier was followed by a break in the discoveries; but in 1439 Prince Henry was authorized to people the Azores, and from 1440 further expeditions equipped with a new and lighter ship, the caravel, reached Arguin, Senegambia (1444), Cape Verde and a point 100 leagues beyond (1446). This last point, near Sierra Leone, seems to have been the limit of the discoveries at the time of Prince Henry's death.

Under Alphonso V three military expeditions were sent against Morocco (1458, 1461 and 1471); by the last of them Tangier and Arzila were captured. The African explorations were not entirely neglected, but it remained for John II, with his sharp sense of the national interest, to found a fortress and trading post in the Gulf of Guinea at Elmina (São Jorge da Mina, 1481–82). Diogo Cam (Cão) discovered the mouth of the Congo in 1482 and then advanced to Cape Cross, 200 leagues beyond (1486). In 1488 Bartholomeu Diaz de Novaes at length rounded the Cape of Good Hope and reached the East African coast, and the seaway to India lay open. His return was followed in 1492 with the surprising news that Christopher Columbus had, as he thought, discovered the Indies by sailing west across the Atlantic. Much as this news must have perturbed the Portuguese, Columbus brought no news of the spiceries or the cities of the east, and John II ordered the preparation of an expedition to India by way of South Africa, though this, as it turned out, sailed only after his death, by order of Manoel I. John also contested the Spanish claim to all lands discovered beyond the Atlantic, and by the treaty of Tordesillas (June 7, 1494) Spain's rights were limited to what lay more than 370 leagues west of the Cape Verde Islands. By reason of this the territory that was to become Brazil was reserved for Portugal.

The treaty of Tordesillas had confirmed Portugal's rights to the exploration of Africa and the seaway to India. In July 1497 Vasco da Gama set sail with four ships on the first expedition to India. They reached Calicut the following spring, and the survivors put into Lisbon in the autumn of 1499 with specimens of oriental merchandise. A second fleet was at once prepared under Pedro Álvares Cabral, who touched the Brazilian coast (April 22, 1500) and claimed it for Portugal. One of Cabral's ships, under Lourenço Marques, discovered Madagascar in 1501; João da Nova discovered Ascension in the same year, and St. Helena in 1502. Tristão da Cunha sighted the islands named after him in 1506 and went on to explore Madagascar. Meanwhile, trading posts had been established by Cabral at Cochin and Calicut (1501) and by João da Nova at Cannanor. In 1502 Vasco da Gama made tributary to Portugal the ruler of Kilwa in East Africa.

In 1505 Francisco de Almeida arrived as viceroy of India, strengthening the African station at Kilwa and supporting the ruler of Cochin against the *samorin* of Calicut. The control of sea trade now instituted became the chief source of Portuguese wealth in the east. It was assured by the defeat of Moslem naval forces off Diu in 1509. Almeida's successor Alphonso d'Albuquerque conquered Goa (1510), which he made the seat of Portuguese power, and Malacca (1511); sent two expeditions to the Moluccas (1512 and 1514); and captured Ormuz in the Persian gulf (1515). Soon after Fernão Pires de Andrade reached Canton; in 1542 Portuguese merchants were permitted to settle at Liampo and in 1557 they founded the colony of Macao (Macau).

Alphonso d'Albuquerque (*q.v.*) was responsible for the establishment of Goa as the capital of the Portuguese east and to a large extent for the conception of a system of strong points which secured the trade of the orient to Portugal for nearly a century. Goa, seized from the sultan of Bijapur, soon became the chief port of western India; Ormuz controlled the Persian gulf and Malacca

the gateway from the Indian ocean to the South China sea, while a string of fortified trading posts secured the coast of East Africa, the gulf and the shores of India and Ceylon. Farther east, less fortified settlements were set up with the consent of the native rulers from Bengal to China, and the trade of the principal spice islands was in Portuguese hands. The preservation of the whole system was entrusted to a governor, who sometimes held the rank of viceroy, at Goa; and although Portuguese arms had both triumphs and reverses, their control of the oriental trade remained substantial, if never complete, until the 17th century, when the Dutch, at war with the joint crown of Portugal and Spain and deprived of their traditional trade with Lisbon, began to seek spices from their source and effectively demolished the Portuguese monopoly.

The "Captivity," 1580–1640.—After Philip II had occupied Portugal, the island of Terceira in the Azores held out for Antonio of Crato, who himself sought alliances in England and France. In 1582 a French expedition to establish him in the Azores was defeated, and in 1589 an English attempt upon Lisbon, led by Sir Francis Drake and Sir John Norris, failed dismally. But although Antonio died in Paris in 1594, the true symbol of Portuguese independence was not the prior of Crato but Sebastian himself. The Portuguese populace refused to believe that he was dead and nourished a messianic faith in his reappearance, of which no fewer than four pretenders sought to avail themselves, the last as late as 1600 and as far afield as Venice.

Meanwhile, Philip II arrived in Portugal, was crowned king and, by virtue of the *cortes* of Tomar (1581), undertook to preserve Portuguese autonomy, to consider the union as a personal one like that of Aragon and Castile under Ferdinand and Isabella, to appoint only Portuguese to the administration, to summon *cortes* frequently and to be accompanied by a Portuguese council in Madrid. These undertakings were adhered to by Philip II (I of Portugal, 1580–98), neglected by Philip III (II, 1598–1621) and completely violated by Philip IV (III, 1621–40).

The resentment of the Portuguese against Spanish rule was increased by the failure of the kings to visit Portugal, lack of redress, the appointment of Spaniards to Portuguese offices, the loss of trade consequent on Spain's foreign wars and the levying of taxation to sustain these. The final straw was the count of Olivares' policy of setting the Portuguese against the equally discontented Catalans. Two Portuguese insurrections in 1634 and 1637 failed to attain dangerous proportions, but in 1640 Spain's powers were extended to the utmost by war with France and revolt in Catalonia. Richelieu already had agents in Lisbon, and a leader was found in John, duke of Braganza, a grandson of the duchess Catherine whose claims had been overriden by Philip II. Taking advantage of the unpopularity of the governor, Margaret of Savoy, duchess of Mantua, and her secretary of state Miguel de Vasconcelos, the leaders of the party of independence carried through a nationalist revolution on Dec. 1, 1640. Vasconcelos was almost the only victim of the movement; the Spanish garrisons were driven out; and on Dec. 15 the duke of Braganza was crowned as John IV.

The House of Braganza.—Although the *cortes* confirmed the accession of the dynasty of Braganza and John's coronation on Jan. 28, 1641, the success of the new regime was not finally assured till 1668, when Spain at last recognized Portuguese independence. Faced with the threat of a Spanish invasion, John had at once sent missions to the courts of Europe in quest of alliances. France now refused a formal treaty. The Dutch, having seized Brazil, accepted a truce in Europe and proceeded to capture Angola. In England John made a treaty with Charles I, which was almost at once voided by the regicide. Meanwhile, the Portuguese defeated the Spaniards at Montijo (May 26, 1644) and warded off several invasions. In 1654 they negotiated a treaty with the English commonwealth, obtaining promises of aid in return for very considerable commercial and other concessions. By a secret article of the treaty of the Pyrenees (1659) France promised Spain to give no further aid to Portugal, but in 1661 negotiations began for a treaty with the restored English monarchy. In 1662 Charles II of England married John's daughter Catherine of Braganza and, in return for a large dowry, including the cession of Bombay and Tangier, provided arms and men for the war with Spain. Portuguese defense was organized by the count-duke of Schomberg; in June 1663 Sancho Manoel, count of Vila Flor, defeated Don John of Austria and on June 17, 1665, António Luis de Meneses, marquis of Marialva, won the important victory of Montes Claros. Peace was negotiated by Sir Robert Southwell and Sir Richard Fanshawe (the translator of the *Lusiads*) and signed on Feb. 13, 1668.

On the death of John IV his second son Alphonso VI (1656–83) was 13. His mother, Luisa de Gusmão, acted as regent until on June 23, 1662, he began to rule. Alphonso himself was feeble-minded, but the country was capably governed by Luis de Vasconcelos e Sousa, count of Castelo-Melhor, until 1667. The French princess Maria-Francisca of Savoy, who had married Alphonso in the previous year, now entered into an intrigue with his more personable brother Peter. They contrived to dismiss Castelo-Melhor and to have Maria-Francisca's marriage annulled. She at once married Peter, who was declared regent. Alphonso was imprisoned until his death in 1683.

During the reign of Peter II (1683–1706), Portugal recovered from the strain of the Spanish wars and began to feel the effects of the discovery of gold and precious stones in Brazil. The first strike of gold in Minas Gerais took place in 1692, and in the last years of the 17th century considerable wealth was being extracted; however, it was not until 1728 that diamonds were discovered and the wealth of Brazil came to form an appreciable part of the revenue of the Portuguese crown.

The struggle for the Spanish succession saw Portugal's recent friends, England and France, on opposing sides; and although Peter sought at first to remain neutral, Portugal joined the Grand Alliance in 1703, by which it afforded a base for the archduke Charles to conduct his war for the Spanish throne. In the same year (Dec. 27) John Methuen also concluded the brief treaty which bears his name, by which the exchange of port wine for English woollens became the basis for Anglo-Portuguese trade. Although the treaty of 1654 had secured great privileges for English merchants in Lisbon, neither it nor the treaties of 1642 and 1661 by which the traditional alliance was restored had created trade. This was now done, and by reason of the wealth that soon poured into Lisbon from Brazil, the English merchants gained a commanding position in the trade of Portugal. The political treaties of 1703 proved less fruitful. The marquês das Minas (Antonio Luis de Sousa) entered Madrid in 1706, but French and Spanish forces were victorious at Almansa, and in 1711 the French admiral René Duguay-Trouin sacked Rio de Janeiro. At the end of the war Portugal was not included in the peace of Utrecht, but at length in Feb. 1715 Portugal concluded peace with Spain at Madrid.

Under Peter's son John V (1706–50) Portugal attained a degree of prosperity unknown since the restoration. The royal fifth levied on the precious metals and stones of Brazil gave the monarchy an independent source of wealth. *Cortes*, which had met irregularly since the restoration, were no longer summoned, and government was carried out by ministers appointed by the king. John V himself showed little interest in administration, though he did not fail to convert his wealth into papal and other dignities. The archbishop of Lisbon became a patriarch and the king of Portugal "his most faithful majesty"; and royal academies, palaces and libraries made their appearance. But in the second half of the reign the ministers proved inadequate and the kingdom sank into stagnation. However, on John's death his son Joseph (1750–77) appointed as minister Sebastião José de Carvalho e Mello, later count of Oeiras and marquis of Pombal (*q.v.*), who soon gained a complete ascendancy over the king and endeavoured to replace the stagnant absolutism with a more active type of despotism which, with some qualifications, deserves the epithet "enlightened." His full powers date from his efficient handling of the crisis caused by the disastrous Lisbon earthquake of Nov. 1755; but even before this he had reformed the sugar and diamond trades, set up a national silk industry (1752) and formed one chartered company to control the sardine- and tunny-fishing industry of the Algarve and another to trade with northern Brazil

In 1756 he founded a board of trade with powers to limit the privileges enjoyed by the English merchants under the treaties of 1654 and 1661 and set up the General Company for Wine-Culture to control the port wine trade. Industries for the manufacture of hats (1759), cutlery (1764) and other articles were set up with varying success; the University of Coimbra was reformed (1772), and the royal board of censorship (1768) directed lower education from 1771.

Pombal's methods were arbitrary and his enemies numerous. His reform of the wine industry provoked a riot in Oporto (1757) which was savagely repressed; but his principal victims were the Jesuits, expelled in 1759 from all the Portuguese dominions, and the nobility, in particular José Mascarenhas, duke of Aveiro, and the Távora family, who were accused of an attack on the king (Sept. 3, 1758), condemned and executed (Jan. 12, 1759).

While Pombal succeeded in modifying the ascendancy of the British merchants in Portugal, he invoked the alliance in 1762 when Spain, prompted by the Family Compact, invaded Portugal. The Portuguese army was reformed by Count William of Lippe-Bückeburg, under whom John Burgoyne served as brigadier general, and an English force was led by James O'Hara, second Lord Tyrawley, and John Campbell, fourth earl of Loudoun. Peace was signed in Feb. 1763 at Fontainebleau. Only the death of Joseph (Feb. 24, 1777) ended Pombal's regime. After the accession of Joseph's daughter Maria I (1777–1816), who had married his brother, her uncle Peter III, the aged dictator was dismissed and eventually condemned on several charges. His successors restored the Jesuits and made peace with Spain by the treaty of San Ildefonso (1777).

Maria I suffered from fits of melancholia after the loss of her consort (1786) and eldest son. In 1792 her mental balance was further disturbed, probably by the news of the French Revolution, and she ceased to reign. Her son, who on her death was to ascend the throne as John VI (1816), became prince regent. In 1793 Portugal joined England and Spain against France, sending a naval division to assist the English Mediterranean fleet and an army to the Catalan front. The peace of Basle (July, 1795), by which Spain abandoned its allies, left Portugal still at war. Although subjected to pressure from the Directory and from Manuel de Godoy, Portugal remained unmolested until 1801, when an ultimatum was delivered and Godoy invaded the Alentejo. By the peace of Badajoz (June 6, 1801) Portugal lost the town of Olivenza and paid an indemnity. From the peace of Amiens (1802) until 1807 Portugal was once more immune from attack, though subjected to continuous pressure to break off the English connection. By the Berlin decree of Nov. 21, 1806, Napoleon sought to close all continental ports to British ships. Portugal endeavoured to maintain neutrality, but the secret treaty of Fontainebleau (Oct. 1807) provided for its eventual dismemberment by Napoleon and Godoy. Already Gen. Andache Junot was hastening across Spain with a French army, and on Nov. 27 the prince regent and the royal family and court embarked on a fleet lying in the Tagus and were escorted by British vessels under the command of Sir Sidney Smith to Brazil. Junot declared the Braganzas deposed, but his occupation of Portugal was challenged in Aug. 1808 by the arrival of Sir Arthur Wellesley (later duke of Wellington) and 9,000 British troops at the mouth of the Mondego. Winning the victories of Roliça (Aug. 17) and Vimeiro (Aug. 21), Wellesley enabled his superiors to negotiate the so-called convention of Cintra (Aug. 30) by which Junot was allowed to evacuate Portugal with his army. A second French invasion threatened early in 1809, when Sir John Moore's force withdrew to Corunna to re-embark. In February William Carr Beresford was placed in command of the Portuguese army, and in March Marshal Soult advanced from Galicia and occupied Oporto. Wellesley returned in April, drove Soult from northern Portugal and cleared the Tagus valley with the victory of Talavera de la Reina at the end of July. The third French invasion followed late in Aug. 1810 when Marshal André Masséna with Marshal Michel Ney and Junot entered Beira. Defeated by Wellington at Bussaco near Coimbra, the French found themselves facing the prepared lines of Torres Vedras, where they wintered amid great privations. By the spring of 1811 they could only retreat and, on March 5, began the evacuation of Portugal, beset all the way by English and Portuguese attacks and crossing the frontier after the defeat of Sabugal (April 3).

Portugal made peace with France on May 30, 1814. It was represented at the congress of Vienna but did not play a prominent part in the settlement. However, the series of Anglo-Portuguese treaties concluded between the years 1809 and 1817 was important in so far as it extended many of the conditions of the Anglo-Portuguese alliance to Brazil and had an influence on the future of Africa. England's efforts to get Portuguese collaboration in suppressing the slave trade resulted in the treaty of Jan. 22, 1815 (signed in Vienna), and in the additional convention of 1817, by reason of which Portugal's claims to a considerable part of Africa were admitted. Although England had agreed in 1809 and in 1810 to try to recover Olivenza for Portugal and was to receive part of Portuguese Guinea should it succeed, Spain nevertheless held and continues to hold this frontier town.

Constitutionalism.—The Napoleonic campaigns had caused great devastation in Portugal, and the absence of the royal family and the presence of a foreign commander (Beresford) combined with revolutionary agitation and the influence of Spanish liberalism to produce an atmosphere of discontent and restlessness. On Dec. 16, 1815, Brazil was raised to the rank of a kingdom united with Portugal, and John, who succeeded to the throne in March 1816, showed no desire to return though in anticipation of his arrival George Canning was sent as ambassador to Lisbon to welcome him. In 1817 Beresford suppressed a conspiracy in Lisbon, and the Masonic leader Gen. Gomes Freire de Andrade was executed. Unrest increased, and when Beresford himself went to Brazil to press John to return, a constitutionalist revolution began in Oporto (Aug. 24, 1820), spread over the country and led to the formation of a junta in Lisbon (Oct. 4). On Beresford's return he was not allowed to land, and British officers were expelled from the army. A constituent assembly was summoned which drew up a very "democratic" constitution, thus confronting John VI with an accomplished fact. His reluctance to return was at last overcome, and he left his elder son Pedro to govern Brazil, landing at Lisbon on July 4, 1821. He swore to uphold the constitution, but his wife, Carlota Joaquina, and their second son, Miguel, refused to take the oath and were duly sentenced to banishment, though this was not carried out. The Portuguese constitutionalists, not appreciating the determination of Brazil not to yield up its status as a kingdom, sought to compel Pedro to return; but he, rather than sacrifice the rule of the Braganzas in Brazil, declared for Brazilian independence (Sept. 7, 1822) and became emperor of Brazil as Pedro I. This enabled his brother Miguel to appeal to absolutist forces in Portugal to overthrow the constitutionalists, and an insurrection led by the prince almost succeeded (April 30, 1824); but through the action of the foreign ministers John VI was restored and Miguel went into exile in Vienna (June 1824).

John VI acknowledged the independence of Brazil in 1825, assuming *pro forma* the imperial title and then yielding it to Pedro, but when he died (March 10, 1826) no provision had been made for the succession except that his daughter Isabel Maria was now named regent. Pedro, as Peter IV of Portugal, issued a constitutional charter, drawn up by himself, providing for a parliamentary regime by the authorization of the monarchy and not based on the sovereignty of the people. He then made a conditional abdication of the Portuguese throne in favour of his daughter Maria da Glória, aged seven, provided that she should marry her uncle Miguel and that he should swear to accept the charter. This compromise could not be effective. The absolutists had hoped that Pedro would resign all rights to the Portuguese crown, and the council of regency hesitated to publish the charter until Gen. João Carlos de Saldanha, later duque de Saldanha, forced their hand. In October Miguel took the oath and was appointed regent, landing in Lisbon in Feb. 1828. His supporters at once began to persecute the liberals. A form of *cortes* met in Lisbon, and in July 1828 repudiated Pedro's claims and declared Miguel rightful king.

Only the island of Terceira in the Azores sustained the liberal cause, but when the liberal refugees in England tried to repair there they were intercepted by a British ship (Jan. 1829). In June 1829, however, a regency on behalf of Maria da Glória was set up in Terceira, and in 1831 Pedro, having abdicated the Brazilian throne, came to Europe and began to raise money and men for the conquest of Portugal. In Feb. 1832 the expedition sailed to the Azores, and in July the liberals disembarked at Mindelo near Oporto, which city they soon occupied. However, the rest of the country stood by Miguel, who besieged the liberals in Oporto for a year (July 1832–July 1833). By now Miguelite enthusiasm had waned, and António José de Sousa Manoel, duke of Terceira, and Capt. Charles Napier, who had taken command of the liberal navy, made a successful landing in the Algarve. Terceira advanced on Lisbon, which fell on July 24, 1833, and Miguel capitulated at Evora-Monte on May 26, 1834.

The War of the Two Brothers ended with the exile of one and was soon followed by the death of the other (Sept. 24). Maria da Glória (Maria II) was now queen at the age of 15. She was twice married: to Augustus, duke of Leuchtenberg, in Jan. 1835; and to Ferdinand of Saxe-Coburg in April 1836. While Maria necessarily came under the influence of the successful generals of the civil war, her chief aim was to defend her father's charter (which had been *octroyée*) from those who demanded a "democratic" constitution like that of 1822, asserting the sovereignty of the people. In Sept. 1836 the latter, thenceforth called Septembrists, seized power. The chartist leaders rebelled and were exiled, but by 1842 the Septembrist front was no longer united and António Bernardo da Costa Cabral restored the charter. In May 1846 the movement of Maria da Fonte, a popular rising in which almost all parties joined, put an end to Costa Cabral's government but left Portugal divided between the Septembrists, who held Oporto, and Saldanha, now in Queen Maria's confidence, in Lisbon. Saldanha negotiated for the intervention of the Quadruple Alliance, and a combined British and Spanish force received the surrender of the Oporto junta in June 1847 and ended the war with the convention of Gramido (June 29, 1847). Saldanha governed until 1849, when Costa Cabral resumed office only to be overthrown on April 7, 1851. Saldanha then held office for five years (1851–56), and the period of peace at length permitted the country to settle down.

When Maria II died she was succeeded by her eldest son, Peter V (1853–61), who married Stephanie of Hohenzollern in 1857. He promised to be a capable and conscientious monarch, but died of cholera on Nov. 11, 1861. His brother Luis (1861–89) seemed to have inherited a country that had recovered from the Napoleonic invasions and from civil wars, political strife and *pronunciamentos*. But although the main parties were now defined as Historicals (*i.e.*, radicals) and Regenerators (or moderates), the alternation of governments gradually ceased to reflect popular feeling, and in the last years of Luis' reign republicanism was already gaining ground. With the accession of Carlos (1889–1908) there occurred a serious dispute with Great Britain. Portugal's possessions in Africa had been recognized by Great Britain in the treaty of 1815; but more recently the entry of Germany and Leopold of the Belgians into the colonial field had led to the definition of effective occupation as the basis for possession of colonial territories (conference of Berlin, 1885). A colonial movement had gained momentum in Lisbon, and Portuguese claims to the "Rose-Coloured Map," a colony stretching across Africa from Angola to Mozambique, were recognized by France and Germany (1886). Although Lord Salisbury registered a protest (1888), the Portuguese foreign minister Henrique de Barros Gomes sent Maj. Alexandre de Serpa Pinto to the Shiré highlands with a view to their annexation. He became involved in a fight with the Makololos, who were under British protection, and a series of communications between London and Lisbon ended in the dispatch of the British ultimatum of Jan. 11, 1890, demanding the withdrawal of all Portuguese from the Shiré. Amid great popular excitement Barros Gomes had no alternative but to comply, and the government resigned. The incident caused the deepest resentment in Portugal, not only against the ancient ally but also against the monarchy, which was menaced by a republican revolution in Oporto (Jan. 31, 1891).

During the following years, the Portuguese African colonies were defined as a result of the treaty of May 1891, but the financial position of the country was so bad that it seemed unlikely that the efforts to consolidate the African colonies would succeed. In 1897 it became clear that Portugal would require a considerable loan, and Germany demanded to partake in any assistance that was offered. On Aug. 30, 1898, Lord Balfour concluded an Anglo-German convention assigning spheres of influence in the Portuguese colonies to Great Britain and Germany in the event of such a loan. In 1899 the Germans endeavoured to persuade the Portuguese to accept a loan, and this and the imminent danger of a conflict in the Transvaal caused an Anglo-Portuguese approximation. On Oct. 14, 1899, the ancient treaties of alliance were reaffirmed in a secret declaration, later made public.

Meanwhile, the financial situation showed little improvement, and the republicans continued to progress. In 1906 João Franco, formerly a Regenerator, came to power as champion of the failing monarchist cause. Unable to obtain the support of the other monarchists, he began to govern by decree (May 19, 1906). Although Franco bravely undertook to reform the finances and administration, he was accused of illegally advancing money to the king. These scandals were followed by rumours of plots, and on Feb. 1, 1908, Carlos and his heir, Luis Felipe, were assassinated as they rode in an open carriage in Lisbon. Whether or not the regicides were isolated fanatics or agents of a wide organization such as the *Carbonários*, the deed was applauded by the republicans, who now prepared for a final attack on the monarchy. King Manoel II (1908–10) found no unity among the monarchist politicians, who continued to squabble till the last minute. The general election of Aug. 1910 showed republican majorities in Lisbon and Oporto, and on Oct. 3 the murder by a madman of one of the republican leaders, the distinguished physician Miguel Bombarda, offered the pretext for a rising that was already organized. Armed civilians, soldiers and the men aboard some ships in the Tagus began the republican revolution on Oct. 4 and, after faltering, their movement succeeded on Oct. 5. Manoel escaped to Ericeira and thence by sea to Gibraltar and to England, where he resided at Twickenham. On his death in 1932 his body was returned to Portugal.

The Republic.—The new regime formed a provisional government under the presidency of Theophilo Braga, a well-known writer. This in turn issued a new electoral law giving the vote to all adult Portuguese and presided over the election of a constituent assembly which opened on June 19, 1911. The constitution was passed on Aug. 20, and the provisional government surrendered its authority on Aug. 24 to the new president, Manoel José d'Arriaga.

Although a monarchist invasion was unsuccessfully attempted by Henrique de Paiva Couceiro in Oct. 1911, the main danger to the new regime came from its internal divisions. For the moment it was fairly united in denouncing monarchism and persecuting the church. The religious orders were expelled (Oct. 8, 1910) and their property confiscated. The teaching of religion in primary schools was abolished, the marriage of priests legalized and the Roman Catholic Church disestablished. The conditions under which Catholics and monarchists were imprisoned attracted attention abroad, and it was only gradually that this legislation was modified. New universities were founded at Lisbon and Oporto, but the task of destruction proved easier than that of construction, and before long the republicans were divided into Evolutionists (moderates), led by António José de Almeida; Unionists (centre party), led by Manoel Brito Camacho; and Democrats (the left wing), led by Afonso Augusto da Costa. A number of prominent republicans had no specific party. The whirligig of republican political life offered little improvement on the monarchist regime, and in 1915 the army showed signs of restlessness. Gen. Pimenta de Castro formed a military government and permitted the monarchists to reorganize, but a Democratic revolution (May 14) led to his arrest and consignment to the Azores. President Arriaga resigned and was succeeded by Braga ad interim and then by Bernardino Machado (Oct. 5, 1915

Dec. 8, 1917). The Democratic regime, in which Costa was paramount, was ended by the revolution of Maj. Sidónio Pais, who established a "New Republic" of a right-wing tendency, supported at first by the Unionists, but on their separation driven to found its own National Republican party. Sidónio Pais' "presidentialist" regime was abruptly ended with his assassination on Dec. 14, 1918, when, after the provisional presidency of Adm. João de Canto e Castro, power passed gradually back to the Democrats.

Meanwhile, on Aug. 7, 1914, Portugal had proclaimed its adhesion to the English alliance, and on Nov. 23 committed itself to military operations against Germany. On Sept. 11 a first expedition left to reinforce the colonies, and there was fighting in northern Mozambique, on the Tanganyika frontier and in southern Angola, on the frontier of German South-West Africa. In Feb. 1916 Portugal seized German ships lying in Portuguese ports and Germany declared war (March 9). A Portuguese expeditionary force went to the western front in 1917, under Gen. Fernão Tamagnini de Abreu; on April 9, 1918, they were under heavy German attack in the battle of the Lys. In the peace treaty Portugal received 0.75% of the indemnity payable by Germany and the Kionga area captured by Portuguese forces in East Africa.

Almeida completed his term of office as president (Oct. 5, 1919–Oct. 5, 1923), but ministries succeeded one another in rapid succession. In 1921 the founder of the republic, António Machado Santos, was among those murdered by enemies of Sidónio Pais; and although António Maria da Silva contrived to govern in the Democratic interest for a year and nine months, his fall in 1923 was followed by a number of short-lived ministries.

Revolutionary movements grew more frequent as the Democratic party lost its cohesion, and there were signs of impatience with the political turmoil on the part of the army. Although the Democrats obtained a clear majority in 1925 and Manoel Teixeira Gomes (1923–25) yielded the presidency to Bernardino Machado without incident, a military revolt occurred in Lisbon on Feb. 2, 1926. It was quelled, but on May 28 Commander Joaquim Mendes Cabeçadas and Gen. Manoel de Oliveira Gomes da Costa rebelled at Braga. Within two days the whole country was in their hands; Machado was deposed, and a provisional government was formed. The *pronunciamento* was the 18th since the establishment of the republic in 1910, and Silva's cabinet was the 40th to be overthrown in less than 16 years.

The "New State."—At first Cabeçadas was head of the provisional government and Gomes da Costa minister of war; but the former was regarded as too close to the politicians, and Gomes da Costa unseated him. Within a few weeks he too was deposed and his place taken by his foreign minister, Gen. António Oscar de Fragoso Carmona (July 9, 1926). Carmona was elected president of the republic in March 1928 and re-elected in 1935, 1942 and 1949, in each case without opposition; he remained president until his death in April 1951. After an attempt at revolution in Feb. 1927, which resulted in considerable bloodshed, Carmona's government was not seriously interrupted. The program of the military regime was merely to restore order. To remedy the financial plight of the country, it had been proposed to borrow money from the League of Nations, but the conditions offered included supervision of the finances, which was regarded as offensive to national sovereignty. The loan was therefore rejected, and Carmona called on António de Oliveira Salazar to take the ministry of finance. Salazar (born at Santa Comba Dão, 1889), professor of law at Coimbra, obtained full powers over all expenditure and revenue and embarked on a complete overhaul of the administration. As minister of finance from 1928 to 1940 he produced an unbroken series of budgetary surpluses, which restored Portugal's financial credit. As prime minister from 1932 he ushered in the new constitution of 1933; as minister of colonies in 1930, he prepared the Colonial act governing the administration of Portugal's colonial empire; and as minister for foreign affairs from 1936 he guided Portugal through the difficulties caused by the Spanish Civil War and practised a form of neutrality compatible with the Anglo-Portuguese alliance during World War II. On the death of Carmona in 1951, Salazar assumed under the constitution the attributes of the presidency, until Gen. Francisco Craveiro Lopes, elected on July 22, was sworn as president on Aug. 9, 1951. By then Salazar had exercised the widest political and economic influence for nearly a quarter of a century and had left the stamp of his mind on almost every aspect of Portuguese life.

His "New State" as defined by the constitution of 1933, provided for a president, elected for a period of seven years, who appointed a prime minister and a variable number of ministers; a national assembly of 120 deputies elected as a block, meeting for at least three months annually; and a corporative chamber consisting of representatives of trades and professions and acting as a consultative assembly.

POPULATION

The population of continental Portugal was 7,902,590 in 1950; it was 7,185,143 in 1940 and 6,360,347 in 1930. With the Azores and Madeira it was 8,490,455 in 1950 and 7,722,152 in 1940. The colonies, with an area of 803,835 sq.mi., have a population of 10,875,051. A decrease in the rate of emigration in the early years of World War II was reflected in a rather steep increase of population, and the urban population grew more rapidly than the rural because of internal migration. In 1940 the population of the chief towns was: Lisbon 709,179; Oporto 262,309; Funchal (Madeira) 54,856; Coimbra 35,437; Setúbal 37,071; Braga 29,875; Évora 21,851; Ponta Delgada 21,048; Faro 19,695; and Covilhã 19,213.

The Portuguese population has increased rapidly in relation to the size of the country. The birth rate, at about 25 per 1,000, is one of the highest in western Europe. The death rate (14 per 1,000) is also high, but the difference gives an annual increase of population that averaged more than 89,000 between 1930 and 1940 and 82,000 between 1940 and 1945. The population is unevenly distributed, all but one-seventh inhabiting the provinces north of the Tagus. The density of population in continental Portugal reaches 1,065 per square mile in the district of Oporto but only about 70 in that of Beja. The average for the whole country is 230 per square mile. The island of Madeira is more thickly peopled than the mainland (except for the districts of Oporto and Lisbon), with 853 people to the square mile, while the Azores have about 322 per square mile.

Areas such as Minho are seriously overpopulated: the division of land has proceeded so far that it is often uneconomically cultivated. The less populated areas, on the other hand, will not bear any very considerable increase, since the soil is too poor to carry more inhabitants. There has therefore for long been a considerable emigration of Portuguese, principally to Brazil but also to the United States, other parts of Latin America and Africa. The remittances of Portuguese residing in Brazil played an important part in the economy of some areas of Portugal, while many large houses were built by returned "Americans." The emigrants are hard-working and vigorous, but while their unskilled labour commands a ready market in Brazil they find little opportunity in the Portuguese colonies, where unskilled work can be done by the natives. The difficulties that beset emigration from the 1920s had serious effects, one of them being to swell the population of the capital and other towns.

Racial Composition.—The original Portuguese stock has received transfusions of blood from many races: Romans, Goths, Arabs and Berbers, settlers from northern Europe, Jews, Negroes, etc. In general, however, the typical Portuguese stock is rather short, dark and sturdy, and among the peasantry the strain seems to be remarkably pure. The type is thought by some to be characteristically Iberian and by others to represent Mediterranean man. It is in any case not dissimilar from the prevalent type in Galicia or Asturias. Although the Romans stamped the country with their language, institutions and civilization, they appear to have had little influence on the racial composition of the people, which may have been fairly constant from their arrival until their departure. The Suebi and Visigoths, who arrived in the 5th century A.D., left traces of more northern physical characteristics, which are especially common in the north. A number of Gothic place names suggest settlements or colonies of these people.

The overthrow of the Visigothic kingdom by the Moorish invasion of 711 introduced a new stock and a new religion. The so-called Moors included Arabs (some of them from Syria) and Berbers, and they influenced deeply the language, life, architecture and handicrafts of the Portuguese. This influence varied from region to region. North of the Douro it was negligible, since this region was shortly reconquered by the Christians. South of the Douro there was a Mozarabic civilization centred on Coimbra, in which Portuguese stock, still professing the Christian faith, adopted Arab ways and, to some extent, the Arabic language; mixed proper names are common, and it is not unusual to find records even of priests bearing Arab names. With the reconquest, the Mozarabic civilization was again gothicized, but farther south the Arabic element persisted and is strongest in the Algarve. There were Jews in Portugal in Visigothic times, and they flourished under the Moslems. During the middle ages there were many Jewries, some of them extremely prosperous. Under the influence of Queen Isabella of Spain, King Manoel I (1495–1521) was persuaded to expel the Jews. Many were forcibly converted and, in some cases, intermarried into the population, but others retained their racial and cultural peculiarities. From the foundation of the kingdom to modern times there has been a gradual introduction of other European stocks by settlement. Negroes from Africa were introduced as slaves in fairly considerable numbers after 1450 and left their mark especially in the south, where they were employed on the land, and in such towns as Lisbon, where they were drawers of water or performed similar tasks.

Customs.—The staple diet of the Portuguese people is one of fish, vegetables and fruit; the fish includes dried cod (*bacalhau*), which is prepared in many ways. Cooking is usually done in olive oil, and meat is rarely eaten by the labouring classes. Rice, maize bread and beans are characteristic of the popular diet. Wine is consumed generally but sparingly.

A great variety of picturesque costumes are worn. These may be seen at their best at the *romarias*, or pilgrimages, which combine religion with the attractions of a fair. A characteristic male dress is a white shirt and black trousers with a red sash. In the Alentejo this is accompanied by a stocking cap, and a copper-tipped quarterstaff is carried. Elsewhere a broad-brimmed hat is worn. In the north an umbrella is usually carried by countrymen, and in places short capes are made of reeds. Fishermen may wear a check or tartan shirt. Female peasant dress is extremely varied, though above a certain age black is usually worn. A white blouse and a full black skirt is a common dress, and a daily clean apron is a general practice. On holidays girls wear brightly coloured cotton dresses with gold or silver filigree ornaments. Headgear ranges from kerchiefs to round felt or straw hats according to the season and locality.

The sport of bullfighting is conducted without the bull's being killed. Duelling with staves and rowing are other sports; football is popular. Dancing and singing play a prominent part in the life of the people. Almost every village has its *terreiro*, or dancing floor of beaten earth, and band. The traditional songs are of a slower rhythm than the Spanish, but the melody is robust and generally lyrical. The usual popular instruments are the *gaita* or bagpipe (commonly used in the north for dancing), the pipe, fiddle and drum. The *gaita* has been to some extent ousted by the accordion, but the Portuguese guitar, which is quite distinct from the Spanish guitar (known in Portugal as the *viola*), maintains its popularity. In Lisbon the *fado* is a ballad of crime or jealousy; a more lyrical form comes from Coimbra. Genuine popular ballads are still composed and recited to celebrate or commemorate local events.

Many curious superstitions survive in rural Portugal. A large part are concerned with witches (*bruxas* or *feiticeiras*); there are also enchanted Moors (*mouras encantadas*), mermaids (*sereias*) who lure fishermen to destruction, and werewolves (*lobis-homens*).

There are considerable regional variations in Portugal, and local differences are quite strongly preserved, but regionalism is less pronounced than in Spain and is almost devoid of political complications.

ECONOMICS, DEFENSE AND COLONIES

Agriculture, Livestock and Fishing.—Portugal is primarily an agricultural country, and 60% of the population of continental Portugal is engaged in agricultural pursuits.

Approximately two-fifths of Portugal is arable, and the main cereal crops are maize, wheat, rye, oats, barley and rice. Maize is grown especially in the north (districts of Oporto and Braga) and the coastal zone, while wheat, the most valuable crop, is produced in large quantities in the districts of Beja, Évora and Portalegre (Alentejo). The consumption of wheat increased considerably in the 20th century, and Portugal can rarely grow enough to meet its needs. An energetic wheat campaign led to a year or two of self-sufficiency in the early 1930s, but thereafter importation again became normal as it seems to have been for centuries, though on a smaller scale than before. The olive tree is widely distributed, and olive oil is Portugal's second most valuable crop; Portugal is the world's third largest producer.

Wine is grown over most of northern and central Portugal, and from 10,000,000 to 15,000,000 hl. are produced annually. The most valuable part of the vintage is port wine, which is also Portugal's principal export, but table wines are exported in considerable quantities to the colonies and to some extent to Brazil and other markets. Rice is grown in the valleys of several rivers. Fruit, abundant almost everywhere, is exported in its natural state, or dried or candied. The Algarve is famous for almonds and figs, Setúbal for oranges and Elvas for plums.

Other important rural products are cork, of which Portugal is the world's largest producer and which is exported either crude or manufactured, and the products of the country's pine forests, including resin, turpentine, pit props and sawn wood. Resin, a comparatively recent industry, had risen to be Portugal's fourth most important export by the end of World War II.

Oxen are widely used for plowing, especially in the north. Sheep are numerous in eastern Portugal. The donkey is the usual beast of burden. Pigs and mules are bred in the Alentejo, as are also bulls for the ring.

Fishing villages are found at frequent intervals round almost the whole Portuguese coast. A fleet sails annually from Lisbon to the Newfoundland banks to procure the cod from which the staple *bacalhau* is made. The most valuable catch is the sardine, always a main export and occasionally the leading one. The centres of the sardine industry are at Setúbal and at Matozinhos (near Oporto). The tunny is fished off the Algarve.

Industry and Mining.—Much of Portugal's industry is connected with the preparation of export products—the manufacture of cork and of glass for wine bottles, the canning of sardines, the extraction of resins and turpentine, etc. In addition, textiles of good quality are manufactured with home-grown wool or colonial cotton; other industries include cement and other construction materials, paper, soap, fertilizers, etc.

Various minerals occur in Portugal, including tin, wolfram, copper, sulphur, uranium, titanium, manganese, lead, zinc and kaolin. Tin, wolfram and copper are exported. Coal is found in a few places, but production is insufficient for domestic consumption. Iron ore exists in considerable quantities but is little exploited.

Trade.—Portugal's traditional exports are sardines, port wine and cork. Before World War II these commodities each brought in more than 110,000,000 escudos a year. Less important were fruits and nuts and ores, but resin, turpentine, pit props and sawn wood were increasing factors in Portuguese overseas trade. During World War II a great boom was produced by the competitive buying by both belligerents of rare ores, especially wolfram. Given the narrow range of Portugal's exports, there is normally a passive balance of trade, since it must import a wide range of manufactured goods, including machinery, vehicles, ships, electrical goods, arms, etc., as well as coal, metals and chemicals and finally such essentials as wheat, fish and other foodstuffs. The true extent of the gap, however, was exaggerated by official figures until World War II, when the method of evaluation was altered. The deficits were met by agiotage on colonial goods, remittances from emigrants, services to shipping, etc.

In 1950 the total value of Portuguese exports was 5,333,703,000 escudos; of this, wine accounted for 583,302,000 escudos, sardines for 334,883,000 escudos and cork for 891,719,000 escudos. The total value of imports was 7,878,850,000 escudos. Portugal's chief customer and supplier is traditionally the United Kingdom, followed by the United States, Mozambique, Angola, France, Belgium and Germany in varying order. According to the British board of trade's returns, British imports from Portugal were valued at £4,718,733 in 1927, at £3,658,763 in 1938, at £7,031,000 in 1944, at £8,397,062 in 1946, at £8,318,532 in 1948 and at £11,613,367 in 1950. Portuguese imports from Great Britain were valued at £3,889,703 in 1927, at £2,956,271 in 1938, at £9,856,999 in 1946, at £23,900,739 in 1948 and at £16,132,625 (plus reexports £178,941) in 1950.

Finance.—Until Salazar became minister of finance in 1928, the Portuguese budget showed a deficit regularly, the only surplus for generations having occurred in one of the early years of the republic. Foreign indebtedness was high, and between 1917 and 1923 the escudo had dropped in value from 4*s.* to 2½*d.* When Salazar came to power, he applied a severe system of financial orthodoxy and produced a balanced budget in his first year. This feat was repeated annually, and the considerable surpluses garnered were used to promote public works, education, colonial development, equipment of the armed forces, etc. The foreign debt was greatly reduced. Revenue and expenditure for alternate years 1942–50 are shown in the table.

Portuguese Revenue and Expenditure

(In millions of escudos)

Item	1942	1944	1946	1948	1950
Revenue	3,081.6	3,807.1	4,684.9	5,761.0	5,271.5
Expenditure	2,954.5	3,680.9	4,623.9	5,699.0	5,268.3
Balance	127.1	126.2	61.0	62.0	3.2

Communications.—The Portuguese roads were greatly improved and extended by Salazar's government and are usually well maintained. There are about 2,250 mi. of railway line, mostly of the broad or Spanish gauge. Part of this is state-owned, part privately owned. The Companhia dos Caminhos de Ferro Portugueses administers some private and some state-owned lines. The principal line is that running from Lisbon to Oporto via Coimbra. Lisbon is connected with Madrid by the Tagus valley, with Seville and Madrid via Elvas and Badajoz and with northern Spain and France by Guarda and Salamanca. From Oporto one can go to Salamanca via the Douro valley and into Galicia by the line crossing the Minho at Valença-Tuy.

Defense.—In peacetime, the ministry of defense co-ordinates the activities of the ministries for the army and the navy through a general secretariat for national defense under the direction of the chief of the general staff of the armed forces.

There is a supreme national defense council whose ex-officio president is the president of the cabinet of ministers, but which may be presided over by the president of the republic when necessary.

The Portuguese army in 1951 consisted of 16 infantry regiments, 3 independent battalions, 10 battalions of chasseurs and 3 machine-gun battalions; 5 motorized regiments of light artillery, 3 of heavy artillery and 1 of coastal artillery; 1 regiment and 3 independent groups of anti-aircraft artillery; 1 regiment of mountain artillery; 4 mechanized regiments; 2 regiments of engineers, each with telegraphists and sappers; 1 railway battalion; and 1 group of motor convoy companies, pontoon units and other services. The permanent effectives, including officers, total about 30,000 men in peacetime.

The national republican guard, comprising infantry and cavalry, had a total effective of 7,000 men in 1951. The total effective of the fiscal customs guard is 5,400 men. The Portuguese legion (Legião Portuguesa) is a voluntary patriotic organization with about 50,000 men. Military service is compulsory and involves preliminary training, a period of 8 years on the active strength and a period of 12 years in the reserve, followed by 5 years in the territorial army. Service normally ends at the age of 45. In the colonial forces, service is normally for ten years in the active army and five in the territorial reserve. Members of the home army can be seconded to the colonial army for shorter periods, and reductions are made for volunteers.

Continental Portugal is divided into five military regions: Oporto, Coimbra, Tomar, Évora and Lisbon. There are separate commands in Madeira and the Azores. In the colonies there are commands in Angola, Mozambique and Cape Verde and military departments in Guinea, India, Macao and Timor.

The air force consists of offensive and defensive groups, a bombing and an observation group and a training and depot squadron. The air service includes a command headquarters and inspectorate, aeroplane and balloon departments, anti-aircraft defense and flying schools.

The Portuguese navy in 1951 consisted of six sloops, five destroyers, two frigates, six submarines, six patrol vessels, seven submarine chasers, four gunboats and one sailing ship for training, as well as surveying and fishery-protection vessels, etc. The normal complement is 761 officers and 6,159 ratings.

Colonies.—The Portuguese colonial empire consists of eight separate colonies of which five are in Africa, two in Asia and one in Oceania. The two large colonies of the African mainland, Angola (Portuguese West Africa) and Mozambique (Portuguese East Africa), represent more than 90% of the empire by area. Third in size is Portuguese Guinea. Almost opposite Guinea lie the Cape Verde Islands, while in the Gulf of Guinea the tropical islands of St. Thomas (São Tomé) and Prince's (Príncipe) form the fifth of the African colonies. In India, the Portuguese "state of India" has its capital at New Goa and consists of three separate pieces of territory, Goa, Damão and Diu. In China, the promontory of Macao (Macau) on the Pearl river lies between Canton and Hong Kong. Timor, the largest of the Lesser Sunda Islands, is divided between Portugal and Indonesia (formerly Dutch). All these are described in separate articles.

The Colonial act of 1933 formulated the rights and duties of the colonies and the main outlines of colonial policy. The minister for colonies in Lisbon is assisted by a supreme colonial council and other advisory committees. The governor of each colony has a colonial council, and there are periodical meetings of governors in Lisbon. For a time after 1921 there were parliamentary institutions in the colonies, but under the corporative regime these organs of sovereignty disappeared and colonial policy was co-ordinated in Lisbon.

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PORTUGUESE EAST AFRICA or MOZAMBIQUE (official name: A Provincia de Moçambique). This Portuguese possession, bounded east by the Indian ocean, north by Tanganyika Territory, west by the Nyasaland Protectorate, Rhodesia and the Transvaal, south by Tongaland (Natal), has an area of 297,654 sq.mi. It is divided in two by the river Zambezi. The northern portion, between the ocean and Lake Nyasa and the Shiré river is a compact block of territory, squarish in shape, being about 400 mi. long by 360 mi. broad. South of the Zambezi the province consists of a strip of land along the coast varying from 50 to 200 mi. in depth.

Physical Features.—The coast line extends from 26° 52′ S. to 10° 40′ S., and from south to north makes a double curve with a general trend outward; *i.e.,* to the east. It has a length of 1,430 mi. About 40 mi. N. of the Natal frontier is the deep indentation of Delagoa bay (*q.v.*). Far to the north is the wide Zambezi delta. From this point onward the coast is studded with small islands, mainly of coral formation, on one of which is Mozambique. To the north of Mozambique the coast is much indented, abounding in high, rocky headlands and rugged cliffs. South of Mozambique the coast line is low, sandy and lined with swamps. The eastern scarp of the continental plateau is much broken in the lower Zambezi region but elsewhere rises to heights of 6,000–7,875 ft. in the south, though behind Delagoa bay the greatest height is only 2,070 ft. In the north the forested hills of the scarp reach 6,500–8,600 ft.

Near the southeast shore of Nyasa there is a high range (5,000 to 6,000 ft.) with an abrupt descent to the lake—about 3,000 ft. in six miles. The plateau lands west of the escarpment are of moderate elevation—perhaps averaging 2,000 to 2,500 ft. The chief rivers are the Zambezi and Limpopo, both cutting back far into the plateau.

Geology.—The central plateau consists of gneisses, granites and schists of the usual East African type which in part or in whole are to be referred to the Archaean system. Rocks of the Karroo period occur in the Zambezi basin, where at Tete they contain workable seams of coal, and have yielded plant remains of Upper Carboniferous age. Sandstones and shales, possibly of Upper Karroo age, form a narrow belt at the edge of the foot plateau. Upper Cretaceous rocks crop out from beneath the superficial deposits along the coast belt between Delagoa bay and Mozambique. The highest Cretaceous strata occur in Conducia, where they contain the huge ammonite *Pachydiscus conduciensis.* The Eocene formation is well represented in Gazaland by the nummulitic limestones which have been found to extend for a considerable distance inland. Basalts occur at several localities in the Zambezi basin. On the flanks of Mount Milanje there are two volcanic cones which would appear to be of comparatively recent date; but the most interesting igneous rocks are the rhyolitic lavas of the Lebombo range.

Fauna and Flora.—The lion, of both the yellow- and the black-maned varieties, leopard, spotted hyena, jackal, serval, civet cat, genet, hunting dog (*Lycaon pictus*) and mongoose occur in the Mozambique district. The elephant and the black rhinoceros are common, and south of the Zambezi are a few specimens of white rhinoceros (*R. simus*). The rivers and marshes are the home of hippopotami, which have, however, deserted the lower Zambezi. The wart hog and the smaller red hog are common. A species of zebra is plentiful, and herds of buffalo (*Bos caffer*) are numerous in the plains and in open woods. Many antelopes are found, but the giraffe does not occur. The scaly anteater is fairly numerous, and rodents are common. There are several kinds of monkeys and lemuroids, but the anthropoids are absent. Crocodiles, lizards, chameleons, land and river tortoises are all very numerous, as are

pythons (some 18 ft. long), cobras, puff-adders and vipers. Centipedes and scorpions and insects are innumerable. Among insects mosquitoes, locusts, the tsetse fly, the hippo fly, cockroaches, phylloxera, termites, soldier ants and flying ants are common plagues. As has been indicated, the Zambezi forms a dividing line not crossed by certain animals, so that the fauna north of that river presents some marked contrasts to that of the south.

Flamingoes are common in the Mozambique district. Cranes, herons, storks, pelicans and ibises are numerous, including the beautiful crested crane and the saddle-billed stork (*Mycteria senegalensis*), the last-named comparatively rare. The eagle, vulture, kite, buzzard and crow are well represented, though the crested eagle is not found. The guinea fowl, partridge, bustard, quail, wild goose, teal, widgeon, mallard and other kinds of duck are all common. A small green parrot is found.

The coconut is common in the coast regions and often attains 100 ft.; the date palm, mostly in marshy ground and near rivers, is seldom more than 20 ft. in height; four other palms occur. A kind of cedar is found in the lower forests; ironwood and ebony are common, and other trees resemble satin and rosewood. The large *Khaya senegalensis* found in ravines and by river banks, affords durable and easily-worked timber; there are several varieties of vitex and of ficus, notably the sycamore, which bears edible fruit. Excellent hardwood is obtained from a species of grewia. Other characteristic trees are the mangrove (along the sea shore), sandal-wood, gum copal, baobab and bombax, and, in the lower plain, dracaenas (dragon trees), candelabra euphorbia, and many species of creepers and flowering shrubs, and several prickly shrubs. Acacias are numerous, including the gum-yielding variety, while landolphia rubber vines grow freely in the forests. Coffee, cotton, indigo and tobacco plants, castor oil, bananas, mangoes and pineapples are found. The bamboo is common. *Phragmites communis*, spear grass, with its waving, snowy plumes, grows 12 to 14 ft. and is abundant along the river banks and along the edges of the marshes.

Climate and Health.—Malaria is endemic on the coast and along the banks of the Zambezi. On the uplands and the plateaus the climate is temperate and healthy. At Tete, on the lower Zambezi, the annual mean temperature is 77.9°, the hottest month being November, 83.3°, and the coldest July, 72.5°. At Quelimane, on the coast, the mean temperature is 85.1°, maximum 106.7° and minimum 49.1°. The cool season is from April to August. During the monsoons the districts bordering the Mozambique channel enjoy a fairly even mean temperature of 76.1°, maximum mean 88.7°, and minimum mean 65.3°. The rainy season lasts from December to March, and the dry season from May to the end of September. November is a month of light rains. Rainfall, average mean for many years, in inches, is: Lourenço Marques 30.6, Beira 60.4, Quelimane 56.4, Mozambique 31.4, Tete 21.2, Shiré 72.2.

A scientific mission has verified endemic foci of sleeping-sickness of the Rhodesian type in 18 places in the territory studied. Cases of fever were also noted, due generally to *Laverania malariae*, but also to *Plasmodius vivax;* and malaria, recurrent fever and filariasis. The tsetse fly, mostly *morsitans*, was found in several districts. It is spreading in that of Tete. Good results had been obtained by the use of atoxil in the initial stages, and of trypars-mide in advanced cases of the disease. The mission emphasizes the necessity of the study of the disease *nagana* in cattle.

There are good government hospitals at Lourenço Marques and other centres.

Population and Towns.—Portuguese East Africa is sparsely inhabited, with a total population in 1940 of 5,085,630, of whom 27,438 were Europeans and 5,030,179 were natives. Of this total, 434,718 were inhabitants of the territory administered by the Mozambique company. Ninety-nine per cent of the inhabitants are native Africans of the Bantu tribes, from whose ranks most of the natives employed in the Transvaal gold mines are recruited. The most important in the northern half of the province are the Yaos (*q.v.*) and the Ma Kua (Makwa). The Makwa, notwithstanding the presence of Arabs, Banyans (Hindus) and Battias in all the coast districts, have preserved in a remarkable degree their purity of race, although their language has undergone considerable change (*see* Bantu Languages). The Makwa are divided into four families or groups—the low Makwa, the Lomwe or Upper Makwa, the Maua and the Medo. Yao possess the country between the Msalu river and Nyasa. The dominant race between the Zambezi and the Mazoe are the Tavala, with other tribes mainly of Zulu origin. Between the Zambezi and the Pungwe are the Barue, Batoka, etc. In the district south of the Pungwe river, known as Gazaland, the ruling tribes are of Zulu origin, all other tribes of different stock being known as Thongas, resembling the Basutos, peaceful stock raisers and cultivators. Among them are the BaTonga south of Inhambane, and the BaRonga mainly in the Lourenço Marques district. The BaChopi in the Inhambane district are a Bantu tribe of different origin and language. The non-native inhabitants are chiefly Portuguese, British and Indians, the latter coming from both Portuguese (Goa) and British India. About half of the whites live in Lourenço Marques.

The most important towns are Lourenço Marques (the capital), Mozambique, Quelimane, Inhambane, Beira and Chinde. Sofala has now little but historical interest. These towns are separately noticed. Other European settlements are Chingune (*see* Sofala), Angoche and Ibo, Porto Amelia on the coast, and Sena, Tete and Zumbo on the Zambezi, Macequece and Vila João Belo. Angoche, midway between Quelimane and Mozambique, dates from the 17th century. It has become the port of one of the most important commercial centres of the district of Mozambique, the coconut industry being rapidly developed there. It is connected with the Mossuril-Mozambique motor road. Ibo, founded at the beginning of the 17th century, on Ibo island, one of the Querimba archipelago, stands in 12° 20′ S., 40° 38′ E., off the northern arm of Montepuesi bay. It is 180 mi. north of Mozambique. The harbour is sheltered but shallow.

The Zambezi towns, Sena, Tete and Zumbo, for long marked the limits of Portuguese penetration inland. Comparatively important places in the 17th and 18th centuries, with the decline of Portuguese power they fell into a ruinous condition. The opening up of Rhodesia and British Central Africa in the last quarter of the 19th century gave them renewed life.

Sena, about 150 mi. by river from Chinde, is built at the foot of a hill on the southern side of the Zambezi, from which it is now distant 2 mi. It has an 18th century fort, and is the head of a circumscription with a population of 78 Europeans and 40,140 natives.

Tete, founded about the same time as Sena, is also on the south bank of the Zambezi. It is about 140 mi. by river above Sena. Since 1894 there has been a regular service of steamers between Tete and Chinde. A transit trade to British possessions north and south of Tete was later developed. It is the seat of government of a district of 65,000 sq.mi. with a population of 485,654 (1940), including 685 Europeans. The district is rich in minerals.

Zumbo is picturesquely situated just below the Loangwe confluence and commands large stretches of navigable water on the Loangwe and middle Zambezi. Zumbo is 244 mi. distant from Tete, and is in 15° 37′ 36″ S., 30° 24′ 38″ E. The subdistrict has a population of 33,106 natives.

Porto Amelia, 50 mi. S. of Ibo, is the main seat of government of the Nyasa company, the charter of which expired in Oct. 1929, when the state took over the administration of the company's territory. Porto Amelia stands on Pemba bay, one of the finest harbours in the world, which, a mile and a half wide at the entrance, has an extent of seven miles by five. It is the natural port, not only of its own hinterland, but of part of the highly developed Nyasaland Protectorate and perhaps a part of Northern Rhodesia also. It is healthy, well drained and free from malaria. It is connected with the state telegraphs at Mozambique.

Macequece (pop. 8,281), on the railway line from Beira to Rhodesia, 17 mi. from the border, is the centre of the Manica goldfields and capital of Manicaland company territory. It is 2,500 ft. above the sea, and 194 mi. N.W. of Beira by rail. It is picturesquely situated in a fertile and well-wooded district with a good water supply. The climate is healthy except in February and

March. On the railway line from Lourenço Marques to the Transvaal, Moamba, the junction for the Xinavane railway and seat of the Sabie circumscription, and Ressano Garcia, the last Portuguese station, are also trading settlements, cotton being grown near the former.

Vila João Belo (formerly Chai-Chai and later Vila Nova de Gaza), 23 mi. up the Limpopo river, is a growing commercial settlement doing an increasing business with the interior in agricultural products. There is a bi-weekly steamer service to Lourenço Marques.

Communications.—The province is served by many regular lines of steamships, furnishing communication between Lourenço Marques, South African ports, Europe, India and America. In 1938, 2,736 ships with a gross tonnage of 12,785,000, entered the colony's ports, carrying 79,209 passengers and unloading 1,337,726 tons of cargo.

The road system is on the whole only fair. The principal towns are connected by adequate roads, generally of sand reinforced by gravel, but vast areas of the hinterland are inaccessible to automobiles because of boggy lowlands. Approximately 3,000 mi. of the 17,000 mi. of road are listed as "first class," although not metalled, except in the vicinity of Lourenço Marques and Beira. Eight main roads link up the colony with the Union of South Africa: Lourenço Marques to Swaziland; Lourenço Marques to the Transvaal; Beira to Umtali, Southern Rhodesia; Tete to Salisbury, Southern Rhodesia; Tete to Blantyre, Nyasaland; Quelimane to Blantyre; Tete to Fort Jameson, Northern Rhodesia; and Mossuril to Nyasaland via Mandimba. The province belongs to the South African postal union, and is in telegraphic communication with Europe via South Africa and via Zanzibar. A cable connects Mozambique with Madagascar, and the colony is connected with the British-owned Aden-Durban cable. There were, in 1940, approximately 6,000 mi. of telephone wire, served by 200 exchanges, and *c.* 8,000 mi. of telegraph lines served by 198 stations. There is a direct wireless service, with 13 stations, to the west coast, Europe, North and South America.

In 1941 there were about 1,200 mi. of railroad line in operation. The railway to the Transvaal (55 mi.) belongs to the state, connecting with the Union of South Africa railways at Komatipoort, and is of prime importance. The Swaziland line (44 mi.) to Goba on the Swaziland border, is to link up eventually with the Union system at Breyten, considerably reducing the distance from Lourenço Marques to Germiston. The Gaza railway (51 mi.) with a 2 ft. 6 in. gauge, runs from Vila João Belo (Chai-Chai) to Chicomo, near the river Inharrime. This railway handles about 9,000 tons of goods per year, mostly agricultural produce. The Beira railway (200 mi.) in the Mozambique company's territory, links up with Rhodesian railways at the frontier. The Trans-Zambezia railway (156 mi.) from Dondo on the Beira Junction railway to Murraça, on the south bank of the Zambezi, was opened in 1922. The Central African railway on the north bank of the Zambezi (61 mi. long, of which 45 mi. are in Portuguese territory) is connected at Port Herald with the Shiré Highlands railway. The Xinavane railway from Moamba to Xinavane (55 mi.) is to be prolonged via Chissano to Vila João Belo, or via Chibuto to Chicomo (70 mi.). The line from Inhambane to Inharrime is 56 mi.; and that from Lourenço Marques to Marracuene is a light railway (extension to Manhica is authorized) with gauge 0.60 metres, 19.5 mi. long. In 1942 it carried 122,988 passengers, and receipts were $51,380. The Quelimane-Mocuba line is on the river Lujella; the Lumbo line (on the mainland off Mozambique), to Mkonta, is 57.3 mi. This is to be extended to the Nyasaland border, when it will be the shortest route from the sea to Lake Nyasa. Lines projected are: the prolongation of the Gaza railway. Chicomo via Jinagai to Inharrime, 51 mi., and southwards to Xinavane; Quelimane—Shiré highlands; Port Amelia—Lagos district; Nambula and Serra de Chinde sections of the Mozambique railway.

The Zambezi is navigable by light-draught steamers throughout its course in Portuguese territory with one break at the Kebrassa Rapids—400 mi. from its mouth. By means of the Shiré affluent of the Zambezi there is direct steamer and railway connection with British Central Africa.

Agriculture.—The province is, on the whole, very fertile, especially between Angoche and Quelimane, and in the Limpopo valley, where, as in the valley of the Zambezi, the soil is fertilized by inundations. The chief products are: sesame, indigo, coffee, groundnuts, gum copal, rubber, sugar, cashew nuts, coconuts, copra, mangrove bark, maize, tobacco, cotton and sisal. The irrigation and drainage scheme for the Limpopo valley, worked out by Col. Balfour, which will affect 49,400 ac. of good land, and cost £500,000, providing work for about 40,000 natives, has been officially approved. Hand labour prevails although some of the large plantations are partially mechanized. Some progress has been reported in training eland, African antelope, for farm work. The government is the original owner of all land.

The following are notes on some chief products (*see* further under section on Mozambique and Nyasa companies). Sugar has become the best cash crop, and its production approximated 80,000 short tons in 1940–41. About half of this production was in Mozambique chartered company territory, which had 29,000 ac. under sugar in 1939. Sisal has become important, and production reached a peak of 24,640 short tons before World War II. Both sugar and sisal are chiefly plantation products. Cotton, mainly under native cultivation, is of lesser importance with a production of about 6,614 short tons in 1940. In 1938 the colony exported 38,000 short tons of copra of high quality, most of it being produced in the 200,000 ac. of coconut plantations in the coastal area north of the Zambezi. Although large quantities of peanuts and cashew nuts are grown by the natives throughout the colony, only a small proportion reaches the market owing to native consumption. About 26,000 short tons were exported from the colony in 1937. Rice, coffee, tea and tobacco are of only secondary and purely local importance. Owing to wide tsetse fly areas, livestock raising has not developed very extensively. Maize grows everywhere and is cultivated universally by natives, it being the staple item in their diet. Although previously of some importance as an export, little has been exported since the drop in world prices in 1930. Cotton production has diminished south of the Save river, owing to irregular rains.

Forestry, Stock-raising and Other Industries.—Timber resources are abundant but have not been greatly exploited. Lumber and wood products in 1939 totalled 10,960 short tons at a value of $74,108.

The most important timbers produced are: mahogany (*Khaya Nyassica*); ebony or grandilha (*Dalbergia melanoxylon*); mussacossa or pod mahogany (*Afzelia Quanzensis*), called chanfuta in the south of the province, used for furniture, vehicles, etc.; m'bila (*Ptero carpus erinaceus*) or bloodwood; pau-ferro (*Swartzea Madagascarensis*), suitable for high class furniture; African sandalwood (*Excoecaria Africana*) for furniture and wagon work, etc.; ziba (*Andrades arborea*) a valuable hardwood; moanjwa (*Cordyla Africana*); m'zimbiti (*Androstachys Johnsoni*), impervious to white ants, and used for railway sleepers and piles; pangapanga (*Lonchocarpus Mossambicensis*) suitable for furniture; muanga or chuanga (*Ormosia Angolensis*) used for bridge building, being impervious to white ants; monhé or gone (*Adina microcephala*) similar to teak; messanda (*Erythophloeum Guineensis*), a very hard red wood, suitable for railway sleepers.

There is little industrial development in the colony, but in an effort to encourage industrialization the Mozambique administration has instituted protective tariffs on some products and has granted monopolies for the manufacture of others. A modern, well-equipped cement factory, owned by the Mozambique Portland company, is working at Matola, near Lourenço Marques, and is capable of producing 50,000 short tons of cement a year. Its products are used in the province. Tobacco is manufactured, four factories being at work. Bricks and tiles are made at Incomati, on the Lourenço Marques railway. Oils and soaps, in the Lourenço Marques and Inhambane districts. Milling is carried on. Tannin is extracted in the Quelimane and Mozambique districts. A Portuguese company has undertaken the production of paper and paper pulp.

Minerals and Mining.—Mining can be carried on only under concession from the government. In the future, exclusive conces-

sions for prospecting for minerals are not to be renewed. The mining industry is not well-developed largely owing to lack of a thorough geological survey, inadequate capital, lack of skilled labour and transportation difficulties. Coal, gold and silver are the minerals chiefly exploited. The chief mining centre is Manicaland, but minerals have been extensively proved elsewhere. Active prospecting is being carried on in the Lourenço Marques and other districts. The Zambezia Development company is prospecting systematically the whole of the Tete district. Extensive coal fields exist near Zumbo. The quality is excellent. Other deposits are known at Sena and Massurize, along the Shiré and Zambezi rivers, and in the Nyasa Co.'s territory. Coal has been reported in the Lourenço Marques district, but not proved. The Zambezia Mining company is working coal at Mantize. Malachite is found in the interior, northwest of Mozambique. The whole of the region north of Delagoa bay to the Zambezi, and inland to and beyond the Portuguese frontier, is auriferous, and ancient gold workings abound. Many writers have sought to identify this region with the land of Ophir. In Manica several gold mines are worked (quartz formation). In 1906–07 a rich formation similar to the American "placer" deposits was discovered in the Manica goldfields. Gold mines are also worked at Missale and Chifumbaze, north of Tete. The Missale mines are just south of the frontier of British Central Africa.

An important tin deposit is being worked at Neves Ferreira. Iron is found at Sena and Tete, and in the area of the Nyasa company. Asbestos occurs in the area of the Nyasa company. Copper is found at Sena and Tete, along the Shiré and Zambezi rivers. It is chiefly worked near Macequece. Diamondiferous ground is known at Govuro. Wulfram also occurs and graphite is found along the Shiré and Zambezi rivers. Mineral oils occur in the lands of the Nyasa company, and near Inhambane.

Administration and Finance.—The government of the colony has limited administrative and financial autonomy under the provisions of the Organic Charter of the Colonial empire and the Colonial Administration reform of Nov. 15, 1933, which define the relationship between Portugal and the colony. The head of the colony's government is the governor-general who is appointed by the council of ministers in Lisbon for a four-year term, subject to re-appointment, and who is directly responsible to the minister of colonies in Portugal. Although he may be over-ruled in Lisbon on important matters, the governor-general exercises wide powers in the colony. He resides in Lourenço Marques. He is assisted by an advisory government council and the three provincial governors. There are no representative institutions, the only elected officials being the five unofficial members of the government council, who are elected by certain economic organizations such as the chambers of commerce, and the elected members of the town councils in the few municipal areas designated as communes. The five unofficial members of the government council are more than offset by the seven official members who sit on the council by reason of their positions in the local administration. The council normally holds but one short session each year and is strictly consultative. The administration of the colony is carried out through 17 administrative departments. The colony is divided into three provinces, each of which is subdivided into districts. The provinces are: Zambezia, whose capital is Quelimane, and which is divided into the districts of Quelimane and Tete; Sul do Save, whose capital is Lourenço Marques, and which is divided into the districts of Lourenço Marques and Inhambane; and Niassa, whose capital is Nampula, and which is divided into the districts of Mozambique and Porto Amelia. The territory of Manica and Sofala, which had been the territory of the Mozambique company, became the new district of Beira in the province of Zambezia after the termination of the company's charter. The districts are in turn divided into subdistricts, each being under an administrator, and each subdistrict (*circunscricôes civis*) is redivided into one to four administrative posts, in which are located the post offices, police stations, etc. The provinces are headed by provincial governors who can be over-ruled by the governor-general. An administrator heads each district. A judicial system, comprising a court of appeals and courts of preliminary investigation in ten judicial divisions, maintains separate sections for native cases, and applies the Portuguese law (*Codigo Civil*).

The Mozambique company is a Lisbon company, incorporated by royal charter (1891), for a term of 50 years, renewable on expiry. Its capital is £1,500,000, much of which is foreign, and until its rights reverted to the Portuguese government in 1942 through its refusal of renewal, it exercised sovereign rights over the territories of Manica and Sofala, an area of 59,315 sq.mi. In this territory the company held a monopoly of agriculture, commerce, industry, mining, communications and transport, taxation, customs and the right to issue notes. Its main activities are agricultural, but mining operations are very promising. Its capital Beira (*q.v.*) is the natural port of Rhodesia, and the carrying trade is constantly developing. The company's profits in 1939 totalled $600,000. Gold, both reef and alluvial is produced, as also silver, tin and copper. Coal measures are known. The chief agricultural products are: cotton, of good staple, mainly on the Zambezi, and in Manica, Chimoio, Neves Ferreira and Buzi; sisal at Chupanga on the Zambezi; maize throughout the territory; oilseeds; rice, in increasing quantity, and citrus fruits. In 1926 there were 88,060 head of cattle in the territory.

The Nyasa company, which began work in 1894, had rights similar to those of the Mozambique company. It has had under its control territories, with area 73,292 square miles, in the north, the region between the Rovuma, the Lurio and Lake Nyasa. Porto Amelia, the capital, is about 150 miles north of Mozambique. Trade is mostly in the hands of Indians, and development has been slow and inconsiderable. Agricultural and mineral possibilities are probably considerable. Active prospecting is going on, and there are said to be indications of coal, oil, graphite, mica, iron, and alluvial gold. The territory of the company was taken over by the provincial government in 1929.

The difficult conditions of the last few years have disappeared, and the financial condition of the colony is encouraging. The escudo currency is now on a firm basis. Transfers to Portugal now cost only 3%. Revenue is mainly derived from customs, a hut tax (for which in 1925 a poll tax was substituted) and a tax on labourers who emigrate. A mild income tax was instituted in 1940. From 1937 until the outbreak of World War II the annual budgets showed a surplus. In 1939 revenue from all sources totalled $23,575,160 as against expenditures for that year of $23,421,640. The colony has no external debt.

Economic Conditions and Commerce.—Economic development is considerable in the province, especially in the Mozambique company's territory. The Portuguese, however, have lacked capital to carry out large enterprises, while the constant ministerial changes at Lisbon and the financial embarrassment of Portugal have reacted unfavourably on Mozambique. Development has been most marked where British interests were concerned and British capital was forthcoming. The transit trade is large, Lourenço Marques serving the eastern Transvaal, and Beira being the chief port for Rhodesia, Katanga and British Nyasaland. A railway from Beira to the Zambezi, completed in 1922, was built with British capital to meet the needs of the Nyasaland Protectorate. This railway superseded the route by the Zambezi. The Beira-Zambezi railway also opened up rich tracts suitable for sugar, cotton and other crops. Moreover it brought a step nearer the exploitation on a large scale of the coal fields on the north side of the Zambezi near Tete. Another railway, from Inhambane to Delagoa bay (280 mi. long), built in sections, is open to Inharrime. This line also serves fertile regions.

Normally, the colony's imports exceed its exports, with Portugal controlling most of the trade. In 1939 imports totalled $19,422,000 as against $7,289,000 of exports. The chief imports in normal years are coal, iron and steel, machinery, cement, flour, rice, wine, textiles and oil. The principal exports are sugar, copra, sisal and nuts. World War II had an adverse effect on the import and export trade of the colony, largely owing to the loss of European markets for agricultural products. There was an increase in trade with the United States and a strengthening of trade relations with Portugal and with other Portuguese colonies.

Apart from local trade, the transit trade to British dominions

through Lourenço Marques and Beira is most important. The chief exports to the Union of South Africa are copra, sugar, fresh fruit and groundnuts; the chief imports from that source being coal, maize, fresh milk, eggs, beer and potatoes. In 1938, 23% of Mozambique's imports came from Portugal; 17% from Great Britain; 10% from Germany; and 9% from the Union of South Africa. 35% of the exports in that year went to Portugal, while the French empire, Belgium and Holland each took about 10%.

Missions and Education.—The province forms a diocese (in the ecclesiastical province of Goa) of the Roman Catholic Church which has been established in the colony from the beginning, ministering to Europeans and carrying on missions and educational work among natives in many places. There are several Protestant missions, co-operating loyally with the government. Their educational work amongst natives is especially valuable. The most important of these are the Mission Suisse Romande, in the Lourenço Marques district; the Universities' Mission in the Nyasa company's territory; the Anglican diocese of Lebombo in the districts of Lourenço Marques and Inhambane; the Methodist Episcopal mission in the Inhambane district; the Wesleyan Methodist church in the Lourenço Marques district; the Church of Scotland in the district of Quelimane; the American Free Methodist mission in the district of Inhambane.

Complete statistics as to education are wanting, but in general it appears that although education on the primary and secondary level is adequate for whites, it is very inadequate for natives. Only about 74,000 native students were enrolled in all schools in 1940. Except for oral teaching, native languages may not be used in the schools. The only secondary school (liceu) in the province is in Lourenço Marques. An elementary commercial course has been instituted in connection with this school. Training schools for native teachers are maintained by the Mission Suisse Romande at Rikatla, near Lourenço Marques; another at Lourenço Marques is conducted jointly by the Anglican, Swiss and Wesleyan Methodist missions; at Lourenço Marques the Anglican mission trains teachers and evangelists; and at Kambini, Inhambane district, the Methodist Episcopal church has a training school.

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HISTORY

By the 10th century A.D. the Arabs had occupied the seaboard of East Africa as far south as Sofala, and until the close of the 15th century their supremacy was unchallenged. But in 1498 Vasco da Gama entered the mouth of a river which he called Rio dos Bons Sinaes (River of Good Tokens), as there he first found himself in contact with the civilization of the East. This stream was the Quelimane river, taken by the Portuguese a little later to be the main mouth of the Zambezi. From this river da Gama continued his voyage, putting in at Mozambique and Mombasa on his way to India. Hostilities between the Arabs and Portuguese broke out almost immediately. In 1502 da Gama paid a visit to Sofala to make enquiries concerning the trade in gold carried on at that place, and the reports as to its wealth which reached Portugal led to the dispatch in 1505 of a fleet of six ships under Pedro da Nhaya with instructions to establish Portuguese influence at Sofala. By 1510 the Portuguese, who had seized and fortified the port of Mozambique in 1507, were masters of all the former Arab sultanates on the East African coast.

Quest for the Land of Gold.—For 40 years Sofala was their only station south of the Zambezi. Thence they traded with the chief of the "Mocaranga" (*i.e.*, the Makalanga or Karanga) in whose territory were the mines whence the gold exported from Sofala was obtained. This potentate was known as the Monomotapa (*q.v.*). The efforts made by the Portuguese from Sofala to reach him were unsuccessful. It was probably the desire to penetrate to the "land of gold" by an easier route that led, in 1544, to the establishment of a station on the River of Good Tokens, a station from which grew the town of Quelimane. It was at this period also that Lourenço Marques and a companion entered Delagoa bay and opened up trade with the natives. This was the most southerly point occupied by the Portuguese. In 1569 the East African dominions, hitherto dependent on the vice-royalty of India, were made a separate government with headquarters at Mozambique.

Francisco Barreto, a former viceroy of India, appointed governor of the newly formed province, was instructed by King Sebastian to conquer the country of the gold mines. Unwisely the route via the Zambezi, and not that from Sofala, was chosen by Barreto. His expedition, including over 1,000 Europeans, started in Nov. 1569, and from Sena marched south. His force was so greatly weakened by deaths and disease that Barreto was obliged to return to Sena, whence he went to Mozambique to put down disorder among the Portuguese there. He returned to Sena in 1570, only to die a few days after his arrival. His successor, Vasco Fernandes Homem, made his way inland from Sofala to a region where he saw the ground being worked for gold. The comparative poorness of the mine filled him, it is stated, with disappointment, and he returned to Sofala.

Era of Decline.—The Portuguese for some time failed to make any effective use of their East African possessions. Among the causes of non-success must be reckoned the "Sixty Years' Captivity" (1580–1640), when the Spanish and Portuguese crowns were united, and the neglect of Africa for the richer possessions in India and the Far East. A more permanent reason for the non-development of Mozambique province was the character of the government and the settlers. For a series of years the Jesuits and Dominicans were the most energetic sections of the white community. The first Jesuit missionaries began work in the neighbourhood of Inhambane in 1560; in the same year another Jesuit, Gonçalo da Silveira, made his way to the zimbabwe (chief kraal) of the monomotapa, by whose orders he and his converts were strangled (March 16, 1561). Mission work was soon afterwards begun by the Dominicans and for nearly two centuries the two orders between them had agents spread over the greater part of the country from Mozambique southward. Traces of their influence are still to be found among the tribes. In 1759 the Jesuits were expelled. Three attempts by the Dutch in the 17th century to capture the port of Mozambique were unsuccessful, but in the early years of the 18th century the Arabs wrested from the Portuguese their African possessions north of Cape Delgado. The merchants of Sofala and Mozambique had, since the middle of the 17th century, found a new source of wealth in the export of slaves to Brazil. This trade, due directly to the capture of the ports of Angola by the Dutch (1640–48), continued until nearly the middle of the 19th century, while slavery in the province was not abolished until 1878; and then abolition was largely nominal.

In 1752 the government of the East African possessions was again, and this time permanently, separated from that of Goa, and 20 years later Francisco José Maria de Lacerda e Almeida, a man of high attainments, made governor of the province at his own request, endeavoured to reform the administration. Lacerda is chiefly remembered for his journey to the heart of Central Africa, where he died in Oct. 1798. After his death a state of decay was again manifest throughout Portuguese East Africa. During the greater part of the 19th century the country south of the Zambezi was devastated by hordes of savages of Zulu origin (*see* GAZALAND).

Modern Developments.—The discoveries of David Livingstone in the period of 1850–65 led to the establishment of British settlements at the southern end of Lake Nyasa and in the Shiré highlands. These events aroused anxiety in Lisbon, which was increased when the British secured Matabele, Mashona and Manica lands—the lands of the earlier monomotapas. With sudden energy the Portuguese engaged in the "scramble for Africa," and they obtained much better terms than might have been anticipated, having regard to the extremely limited area over which they

exercised jurisdiction. (For story of the partition *see* AFRICA.)

Under the republic the Portuguese made serious efforts to improve the administration. In 1914 a measure of autonomy, enlarged in 1920, was granted to the province. In general the treatment of the natives was satisfactory, but labour conditions left much to be desired. Compulsory unpaid labour in the province of Mozambique was not abolished until 1925. In 1927 reports were spread that Germany might acquire a mandate under the League of Nations to administer Mozambique or Angola. This led (Dec. 1927) to a reaffirmation of the ancient Anglo-Portuguese alliance which covers the Portuguese colonies. On Sept. 11, 1928, at Pretoria, after prolonged negotiations the Mozambique Convention was signed with the Union of South Africa respecting the trade of the Transvaal with the port of Lourenço Marques (Delagoa bay), the recruitment of natives in Portuguese territory for work in the Rand mines, and other matters. It replaced the Mozambique Convention which had been concluded with the Transvaal government in 1909 and had lapsed in 1923.

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(F. R. C.)

PORTUGUESE GUINEA, a Portuguese colony on the Guinea coast of Africa, extending from Cape Roxo in 12° 9′ N. to the Congo estuary in 10° 50′ N. It is enclosed landward by French territory, the Casamance district of Senegal to the north and French Guinea to the east and southeast. It covers an area of 13,944 sq.mi. and in 1940 had a population of about 351,089, of which less than 1,500 were Europeans, mostly officials and traders, and about 2,200 were Creoles from the Cape Verde Islands.

Geography.—The country consists of a low-lying coastal region and of numerous (60) islands and islets off shore. Some of these form an archipelago known as Bissagos Islands. The most important islands are Bissau, Bolama, Bubaque, Canhabaque, Uno. The mainland rises gradually towards the interior to about 600 ft. in the southeast. The coastal area, which is just about sea level, is deeply indented, great estuaries running far inland. The principal rivers are the Cacheu or Farim in the north and the Geba and the Corubal in the centre. The Rio Grande, Rio Tombali and Rio Cacine in the south are not rivers but long gulfs. Most of the waterways are navigable for about 100 mi. inland.

Climate.—Along the coast the average temperature varies between 85° in May and 77° in January. During the dry season (December to May) the hot harmattan blows from the north; June and July are marked by severe thunderstorms and by high humidity; the rainy season, beginning in May, lasts to the end of November; the annual rainfall varies between 50–75 in.

Flora and Fauna.—The coastal region and the islands are covered with palm trees; the rest of the country, interspersed with swamps is only lightly forested. The chief trees are the cotton tree, the African mahogany (*khaya senegalensis*), the great ironwood or balsam tree (*copaifera*), the baobab and innumerable varieties of acacia. Fruit trees include the papaw, guava, mango, banana, and orange. Coffee trees, cotton bushes, indigo may be found. Groundnuts, rice, millets are cultivated and are, besides the products of the palm, the chief staples of the native population. The fauna includes water buffaloes, deer, antelopes, lions, leopards, monkeys and many varieties of snakes; occasionally elephants stray in from French territory; crocodiles and sharks abound in the rivers. Birds include the pelican, heron, marabout, egrets, the trumpet bird, and yellow parrots.

Population.—Two major groups may be distinguished among the African inhabitants: the Moslems of the hinterland and the non-Moslems in the coastal region. The first group consists of the Fulani (*q.v.*), the Mandinga (*q.v.*), and the Biafar; the second comprises the Balante, Brame, Papel (Papies), Mandjak living north of the Geba river, the Nalu in the south, the Bissago on the islands, and the Felupe and Bayote, north of the Cacheu river. All of the people are agriculturists with the exception of the Fulani, who are cattle breeders. Although the natives resisted Portuguese control until the early part of the 20th century, many of them, with the exception of the Bissago, Nalu, and Felupe, gradually came under European influence. About two-fifths of the population are Moslems; the remaining natives adhere to their traditional religious beliefs. In the coastal towns of Bissau, Bolama and Cacheu are about 10,000 Africans who have adopted Christianity. The non-native population includes many Creoles from the Cape Verde Islands. They are the country's store keepers and fill posts as minor government officials.

Administration.—The country is under the control of a governor, appointed by and acting on behalf of the minister of colonies in Lisbon. It is divided into ten circumscriptions, each under an administrator who controls several *chefes de posto*. The native administration is left to traditional chiefs as far as these prove loyal to the Portuguese administration. In 1879, when Guinea became independent from Cape Verde Islands, the capital was Bolama; it was shifted to Bissau in 1942.

Education.—Native education is largely managed by the natives themselves; in the Moslem regions Koran schools give instruction in religious matters. After 1925 both missions and the government began to improve the educational standards. In 1936 the country had 31 elementary schools and 3 trade schools.

Economy.—Considering the natural resources, the country's economy was still undeveloped in 1944. The chief exports, all native produce, were groundnuts (34,722 short tons in 1938) and palm kernels; hides, wax, rice and timber were secondary in importance. The total exports in 1941 amounted to 64,000,000 escudos (1 escudo = 4.002 cents U.S.). Imports consisting of cotton fabrics, agricultural implements, wines, beer, and tobacco products totalled 49,000,000 escudos in the same year. The principal ports are Bissau, Bubaque and Cacheu, all of which can accommodate ocean-going vessels. The port activities in 1936 amounted to 107 ships with a gross tonnage of 163,095.

Trading is greatly facilitated by navigable rivers, which offer more than 1,000 mi. of waterways; more than 2,000 mi. of roads had been built up to 1940.

The Banco Nacional Ultramarino enjoys the right to issue banknotes within the colony.

History.—Portuguese Guinea was discovered in 1446 by the Portuguese Nuno Tristão, who, while searching for slaves, was killed in the following year. Although the Cape Verde islanders (Santiago) were granted trading rights in this territory in 1462, few, if any, permanent trading posts appear to have been in existence prior to 1581. Many of these early settlements, such as Sao Felipe and Porto da Cruz, have disappeared, while others, such as Farim, Cacheu, Geba and Buba have survived as minor centres to this day. Cacheu, most important of them, probably established in 1470, was a fortified settlement (*c.* 1,800 inhabitants) in 1589. During the 17th and 18th centuries it was the chief slave trading centre of this region where the Cape Verde islanders retained companies holding monopolistic slave rights such as the Companhia de Cacheu e Rios da Guiné (founded in 1676), the Companhia da Guiné (1684), the Companhia de Cabo Verde e Cacheu (1690), Companhia de Grão Para e Maranhao (1755). After the slave trade declined at the beginning of the 19th century, Bissau (Sao Jose de Bissao), which had been founded as a fort in 1765, became the chief commercial centre.

In the 19th century the Portuguese, who had held only a few posts along the coast and who never explored the interior, found themselves in territorial disputes with France and Great Britain. The island of Bolama, which had been disputed between Great Britain and Portugal for more than 100 years, was finally given to Portugal by President Ulysses S. Grant of the United States who, called upon to act as arbitrator, decided in favour of Portugal (April 21, 1870). France and Portugal settled their border problems in 1886, the Portuguese exchanging against their will the southern bank of the Casamance for the Cacine district in the south. Final demarcation of the frontier was accomplished in 1902–05.

Since the earliest days of Portuguese settlement, relations with the Africans were tense because of the slave trade. Such posts

as Cacheu, Farim, and Bissau were intermittently besieged, and Europeans scarcely ventured outside the town fortifications. When, between 1890–1910, the Portuguese attempted to expand inland, there were continual uprisings on the part of the native tribes. The country was pacified only in 1915, after Capt. Teixeira Pinto succeeded in defeating the Mandinga, Mandjak, Balante and Papel in campaigns between 1912–15. In 1917, 1925 and 1936, the Portuguese dispatched troops to the island of Canhabaque to force the Bissago to pay taxes which they had refused.

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PORTUGUESE LANGUAGE. Portuguese-Galician constitutes the second branch of the Latin of Spain. In it we must distinguish—(1) Portuguese (*Portuguez,* perhaps a contraction from the old *Portugalez*=Portugalensis), the language of the kingdom of Portugal and its colonies in Africa, Asia and America (Brazil); (2) Galician (*Gallego*), or the language of the old kingdom of Galicia (the modern provinces of Pontevedra, La Coruña, Orense and Lugo) and of a portion of the old kingdom of Leon (the territory of Vierzo in the province of Leon). Portuguese, like Castilian, is a literary language, which for ages has served as the vehicle of the literature of the Portuguese nation constituted in the beginning of the 12th century. Galician, on the other hand, which began a literary life early in the middle ages—for it was employed by Alfonso the Learned in his *Cantigas* in honour of the Virgin—decayed in proportion as the monarchy of Castile and Leon, to which Galicia had been annexed, gathered force and unity in its southward conquest.

Vowels.—Lat. *ĕ, ŏ* with the accent have not been diphthongized into *ie, uo, ue: pé* (p e d e m), *bom* (b o n u s). On the other hand, Portuguese has a large number of strong diphthongs produced by the attraction of an *i* in hiatus or the resolution of an explosive into *i: raiba* (r a b i a), *feira* (f e r i a), *oito* (o c t o). A peculiar feature of the language occurs in the "nasal vowels," which are formed by the Latin accented vowels followed by *m, n,* or *nt, nd: bẽ* (b e n e), *grã* (g r a n d e m), *bõ* (b o n u m). These nasal vowels enter into combination with a final atonic vowel: *irmão* (g e r m a n u s); also *amão* (a m a n t), *sermão* (s e r m o n e n), where the *o* is a degenerated representative of the Latin final vowel. In Old Portuguese the nasal vowel or diphthong was not as now marked by the *til* (~), but was expressed indifferently and without regard to the etymology by *m* or *n: bem* (b e n e), *tam* (t a n t u m), *disserom* (d i x e r u n t), *sermom* (s e r m o n e m). The Latin diphthong *au* is rendered in Portuguese by *ou* (*ouro,* a u r u m), also pronounced *oi.* With regard to the atonic vowels, there is a tendency to reduce *a* into a vowel resembling the Fr. *e* "muet," to pronounce *o* as *u,* and to drop *e* after a group of consonants (*dent* for *dente*).

Consonants.—Here the most remarkable feature, and that which most distinctly marks the wear and tear through which the language has passed, is the disappearance of the median consonants *l* and *n: corõa* (c o r o n a), *lua* (l u n a), *pôr* formerly *poer* (p o n e r e), *conego* (c a n o n i c u s), *vir* (v e n i r e), *paço* (p a l a t i u m), *pego* (p e l a g u s). Lat. *b* passes regularly into *v: cavallo* (c a b a l l u s), but, on the other hand, Lat. initial *v* readily tends to become *b: bodo* (v o t u m). Lat. initial *f* never becomes *h: fazer* (f a c e r e). Lat. *c* before *e* and *i* is represented either by the hard sibilant *s* or by the soft *z.* Lat. *g* between vowels is dropped before *e* and *i: ler* for *leer* (l e g e r e), *dedo* (d i g i t u m); the same is the case with *d,* of course, in similar circumstances: *remir* (r e d i m e r e), *rir* (r i d e r e). Lat. *j* has assumed the sound of the French *j.* The Latin combinations *cl, fl, pl* at the beginning of words are transformed in two ways in words of popular origin. Either the initial consonant is retained while the *l* is changed into *r: cravo* (c l a v u m); or the group is changed into *ch* (=Fr. *ch,* Catal. *x*) through the intermediate sounds *kj, fj, pj: chamar* (c l a m a r e), *chão* (p l a n u s), *chamma* (f l a m m a). Within the word the same group and other groups also in which the second consonant is an *l* produce *l* mouillée (written *lh,* just as *n* mouillée is written *nh,* as in Provençal): *ovelha* (o v i c' l a), *velho* (v e c l u s); and sometimes *ch: facho* (f a c' l u m), *ancho* (a m p l u m). Lat. *ss* or *sc* before *e* and *i* gives *x* (Fr. *ch*): *baixo* (b a s s u s), *faxa* (f a s c i a). The group *ct* is reduced to *it: leito* (l e c t u m), sometimes to *ut: douto* (d o c t u s).

Inflexion.—The Portuguese article, now reduced to the vocalic form *o, a, os, as,* was *lo* (exceptionally also *el,* which still survives in the expression *El-Rei*), *la, los, las* in the old language. Words ending in *l* in the singular lose the *l* in the plural (because it then becomes median, and so is dropped): *sol* (s o l e m), but *soes* (s o l e s); those having *ão* in the sing. form the plural either in *ães* or in *ões* according to the etymology: thus *cão* (c a n e m) makes *cães,* but *ração* makes *rações.* Portuguese conjugation has more that is interesting. In the personal suffixes the forms of the 2nd pers. pl. in *ades, edes, ides* lost the *d* in the 15th century, and have now become *ais, eis, is,* through the intermediate forms *aes, ees, eis.* The form in *des* has persisted only in those verbs where it was protected by the consonants *n* or *r* preceding it: *pondes, tendes, vindes, amardes.* Portuguese is the only Romance language which possesses a personal or conjugated infinitive: *amar, amar-es, amar, amar-mos, amar-des, amar-em;* e.g., *antes de sair-mos,* "before we go out." Again, Portuguese alone has preserved the pluperfect in its original meaning, so that, for example, *amara* (a m a v e r a m) signifies not merely as elsewhere "I would love," but also "I had loved." Among the peculiarities of Portuguese conjugation are—(1) the assimilation of the 3rd pers. sing. to the 1st in strong perfects (*houve, pude, quiz, fez*), while Castilian has *hube* and *hubo;* (2) the imperfects *punha, tinha, vinha* (from *pôr, ter* and *vir*), which are accented on the radical in order to avoid the loss of the *n* (*ponía* would have made *poía*), and which substitute *u* and *i* for *o* and *e* in order to distinguish from the present subjunctive (*ponha, tenha, venha*).

Galician.—Almost all the phonetic features which distinguish Portuguese from Castilian are possessed by Gallego also. Portuguese and Galician even now are practically one language, and still more was this the case formerly. In conjugation the peculiarities of Gallego are more marked; some find their explanation within the dialect itself, others seem to be due to Castilian influence. The 2nd persons plural have still their old form *ades, edes, ides,* so that in this instance it would seem as if Gallego had been arrested in its progress while Portuguese had gone on progressing; but with these full forms the grammarians admit contracted forms as well: *ás* (Port. *ais*), *és* (Port. *eis*), *ís* (Port. *is*). The 1st pers. sing. of the perfect of conjugations in *er* and *ir* has come to be complicated by a nasal resonance similar to that which we find in the Portuguese *mim;* we have *vendin, partin,* instead of *vendi, parti,* and by analogy this form in *in* has extended itself also to the perfect of the conjugation in *ar,* and *falin, gardin,* for *falei, gardei* are found. The second persons of the same tense take the ending *che, ches* in the singular and *chedes* in the plural: *falache* or *falaches* (f a b u l a s t i). The 3rd pers. sing. of strong perfect is not in *e* as in Portuguese (*houve, pode*), but in *o* (*houbo, puido, soubo, coubo,* etc.); Castilian influence may be traceable here.

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PORTUGUESE LITERATURE. The literature of the Portuguese is distinguished by the wealth and variety of its

lyric poetry, its primacy in bucolic verse and prose, the number of its epics and historical books, and the relative slightness of its drama, biography and letters. Rich as its *romanceiro* is, its volume is far less than the Spanish, but the *cancioneiros* remain to prove that the early love songs of the whole Peninsula were written in Portuguese, while the primitive prose redaction of *Amadis*, the prototype of all romances of chivalry, was almost certainly made in Portugal, and a native of the same country produced in the *Diana* of Montemôr (Montemayor) the masterpiece of the pastoral novel. *The Lusiads* may be called at once the most successful epic cast in the classical mould, and the most national of poems, and the great historical monuments and books of travel of the 16th and 17th centuries are worthy of a nation of explorers who carried the banner of the Quinas to the ends of the earth. On the other hand, Portugal gave birth to no considerable dramatist from the time of Gil Vicente, in the 16th century, until that of Garrett in the 19th, and it has failed to develop a national drama.

The first literary activity of Portugal was derived from Provence, and Provençal taste ruled for more than a century; the poets of the 15th century imitated the Castilians, and the 16th saw the triumph of Italian or classical influence. Spain again imposed its literary standards and models in the 17th century, France in the 18th, while the Romantic movement reached Portugal by way of England and France; and those countries, and in less degree Germany, have done much to shape the literature of the 19th century. Nearly every Portuguese author of renown from 1450 until the 18th century, except Antonio Ferreira, wrote in Spanish, and some, like Jorge de Montemôr and Manoel de Mello, produced masterpieces in that language and are numbered as Spanish classics. Again, in no country was the victory of the Italian Renaissance and the classical revival so complete, so enduring.

Yet Portuguese literature has a distinct individuality which appears in the *romanceiro*, in the songs named *cantares de amigo* of the *cancioneiros*, in the *Chronicles* of Fernão Lopes, in the *Historia tragico-maritima*, in the plays of Gil Vicente, in the bucolic verse and prose of the early 16th century, in the *Letters* of Marianna Alcoforado and, above all, in *The Lusiads*.

Early Period.—Though no literary documents belonging to the first century of Portuguese history have survived, there is evidence that an indigenous popular poetry both sacred and profane existed, and while Provençal influences moulded the manifestations of poetical talent for nearly 200 years, they did not originate them. A few compositions which have come down to us bear a date slightly anterior to the year 1200. One of the earliest singers was D. Gil Sanches, an illegitimate son of Sancho I., and we possess a *cantar de amigo* in Galician-Portuguese, the first literary vehicle of the whole Peninsula, which appears to be the work of Sancho himself. The pre-Alphonsine period to which these men belong runs from 1200 to 1245 and produced little of moment, but in 1248 the accession of King Alphonso III., who had lived 13 years in France, inaugurated a time of active and rich production which is illustrated in the *Cancioneiro da Ajuda*, the oldest collection of Peninsular verse. The apogee of palace poetry dates from 1275 to 1280, when young Dinis, who had been educated by Aymeric of Cahors, proved himself the most fecund poet-king of his day, though the pleiad of *fidalgos* forming his court and the *jograes* who flocked there from all parts, were fewer in number, less productive, and lacked the originality, vigour and brilliance of the singers who versified round Alphonso III.

The principal names of the Dionysian period (1284–1325) which is illustrated in the *Cancioneiro da Vaticana* are the king himself and his bastards D. Alphonso Sanches and D. Pedro, count of Barcellos. Of the two last, the former sings of love well and sincerely, while the latter is represented by some satirical songs of *maldizer*, a form which, if it rarely contains much poetical feeling or literary value, throws light on the society of the time.

The verses of Dinis, essentially a love poet, are conventional in tone and form except when he uses the indigenous parallel-strophed or *cossante* form which gives their real originality to the Galician-Portuguese *cancioneiros*. Speaking generally, the *cancioneiros* form monotonous reading owing to their poverty of ideas and conventionality of metrical forms and expression, but here and there men of talent endeavoured to lend their work variety by the use of difficult processes like the *lexaprem* and by introducing new forms like the *pastorela* and the *descort*. It is curious to note that no heroic songs are met with in the *cancioneiros;* they are all, with one exception, purely lyrical in form and tone. The *romanceiro*, comprising romances of adventures, war and chivalry, together with religious and sea songs, forms a rich collection of ballad poetry which continued in process of elaboration throughout the whole of the middle ages, but scarcely any of those existing bear a date anterior to the 15th century.

Epic poetry in Portugal developed much later than lyric, but the signal victory of the united Christian hosts over the Moors at the battle of the Salado in 1340 gave occasion to an epic by Alphonso Giraldes of which some fragments remain.

The first frankly literary prose documents appear in the 14th century, and consist of chronicles, lives of saints and genealogical treatises. The more important are the *Chronica breve do archivo nacional*, the *Chronicas de S. Cruz de Coimbra*, the *Chronica da conquista do Algarve* and the *Livros das Linhagens*, portions of which have considerable literary interest. All the above may be found in the *Portugaliae monumenta historica*. *Romania* has printed some hagiographical texts, and the *Vida dos Santos Barlaão e Josafate* has been issued by the Lisbon Academy of Sciences.

Romances of chivalry belonging to the various cycles must have penetrated into Portugal at an early date, and the *Nobiliario* of the Conde D. Pedro contains the genealogy of Arthur and the adventures of Lear and Merlin. There exists a mid-14th-century *Historia do Santo Graal*, and an unprinted *Josep ab Aramatia*, and we have some evidence of the existence of a primitive Portuguese prose redaction of *Amadis de Gaula* anterior to the present Spanish text.

The 15th Century.—In the reign of John I. the court became an important literary centre, and the king himself composed a *Livro de Montaria*. His son, King Edward (Duarte), collected a precious library composed of the ancient classics, some translated by his order, as well as mediaeval poems and histories, and he wrote a moral treatise *Leal conselheiro*, and hints on horsemanship, or *Livro da ensinança de bem cavalgar toda sella*. His brother D. Pedro also wrote a moral treatise *Da virtuosa bemfeitoria*, and caused Vegetius's *De re militari* and Cicero's *De officiis* to be turned into Portuguese. This travelled prince brought back from Venice a ms. of Marco Polo as the gift of the senate. The age is noted for its chronicles, beginning with the anonymous life of the Portuguese Cid, the Holy Constable Nuno Alvares Pereira, told in charming prose. Fernão Lopes (*q.v.*), the father of Portuguese history and author of chronicles of King Pedro, King Ferdinand and King John I., has been called by Southey the best chronicler of any age or nation. Gomes Eannes de Azurara completed Lopes's chronicle of King John by describing the capture of Ceuta, and wrote a chronicle of D. Pedro de Meneses, governor of the town down to 1437, and a chronicle of D. Duarte de Meneses, captain of Alcacer, but his capital work is the chronicle of the conquest of Guinea. (*See* AZURARA.)

Though not a great chronicler or an artist like Lopes, Ruy de Pina is quite free from the rhetorical defects of Azurara, and his chronicles of King Edward and King Alphonso V. are characterized by unusual frankness. All these three writers combined the posts of keeper of the archives and royal chronicler, and were, in fact, the king's men, though Lopes at least seems rather the historian of a people than the oracle of a monarch. Garcia de Resende (*q.v.*) worked up Pina's chronicle of King John II. and added a wealth of anecdote and gossip. The taste for romances of chivalry continued throughout the 15th century, but of all that were produced the only one that has come down to us is the *Estorea do Imperador Vespasiano*, an introduction to the Graal Cycle, based on the apocryphal gospel of Nicodemus.

The Constable D. Pedro of Portugal (1429–66), son of the prince of that name already referred to, has left some verses marked by elevation of thought and deep feeling, the *Satyra de felice e infelice vida*, and the death of his sister inspired his *Tragedia de la insigne reyna Isabel* (1457); he is best remem-

bered by his *Coplas del contempto del mundo* in the *Cancioneiro Geral.* D. Pedro, who wrote in Castilian, is one of the first representatives of those Spanish influences which set aside the Provençal manner and in its place adopted a taste for allegory and a reverence for classical antiquity, both imported from Italy. It was to the constable that the marquis de Santillana addressed his historic letter dealing with the origins of Peninsular verse. The court poetry of the reigns of King Alphonso V. and King John II. is contained in the *Cancioneiro Geral,* compiled by Garcia de Resende and printed in 1516. Some 200 authors are there represented by pieces in Portuguese and Castilian, and they include D. João Manuel, D. João de Meneses, João Rodrigues and de Sá e Meneses, Diogo Brandão, Duarte de Brito and Fernão da Silveira. The main subjects are love, satire and epigram. The epic achievements of the Portuguese in that century hardly find an echo, even in the verses of those who had taken part in them. Instead, an atmosphere of artificiality surrounds these productions, the influence is Spanish, and the verses that reveal genuine poetical feeling are very few, but some names appeared in the *Cancioneiro Geral* which were to be among the foremost in Portuguese literature; *e.g.,* Bernardim Ribeiro, Christovam Falcão, Gil Vicente and Sá de Miranda, who represent the transition between the Spanish school of the 15th and the Italian school of the 16th century, called *Os Quinhentistas.* Ribeiro and Falcão, the introducers of the bucolic style, put new life into the old forms, and by their eclogues in *redondilhas* gave models which subsequent writers worked by but could never equal.

Gil Vicente and the Eschola Velha.—The transition of the drama from the presentment of traditional types to the modern play can be traced in the works of Gil Vicente, the father of the Portuguese theatre. His first efforts belonged to the religious drama, and some of the more notable had edification for their object; *e.g.,* the trilogy of *Barcas,* but even in this class he soon introduces the comic element by way of relief, and in course of time he arrives at pure comedy, and develops the study of character. For a detailed description of his work, *see* VICENTE.

In the various towns where he stayed and produced his plays, writers for the stage sprang up, and these formed the Eschola Velha or school of Gil Vicente, the best known being Affonso Alvarez, author of religious pieces; Antonio Ribeiro, nicknamed "the Chiado," an unfrocked friar with a strong satirical vein who wrote farces in the Bazochian style; and his brother Jeronimo Ribeiro. In Santarem appeared Antonio Prestes, a magistrate, who evinced more knowledge of folk-lore than dramatic talent; while Camoens himself felt Vicente's influence. Another poet of the same school is Balthazar Dias, the blind poet, whose simple religious *autos* are still performed in the villages, and are continually reprinted, the best liked being the *Auto of St. Alexis,* and the *Auto of St. Catherine.* One of the last dramatists of the 16th century belonging to the old school was Simão Machado, who wrote the *Comedy of Diu* and the *Enchantments of Alfea,* two long plays almost entirely in Spanish.

Except Camoens, all these men, though disciples of Gil Vicente, are decidedly inferior to him in dramatic invention, fecundity and power of expression, and they were generally of humble social position. The favour of the court was withdrawn on the death of Gil Vicente and the old dramatists had to face the opposition of the classical school and the hostility of the Inquisition, which early declared war on the popular plays on account of their grossness. The way was thus clear for the Jesuits, who introduced Latin tragi-comedies or dramatized allegories written to commemorate saints or for scholastic festivals. The four Indexes of the 16th century give some idea of the rich repertory of the popular theatre, and of the efforts necessary to destroy it; moreover, the Spanish Index of 1559, by forbidding *autos* of Gil Vicente and other Portuguese authors, is interesting evidence of the extent to which they were appreciated in the neighbouring country.

The movement commonly called the Renaissance reached Portugal both indirectly through Spain and directly from Italy, with which last country it maintained close literary relations throughout the 15th century. King Alphonso V. had been the pupil of Matthew of Pisa and summoned Justus Balduinus to his court to write the national history in Latin, while later King John II. corresponded with Politian, and early in his reign the first printing press got to work. In the next century many famous humanists took up their abode in Portugal. Nicholas Cleynaerts taught the Infant Henry, afterwards cardinal and king, and lectured on the classics at Braga and Evora, Vasaeus directed a school of Latin at Braga, and George Buchanan accompanied other foreign professors to Coimbra when King John III. reformed the university. Many distinguished Portuguese teachers returned from abroad to assist the king at the same time, among them Ayres Barbosa from Salamanca, André de Gouvêa of the Parisian college of St. Barbe, whom Montaigne dubbed "the greatest principal of France," Achilles Estaço and Diogo de Teive.

At home Portugal produced André de Resende (*q.v.*), author of *De antiquitatibus Lusitaniae,* and Francisco de Hollanda, painter, architect, and author of *Quatro dialogos da pintura antiga.* Women took a share in the intellectual movement of the time, and the sisters Luisa and Angela Sigêa, Joanna Vaz and Paula Vicente, daughter of Gil Vicente, constituted an informal female academy under the presidency of the Infanta D. Maria, daughter of King Manuel. Luisa Sigêa was both an orientalist and a Latin poetess, while Publia Hortensia de Castro defended theses at Evora in her 18th year.

The Italian School or Os Quinhentistas.—The Italian school was founded by Sá de Miranda, a man of excellent character, who, on his return in 1526 from a six years' stay in Italy, initiated a reform of Portuguese literature which amounted to a revolution. He introduced and practised the form of the sonnet, canzon, ode and epistle in *ottava rima* and in tercets. At the same time he gave fresh life to the national octosyllabic metre (*medida velha*) by his *Cartas* or *Satiras* which with his *Eclogues,* some in Portuguese, others in Castilian, are his most successful compositions. His chief disciple, Antonio Ferreira (*q.v.*), a convinced classicist, went further, and dropping the use of Castilian, wrote sonnets much superior in form and style, though they lack the rustic atmosphere of those of his master, while his odes and epistles are too obviously reminiscent of Horace. D. Manoel de Portugal, Pero de Andrade Caminha, Diogo Bernardes, Frei Agostinho da Cruz and André Falcão de Resende continued the erudite school, which, after considerable opposition, definitively triumphed in the person of Luis de Camoens. The *Lima* of Bernardes contains some beautiful eclogues as well as *cartas* in the bucolic style, while the odes, sonnets and eclogues of Frei Agostinho are full of mystic charm. Immediately on its appearance *The Lusiads* took rank as the national poem *par excellence,* and its success moved many writers to follow in the same path; of these the most successful was Jeronymo Corte-Real (*q.v.*). All these poems, like the *Elegiada* of Luis Pereira Brandão on the disaster of Al Kasr, the *Primeiro cêrco de Diu* of the chronicler Francisco de Andrade, and even the *Affonso Africano* of Quevedo, for all its futile allegory, contain vigorous descriptive passages.

Sá de Miranda and his followers protested against the name *auto,* restored that of *comedy,* and substituted prose for verse. They generally chose the plays of Terence as models, yet their life is conventional and their types are not Portuguese but Roman-Italian. The revived classical comedy was artificial both in subject and style. Though it secured the favour of the humanists and the nobility, and banished the old popular plays from both court and university soon after Gil Vicente's death, its victory was short-lived. Jorge Ferreira de Vasconcellos, who produced in *Eufrosina* the first prose play, really belongs to the Spanish school, yet, though he wrote under the influence of the *Celestina,* which had a great vogue in Portugal, his types, language and general characteristics are deeply national. This and his other plays, *Ulisipo* and *Aulegraphia,* are novels in dialogue containing a treasury of popular lore and wise and witty sayings with a moral object. So decisive was the success of Jorge Ferreira's new invention, notwithstanding its anonymity, that it decided Sá de Miranda to attempt the prose comedy. He modelled himself on the Roman theatre as reflected by the plays of Ariosto, and he avowedly wrote the *Estrangeiros* to combat the school of Gil Vicente; in it, as in *Os Vilhalpandos,* the action takes place in Italy. Antonio Ferreira,

the chief dramatist of the classical school, attempted both comedy and tragedy, and his success in the latter is due to the fact that he was not content to seek inspiration from Seneca, as were most of the tragedians of the 16th century, but went straight to the fountain heads, Sophocles and Euripides. His *Bristo* is but a youthful essay, but his second piece, *O Cioso,* is almost a comedy of character, though both are Italian even in the names of the personages. Ferreira's real claim to distinction, however, rests on *Ines de Castro.* (*See* FERREIRA.)

Sixteenth-century History.—A pleiad of distinguished writers arose to narrate the discoveries and conquests in Asia, Africa and the ocean. Many of them saw the achievements they relate and were inspired by patriotism to record them, so that their writings gain in picturesqueness what they may lose in scientific value. In the four decades of his *Asia,* João de Barros, the Livy of his country, tells in simple vigorous language the "deeds achieved by the Portuguese." His first decade undoubtedly influenced Camoens, and together the two men fixed the Portuguese written tongue, the one by his prose, the other by his verse. The decades, which were continued by Diogo do Couto, a more critical writer and a clear and correct stylist, must be considered the noblest historical monument of the century. (*See* BARROS.) Couto is also responsible for some acute observations on the causes of Portuguese decadence in the East, entitled *Soldado practico.*

The word encyclopaedist fits Damião de Goes, a diplomatist, traveller, humanist and bosom friend of Erasmus. One of the most critical spirits of the age, his chronicle of King Manoel, the Fortunate Monarch, which he introduced by one of Prince John, afterwards King John II., is worthy of the subject. Goes (*q.v.*) wrote a number of other historical and descriptive works in Portuguese and Latin, some of which were printed during his residence in the Low Countries. After 20 years of investigation at Goa, Fernão Lopes de Castanheda issued his *Historia do descobrimento e conquista da India* (1552–54 and 1561), a book that ranks beside those of Barros and Couto. Antonio Galvão, who, after governing the Moluccas with rare success and integrity, had been offered the native throne of Ternate, went home in 1540, and died a pauper in a hospital. His brief *Tratado,* which appeared posthumously in 1563, is of unique historical value. Like the preceding writers, Gaspar Corrêa lived long years in India and embodied his intimate knowledge of its manners and customs in the picturesque prose of the *Lendas da India,* which embraces the events of the years 1497 to 1550. Among other historical works dealing with the East are the *Commentarios de Affonso d'Albuquerque,* an account of the life of the great captain and administrator, by his natural son, and the *Tratado das cousas da China e de Ormuz,* by Frei Gaspar da Cruz.

Coming back to strictly Portuguese history, we have the uncritical *Chronica de D. João III.* by Francisco de Andrade, and the *Chronica de D. Sebastião* by Frei Bernardo da Cruz, who was with the king at Al Kasr al Kebir, while Miguel Leitão de Andrade, who was taken prisoner in that battle, related his experiences and preserved many popular traditions and customs in his *Miscellanea.* The bishop Osorio, a scholar of European reputation, wrote chiefly in Latin, and his Chronicle of King Manoel, based on that of Goes, is in that tongue.

The books of travel of this century are unusually important, because their authors were often the first Europeans to visit or at least to study the countries they refer to. They include, to quote the more noteworthy, the *Descobrimento de Frolida,* the *Itinerario* of Antonio Tenreiro, the *Verdadeira informacão das terras do Preste Joam* by Francisco Alvares, and the *Ethiopia oriental* by Frei João dos Santos, both dealing with Abyssinia, the *Itinerario da terra santa* by Frei Pantaleão de Aveiro, and that much-translated classic, the *Historia da vida do padre Francisco Xavier* by Padre João de Lucena. Fernão Cardim, in his *Narrativa epistolar,* records a journey through Brazil, and Pedro Teixeira relates his experiences in Persia. But the work that holds the palm in its class is the *Peregrinação* which Fernão Mendes Pinto (*q.v.*), the famous adventurer, composed in his old age for his children's reading. The *Historia tragico-maritima,* a collection of 12 stories of notable wrecks which befell Portuguese ships between 1552 and 1604, contains that of the galleon "St. John" on the Natal coast, an event which inspired Corte-Real's epic poem as well as some poignant stanzas in *The Lusiads,* and the tales form a model of simple spontaneous popular writing.

Sixteenth-century Romances, etc.—The *Menina e moça* of Bernardim Ribeiro, a tender pastoral story inspired by *saudade,* probably moved Montemôr or Montemayor (*q.v.*) to write his *Diana.* To name the *Palmeirim de Inglaterra* of Moraes (*q.v.*) is to mention a famous book from which, we are told, Burke quoted in the House of Commons, while Cervantes declared that it ought to be guarded as carefully as the works of Homer. Its sequels, *D. Duardos* by Diogo Fernandes, and *D. Clarisel de Bretanha* by Goncalves Lobato, are inferior. The historian Barros tried his youthful pen in a romance of chivalry, the *Chronica do Imperador Clarimundo,* while in the Arthurian cycle the dramatist Ferreira de Vasconcellos wrote *Sagramor* or *Memorial das proesas da segunda Tavola Redonda.* A book of quite a different order is the *Contos de proveito e exemplo* by Fernandes Trancoso, containing a series of 29 tales derived from tradition or imitated from Boccaccio and others, which enjoyed favour for over a century.

Among the moralists of the time three at least deserve the title of masters of prose style, Heitor Pinto for his *Imagem da vida Christã,* Bishop Arraez for his *Dialogos,* and Frei Thomé de Jesus for his mystic and devotional treatise *Trabalhos de Jesus,* while the maxims of Joana da Gama, entitled *Ditos da Freira,* though lacking depth, form a curious psychological document. The ranks of scientists include the cosmographer Pedro Nunes (Nonius), a famous mathematician, and the botanist Garcia da Orta, whose *Coloquios dos simples e drogas* was the first book to be printed in the East (1563), while the form of Aristotelian scholastic philosophy known as *Philosophia coimbricensis* had a succession of learned exponents, who mainly used Latin, in which also Francisco Sanches wrote his notable treatise *Qvod nihil scitvr* (1581).

The 17th Century.—From a literary as from a political point of view the 17th century found Portugal in a lamentable state of decadence which dated from the preceding age. In 1536 the Inquisition began its work with the censorship of books and the Index, while between 1552 and 1555 the control of higher education passed into the hands of the Jesuits. Next the taint of Gongorism appeared, and the extent to which it affected the literature of Portugal may be seen in the five volumes of the *Fenix renascida,* where the very titles of the poems suffice to show the emphatic futilities which occupied the attention of some of the best talents. The prevailing European fashion of literary academies was not long in reaching Portugal, and 1647 saw the foundation of the *Academia dos Generosos,* which included in its ranks the men most illustrious by learning and social position, and in 1663, the *Academia dos Singulares* came into being. In bucolics there arose a worthy disciple of Ribeiro in Francisco Rodrigues Lobo (*q.v.*), author of *Corte na Aldeia* and the lengthy pastoral romance *Primavera,* the songs in which, with his eclogues, earned him the name of the Portuguese Theocritus. The foremost literary figure of the time was the encyclopaedic D. Francisco Manuel de Mello (*q.v.*), who, though himself a Spanish classic, strove hard and successfully to free himself from subservience to Spanish forms and style. Most of the remaining lyricists of the period were steeped in Gongorism or, writing in Spanish, have no place here. It suffices to mention Soror Violante do Céo, an exalted mystic called "the tenth muse"; Bernarda Ferreira de Lacerda, author of the *Soledades de Bussaco;* the *Laura do Anfrizo* of Manoel Tagarro, the *Sylvia de Lisardo* attributed to Frei Bernardo de Brito, and the poems of Frei Agostinho das Chagas, who, however, is better represented by his *Cartas espirituaes.* Satirical verse had two notable cultivators in D. Thomas de Noronha and Antonio Serrão de Castro, the first a natural and facile writer, the second the author of *Os Ratos da Inquisição,* a facetious poem composed during his incarceration in the dungeons of the Inquisition, while Diogo de Sousa Camacho satirised the slaves of Gongorism.

The gallery of epic poets is a large one, but most of their productions are little more than rhymed chronicles. These works include the *Ulyssea* of Gabriel Pereira de Castro; the *Ulysipo* of

Sousa de Macedo; the *Malaca conquistada* of Francisco de Sá de Meneses; Rodrigues Lobo's 20 cantos in honour of the Holy Constable; and the *Viriato tragico* of Garcia de Mascarenhas.

History, Oratory and Drama.—Frei Bernardo de Brito began his ponderous *Monarchia Lusitana* with the creation of man and ended it where he should have begun, with the coming of Count Henry to the Peninsula. His contribution is a mass of legends destitute of foundation or critical sense, but both here and in the *Chronica de Cister* he writes a good prose. Of the four continuers of Brito's work, three are no better than their master, but Frei Antonio Brandão, who dealt with the period from King Alphonso Henriques to King John II., proved himself a man of high intelligence and a learned, conscientious historian.

Frei Luis de Sousa, a typical monastic chronicler, although he had begun life as a soldier, worked up the materials collected by others, and after much *labor limae* produced the panegyrical *Vida de D. Frei Bartholemeu dos Martyres,* the *Historia de S. Domingos,* and the *Annaes d'el rei D. João III.* His style is excellent, but he lacks the critical sense. Manuel de Faria y Sousa (*q.v.*), a voluminous writer on Portuguese history and the commentator of Camoens, wrote in Spanish, and Mello's classic account of the Catalan War is also in that language, while in Portuguese Jacinto Freire de Andrade thought to picture and exalt the Cato-like viceroy of India by his grandiloquent *Vida de D. João de Castro.*

Other historical books of the period are the valuable *Discursos* of Severim de Faria, the *Portugal restaurado* of D. Luis de Meneses, conde de Ericeira, the ecclesiastical histories of Archbishop Rodrigo da Cunha, the *Agiologio lusitano* of Jorge Cardoso and the *Chronica da Companhia de Jesus* by Padre Balthazar Telles. The last also wrote an *Historia da Ethiopia,* and, though the travel literature of this century compares badly with that of the preceding, mention may be made of the *Itinerario da India por terra até a ilha de Chipre* of Frei Gaspar de S. Bernardino, and the *Relação do novo caminho através da Arabia e Syria* of Padre Manuel Godinho.

The Jesuit Antonio Vieira (*q.v.*), missionary, diplomat and voluminous writer, repeated the triumphs he had gained in Bahia and Lisbon in Rome, which proclaimed him the prince of Catholic orators. Vieira was a man of action, while the oratorian Manuel Bernardes lived as a recluse, hence his sermons and devotional works, especially *Luz e Calor* and the *Nova Floresta,* breathe a calm and sweetness alien to the other, while they are even richer treasures of pure Portuguese. Perhaps the most human documents of the century are the five epistles written by Marianna Alcoforado (*q.v.*), known to history as the *Letters of a Portuguese Nun.* Padre Ferreira de Almeida's translation of the Bible has considerable linguistic importance, and philological studies had an able exponent in Amaro de Roboredo.

The popular theatre lived on in the *Comedias de Cordel,* mostly anonymous and never printed; the popular *autos* that have survived are mainly religious, and show the abuse of metaphor and the conceits which derive from Gongora. All through this century Portuguese dramatists, who aspired to be heard, wrote, like Jacintho Cordeiro and Mattos Fragoso, in Castilian, though a brilliant exception appeared in the person of D. Francisco Manuel de Mello (*q.v.*), whose witty *Auto do fidalgo aprendiz* is eminently national in language, metre, subject and treatment. The court, after 1640, preferred Italian opera, French plays and *zarzuelas* to dramatic performances in the vernacular, with the result that both Portuguese authors and actors of repute disappeared.

The 18th Century.—In the first part of the 18th century bad taste tended to increase, but gradually signs appeared of a literary revolution, which preceded the political and developed into the Romantic movement. Men of liberal ideas went abroad to France and England, and to their exhortation and example are largely due the reforms which were by degrees inaugurated in every branch of letters. Their names were, among others, Alexandre de Gusmão, the Cavalheiro de Oliveira, Ribeiro Sanches, Corrêa de Serra, Brotero and Nascimento. They had a forerunner in Luiz Antonio Verney, who poured sarcasm on the prevailing methods of education in his *Verdadeiro methodo de estudar.*

From time to time literary societies, variously called academies or arcadias, arose to co-operate in the work of reform. In 1720 King John V., an imitator of Louis XIV., established the academy of history. The 15 volumes of its *Memorias,* published from 1721 to 1756, show the excellent work done by its members, among whom were Caetano de Sousa, author of the colossal *Historia da Casa Real portugueza;* Barbosa Machado, compiler of the invaluable *Bibliotheca Lusitana,* and Soares da Silva, chronicler of the reign of King John I.

The Royal Academy of Sciences, founded in 1780 by the 2nd duke of Lafões, produced a *Diccionario da lingua portugueza* and the *Memorias* (1788–95), and included in its ranks nearly all the learned men of the last part of the 18th century. Among them were the ecclesiastical historian Frei Manoel do Cenaculo, bishop of Beja; the polygraph Ribeiro dos Santos; Caetano do Amaral, a patient investigator of the origins of Portugal; João Pedro Ribeiro, the founder of modern historical studies; and the critics D. Francisco Alexandre Lobo, bishop of Vizeu; Cardinal Saraiva and Frei Fortunato de S. Boaventura.

The Arcadias.—In 1756 Cruz e Silva (*q.v.*), with the aid of friends, established the *Arcadia Ulysiponense.* Garção, the most prominent Arcadian, composed the *Cantata de Dido,* a gem of ancient art, as well as some charming sonnets to friends and elegant odes and epistles. The bucolic verse of Quita, a hairdresser, has a tenderness and simplicity which challenge comparison with Bernardim Ribeiro, and the *Marilia* of Gonzaga contains a celebrated collection of bucolic-erotic verse. Their conventionality sets the lyrics of Cruz e Silva on a lower plane, but in the *Hyssope* he improves on the *Lutrin* of Boileau. In 1790 a New Arcadia came into being. Its two most distinguished members were the rival poets Bocage (*q.v.*) and Agostinho de Macedo (*q.v.*). The only other poet of the New Arcadia who ranks high is Curvo Semedo; but the Dissidents, a name bestowed on those who stood outside the Arcadias, included two distinguished men now to be cited, the second of whom became the herald of a poetical revolution. No Portuguese satirist possessed such a complete equipment for his office as Nicolao Tolentino, and though a dependent position depressed his muse, he painted the customs and follies of the time with almost photographic accuracy, and distributed his attacks or begged for favours in sparkling verse. The task of purifying and enriching the language and restoring the cult of the Quinhentistas was perseveringly carried out by Francisco Manoel de Nascimento (*q.v.*). Shortly before his death in Paris he became a convert to the Romantic movement, and he prepared the way for its triumph in the person of Almeida Garrett, who belonged to the *Filintistas,* or followers of Nascimento, in opposition to the *Elmanistas,* or disciples of Bocage.

Early in the 18th century an attempt at the restoration of the drama by authors sprung from the people was made at the theatres of the Bairro Alto and Mouraria, and the numerous pieces staged there belong to low comedy. The *Operas portuguezas* of Antonio José da Silva (*q.v.*), produced between 1733 and 1741, owe their name to the fact that *arias, minuets* and *modinhas* were interspersed with the prose dialogue, and if neither the plots, style nor language are remarkable, they have a real comic force and a certain originality. Like Silva's operas, the comedies of Nicolao Luiz contain a faithful picture of contemporary society; but except in *Os Maridos Peraltas,* his characters are lifeless and their conventional passions are expressed in inflated language. Notwithstanding their demerits, however, his comedies held the stage from 1760 until the end of the century. Meanwhile the Arcadia also took up the task of raising the tone of the stage, but though the ancients and the classic writers of the 16th century were its ideals, it drew immediate inspiration from the contemporary French theatre. All its efforts failed, however, because its members lacked dramatic talents and, being out of touch with the people, could not create a national drama. Garção (*see* Correa Garção, Pedro Antonio Joaquim) led the way with the *Theatro Novo,* a comedy in blank verse, and followed it up with another, *Assemblêa ou partida;* but he did not persevere. Figueiredo felt he had a mission to restore the drama, and wrote 13 volumes of plays in prose and verse, but, though he chose national subjects, and could invent plots and draw characters, he could not make them live.

Finally, the bucolic poet Quita produced the tragedies *Segunda Castro, Hermione* and two others, but these imitations of the French were still-born.

The 19th Century and After.—The 19th century witnessed a general revival of letters, beginning with the Romantic movement, of which the chief exponents were Garrett (*q.v.*) and Herculano (*q.v.*), both of whom had to leave Portugal on account of their political liberalism, and it was inaugurated in the field of poetry. Garrett read the masterpieces of contemporary foreign literature during his exiles in England and France, and, imbued with the national spirit, he produced in 1825 the poem *Camões*. His poetry, like that of his fellow *émigré*, the austere Herculano, is eminently sincere and natural, but while his short lyrics are personal in subject and his longer poems historical, the verse of Herculano is generally religious or patriotic. The movement not only lost much of its virility and genuineness, but became ultra-romantic with A. F. de Castilho (*q.v.*), whose most conspicuous followers were João de Lemos and the poets of the collection entitled *O Trovador;* Soares de Passos, a singer for the sad; the melodious Thomas Ribeiro, who drew his inspiration from Zorrilla and voiced the opposition to a political union with Spain in the patriotic poem *D. Jayme*. Mendes Leal, a king in the heroic style, Gomes de Amorim and Bulhão Pato, belong more or less to the same school. On the other hand José Simões Dias successfully sought inspiration from popular sources in his *Peninsulares* (1870).

In 1865 the revolt of the younger men of letters against the primacy of Castilho took the form of a fierce war of pamphlets. The leaders in the movement were Anthero de Quental (*q.v.*) and Theophilo Braga, the first a student of German philosophy and poetry, the second a disciple of Comte and author of an epic of humanity, *Visão dos tempos,* whose immense work in the spheres of poetry, criticism and literary history cannot be judged at present. In the issue literature gained considerably, and especially poetry, which entered on a period of active and rich production. The *Campo de flores* of João de Deus (*q.v.*) contains some of the most splendid short poems ever written in Portuguese. Simplicity, spontaneity and harmony distinguished his earlier verses, which are also his best. Anthero de Quental, the chief of the Coimbrans, enshrined his metaphysical neo-Buddhistic ideas, overshadowed by extreme pessimism, and marked the stages of his mental evolution, in a sequence of finely-wrought sonnets. These place him in the sacred circle near to Heine and Leopardi, and though strongly individualistic, it is curious to note in them the influence of Germanism on the mind of a southerner. *Odes modernas,* written in youth, show him in revolutionary, free-thinking and combative mood, but the prose of his essays, *e.g., Considerations on the Philosophy of Portuguese Literary History,* has that peculiar refinement, clearness and conciseness which stamped the later work of this sensitive thinker. A subtle irony pervades the *Rimas* of João Penha, who links the Coimbrans with Guerra Junqueiro and the younger poets. Partly philosophical, partly naturalistic, Junqueiro began with the ironical composition, *A Morte de D. João;* in *Patria* he evoked in a series of dramatic scenes and lashed with satire the kings of the Braganza dynasty; and in *Os Simples* (1892) he interprets in sonorous stanzas the life of country-folk by the light of his powerful imagination and pantheistic tendencies. His last poems appeared in *Poesias Dispersas* (1921). The *Claridades de Sul* of Gomes Leal, a militant anti-Christian, at times recall Baudelaire, and flashes of genius run through *Anti-Christo,* which is alive with the instinct of revolt. The *Só* of Antonio Nobre is intensely Portuguese in subjects, atmosphere and rhythmic sweetness, and had a deep influence. Cesario Verde sought to interpret universal nature and human sorrow, and the Parnassian Gonçalves Crespo may be termed a deeper, richer Coppée. His *Miniaturas* and *Nocturnos* have been re-edited by his widow, D. Maria Amalia Vaz de Carvalho, a highly gifted critic and essayist whose personality and *cercle* call to mind the 18th-century poetess, the Marqueza de Alorna. The French symbolists found an enthusiastic adept in Eugenio de Castro, who adopted a more natural and national manner in later works, such as *Canções desta negra vida* (1922) and *Chamas de uma candeia velha* (1925), and after the death of Junqueiro stood at the head of Portuguese poets. Antonio Feijó and José de Sousa Monteiro have written verse remarkable by its form. The most admired of the younger poets of this period, Antonio Corrêa de Oliveira, draws inspiration from the soil and religion, as in the *Auto das Quatro Estações* (1911) and *Pão nosso, Vinho alegre, Azeite de candeia* (1922). *A Minha terra* (1916) contains some true poetry and technical skill.

The best known books of Augusto Gil are *Sombra de Juno* (1915) and *Alba Plena* (1916). Teixeira de Pascoaes, a sincere but nebulous pantheist, the inventor of what is called *saudosismo,* is distinguished by love of nature, but he pays too little attention to form, though his verse has a music of its own. Affonso Lopes Vieira, a writer of exquisite taste and sense of rhythm, translated the traditions of the race and the poetry of the sea in *Ilhas de Bruma* (1918) and produced *rifacimentos* of two works of world fame in his *Amadis* and *Diana,* marked by rare artistry and understanding of the originals. The last publication of the Republican politician João de Barros, prolific in verse and prose, is a poem *Sisifo,* in which he treats the classical legend in a novel way.

The Drama.—Garrett took in hand the reform of the stage, moved by a desire to exile the translations on which the playhouses had long subsisted. He chose his subjects from the national history, began with the *Auto de Gil Vicente,* and followed this up with other prose plays, among which the *Alfageme de Santarem* takes the palm; finally, he crowned his labours by *Frei Luiz de Sousa,* a tragedy of fatality and pathos, and one of the really notable pieces of the century. The historical bent thus given to the drama was continued by the versatile Mendes Leal, by Gomes da Amorim and by Pinheiro Chagas, who all, however, succumbed more or less to the atmosphere and machinery of ultra-Romanticism, while the plays of Antonio Ennes deal with questions of the day in a spirit of combative liberalism. In the social drama, Ernesto Biester, and in comedy Fernando Caldeira, also no mean lyric poet, are two of the principal names, and the latter's pieces, *A Mantilha da Renda* and *A Madrugada,* have a delicacy and vivacity which justifies their success. The comedies of Gervasio Lobato are marked by an easy dialogue and a sparkling wit, and some of the most popular of them were written in collaboration with D. João de Camara, the leading dramatist of the day, one of whose pieces, *Os Velhos,* was translated and staged abroad. To Henrique Lopes de Mendonça, scholar, critic and poet, we owe some strong historical plays, as well as several stirring tales of old Portugal. Dr. Marcellino Mesquita is the author of *Leonor Teles* and other historical dramas, as well as of a powerful piece, *Dôr suprema.* Julio Dantas wrote many plays remarkable for their pliant style and delicate reconstruction of the past, such as *A Severa* (1901), *Rosas de todo o anno* (1907) and *Mariana* (1915). Among other pieces may be mentioned *O herdeiro* and *Entre Giestas* of Carlos Selvagem, a talented prose writer, *D. João e a mascara* (1924) and the lyrical play *Diniz e Isabel* (1919) of Antonio Patricio, *O Gebo e a Sombra* (1923), a tragedy of unrelieved gloom and considerable power by Raul Brandão, and *Egas Moniz* (1918) by Dr. Jaime Cortesão.

The Novel.—Herculano led the way in the historical romance by his *Lendas e narrativas* and *O Monasticon,* two somewhat laboured productions, whose progenitor was Walter Scott; they still find readers for their impeccable style. Their most popular successors have been *A Moçidade de D. João V.* and *A ultima corrida de touros reaes em Salvaterra* by Rebello da Silva, and *Um Anno na Corte* by the statesman, Andrade Corvo. The novel shares with poetry the predominant place in the modern literature of Portugal, and Camillo Castello Branco (*q.v.*), Gomes Coelho and Eça de Queiroz are names which would stand high in any country. The first, a wonderful impressionist though not perhaps a great novelist, describes to perfection the domestic and social life of Portugal in the early part of the 19th century. His remarkable works include *Amor de Perdição, Amor de Salvação,* and the series entitled *Novelas do Minho.* Gomes Coelho, better known as *Julio Diniz,* records his experiences of English society in Oporto in *A Familia ingleza.* Portuguese critics have accused him of imitating Dickens. His stories, particularly *As Pupillas do Snr. Reitor,* depict country life and scenery with loving sympathy, and hold the

reader by the charm of the characters, but Diniz is a rather subjective monotonous writer and he is no psychologist. Eça de Queiroz (*q.v.*) founded the Naturalist school in Portugal by a powerful book written in 1871, but only published in 1875, under the title *The Crime of Father Amaro;* and two of his great romances, *Cousin Basil* and *Os Maias,* were written during his occupancy of consular posts in England. *The Relic* conveys the impressions of a journey in Palestine and in parts suggests his indebtedness to Flaubert, but its mysticism is entirely new and individual; while the versatility of his talent further appears in *The Correspondence of Fradique Mendes,* where acute observation is combined with brilliant satire or rich humour. The later portion of *The City and the Mountains,* in the truth and beauty of its descriptive passages shows him as a more regional writer. Among other novelists are Oliveira Marreca, Pinheiro Chagas, Arnaldo Gama and Luis de Magalhães.

Constant political unrest has been prejudicial to letters in a small country without a numerous leisured class, and no distinguished literary figure arose during the years 1910–25, but even before 1910 a reaction had begun against revolutionary methods in politics and laxity or agnosticism in religion, which may lead to a healthier national life. This movement showed itself in the later works of Eça de Queiroz, and in the return to the church of the prose writer Ramalho Ortigão and of the poet Guerra Junqueiro. It is not only found in the writers of the Integralist school (a Portuguese counterpart to the *Action française*); most of the leading poets and prose writers are once more declared Catholics, and they have gone back to the people for inspiration, with happy results. Nationalism and regionalism have taken the place of naturalism and symbolism, which were copied from France and never commended themselves to Portuguese feeling as a whole. The inability of 60% of the country-dwellers to read, saved many of them from losing their ideals and character during the period when a Liberal, destructive and anti-religious atmosphere permeated newspapers and books.

The new manner is seen especially in the novel, though it did not touch the austere Republican and conscientious analyst of middle-class society Teixeira de Queiroz (d. 1919). Following in the steps of Oliveira Martins, Anthero de Figueiredo has sought to combine history and art in *D. Pedro e D. Ines* (1913), *Leonor Teles* (1916), and *D. Sebastião* (1924), where he revives the figure of the last crusading king, and paints a picture of the times with abundant imagination. His *Espanha* (1923), *Jornadas em Portugal* (1918) and *Senhora do Amparo* (1920) are regional works, in a glowing style, which in the second suffers from over-elaboration.

The lack of a sound classical education is too evident in modern Portuguese prose, and few dare to attempt the straightforward narrative, sparing of adjectives and uncommon words, which is the chief attraction of the classics. Raul Brandão is an exception; his *Pescadores* (1924) tells of fisher folk and the tragedy of the ocean with poignant realism, and contains magnificent descriptions of the coast scenery. The book is worthy of the author of *Os Pobres* (1921). The trilogy of Manoel Ribeiro, *A Catedral,* probably suggested by Huysmans, *O Deserto* and *A Resurreição,* constitute a remarkable performance in subject and atmosphere, without precedent in modern Portuguese, and its popularity is not less remarkable. No better proof could be adduced of the changed times than these "clerical" books by a man of far from clerical ideas. At the close of this period he initiated a new trilogy with *A Colina Sagrada* (1926) and *A Planicie Heroica* (1927). The naturalism of Eça de Queiroz found a fresh interpreter in Aquilino Ribeiro, a novelist highly considered throughout the Peninsula. He is possessed of a rich vocabulary, and no one can create characters or picture one side of country life so faithfully as he has done in *A Via Sinuosa* (1918). In 1925 he produced *Filhas de Babilonia,* an unpleasant book, and *Estrada de Santiago.* The voluminous João Grave added *Gente Pobre* (1912), *Parsifal* and *A vida e Paixão da Infanta* to his list of romances. A brilliant satire on contemporary political events is to be found in *Saude e Fraternidade* by Campos Monteiro.

History.—Years of persevering toil in archives and editions of old chronicles prepared Herculano for his *magnum opus,* the *Historia de Portugal.* The *Historia da Origem e Estabelecimento da Inquisição em Portugal* followed and confirmed the position of its author as the leading modern historian of the Peninsula, and he further initiated and edited the important series *Portugaliae Monumenta historica.* The Visconde de Santarem, and Judice Biker in geography and diplomatics, produced standard works; Luz Soriano compiled painstaking histories of the reign of King Joseph and of the Peninsular War; Silvestre Ribeiro printed a learned account of the scientific, literary and artistic establishments of Portugal, and Lieut.-Col. Christovam Ayres was the author of a history of the Portuguese army. Rebello da Silva and the voluminous and brilliant publicists, Latino Coelho and Pinheiro Chagas, wrote at second-hand and rank higher as stylists than as historians. Gama Barros (1833–1925) and Costa Lobo followed closely in the footsteps of Herculano, the first by a *Historia da Administração publica em Portugal nos Seculos XII. a XV.,* positively packed with learning, the second by a *Historia da Sociedade em Portugal no Seculo XV.* Though he had no time for original research, Oliveira Martins (*q.v.*) possessed psychological imagination, a rare capacity for general ideas, and the gift of picturesque narration; and in his philosophic *Historia de Portugal,* his sensational *Portugal contemporaneo, Os Filhos de D. João* and *Vida de Nun' Alvarez,* he painted an admirable series of portraits, and, following his master Michelet, made the past live again. Prof. Fortunato de Almeida's *Historia de Portugal* marks a great advance on its predecessors. The same scholar published in four stout volumes a *Historia da Igreja em Portugal* (1910, etc.), equally well documented. J. Lucio d'Azevedo, the authority on Pombal, produced an excellent biography of the 17th century missionary, preacher and diplomat, Antonio Vieira, S. J., and the first volume of his *Cartas* appeared in 1925. D'Azevedo's most notable book is the *Historia dos Christãos novos portugueses* (1922). The same editors published (1912–27) the Lisbon parochial Registers of the 16th century. The statesman João Franco, last minister of King Carlos, issued a number of autograph letters received by him from the King shortly before his tragic death. Affonso de Dornellas in genealogy and history and Antonio Ferrão in the latter have done considerable work.

The Conde de Sabugosa, Lord Chamberlain under the monarchy, published (1912–24) five volumes of historical studies marked by critical ability, imagination and a sense of humour. His most substantial work is *A Rainha D. Leonor* (1921). The Visconde de Santarem printed the correspondence and re-issued some of the geographical and historical works of his famous namesake, including the *Historia e Theoria das Cortes Geraes* (1924). The Integralist leader Antonio Sardinha (d. 1925) left several volumes of essays and poetry. Dr. M. Gonçalves Cerejeira made his name by a work on the Renaissance with versions of the letters of the humanist Cleynaerts. Braamcamp Freire (1849–1921), the historian, was joint editor with D. Carolina Michaëlis de Vasconcellos (1851–1925) of the works of Bernardim Ribeiro and Christovam Falcão. This great Romance scholar issued the 4th of her illuminating *Notas Vicentinas* in 1922. (E. P.; A. B.)

BIBLIOGRAPHY.—The chief works of a bibliographical character are the *Bibliotheca Lusitana* of Barbosa Machado and Innocencio da Silva's *Diccionario Bibliographico Portuguez,* continued by Brito Aranha. A smaller work is the *Manual Bibliographico* (1878) by Pinto de Mattos. Dr. Fidelino de Figueiredo's *A Critica Litteraria como Sciencia,* in its 3rd ed. (1920) contains an elaborate bibliography; and in 1922 the Hispanic Society of America published a concise *Portuguese Bibliography.* The *Catalogo Razonado* (1890) of Garcia Peres, and Figanière's *Catalogo dos Manuscriptos portuguezes no Museu Britannico* (1853) contain invaluable information. The general histories are those of Theophilo Braga, in many separate volumes, with a summary in four (1909–18); *Geschichte der Portugiesischen Literatur* (1894) by Carolina Michaëlis de Vasconcellos in Gröber's *Grundriss;* and three volumes (1912–25) by Dr. Fidelino de Figueiredo, who deals more fully with the modern literature in his *Historia de la Literatura Portuguesa* (Barcelona, 1927). In 1922 the Clarendon Press published the first complete history of *Portuguese Literature* in English (by Mr. A. F. G. Bell). Mr. Edgar Prestage's earlier valuable criticism is dispersed over various publications. Dr. Mendes dos Remedios's compendious *Historia da Literatura Portuguesa* attained a fifth edition in 1921.

Portuguese texts are still deficient as a whole, although much valuable work has been done, in articles and editions, by C. Michaëlis

de Vasconcellos, as in her edition of the *Cancioneiro da Ajuda* (2 vols., 1904); E. Prestage, J. Leite de Vasconcellos, J. J. Nunes (in *Chrestomathia Archaica*, 1905, and many early texts), Col. Esteves Pereira, and A. Braamcamp Freire. Some of the Latin texts of Portuguese humanists have been made accessible, and their poetry was published in *Corpus illustrium poetarum lusitanorum qui latine scripserunt* (1745–48). The *Parnasso Lusitano*, in 6 vols. (1826), and Costa e Silva's *Ensaio Biographico-critico* (10 vols. 1850–55) have been supplemented and superseded by Dr. Agostinho de Campo's *Antologia Portuguesa*. Bouterwek's history, translated into English in 1823, is similarly out of date. No weekly or monthly literary journal exists, but the *Revista Lusitana*, *Lusitania* and the *Boletim* of the Academy of Sciences are published at irregular intervals.

PORTUGUESE MAN-OF-WAR (*Physalia*), a colonial jellyfish, one of the most beautiful of the pelagic group Siphonophora, found in warm seas; it is occasionally drifted as far as the British coasts by the Gulf stream. Its sting is exceedingly powerful and may have serious results. (*See* HYDROZOA.)

PORTUNUS, in Roman cult, originally the god of gates and doors (Lat. *porta*), and as such connected with Janus. Gradually he was transformed into the protector of harbours (*portus*) and ensured a safe return to seafarers. (Cicero, *Nat. deor.* ii. 26; Virgil, *Aen.* v. 241.) With the introduction of the Greek gods, he became merged with Palaemon-Melicertes. He had a special priest (*flamen portunalis*) and temples on the Tiber near the Aemilian bridge and near Ostia, where a festival was celebrated in his honour on Aug. 17. (*See* G. Wissowa, *Rel. u. Kultus der Römer*, pp. 111–112.)

PORTUS, an ancient harbour of Latium, Italy, on the right bank of the Tiber, at its mouth. For its origin *see* OSTIA. Claudius constructed the first harbour here, 2½ m. north of Ostia, enclosing an area of 170 acres, with two long curving moles projecting into the sea, and an artificial island, bearing a lighthouse, in the centre of the space between them; the harbour thus opened directly to the sea on the north-west and communicated with the Tiber by a channel on the south-east. The object was to obtain protection from the prevalent south-west wind, to which the river mouth was exposed. Though Claudius, in the inscription which he caused to be erected in A.D. 46, boasted that he had freed the city of Rome from the danger of inundation, his work was only partially successful. The Via Portuensis (15 m.) ran over the hills as far as the modern Ponte Galera, and then straight across the plain. An older road, the Via Campana, ran along the right bank of the Tiber. In A.D. 103 Trajan constructed another harbour still well preserved farther inland—a hexagonal basin enclosing an area of 97 acres. It communicated with the harbour of Claudius and with the canal constructed by him (though it bears the name Fossa Trajana) now forming the navigable arm of the Tiber (reopened for traffic by Gregory XIII. and again by Paul V.). It was surrounded by extensive warehouses, remains of which may still be seen: the fineness of the brickwork of which they are built is remarkable. The perforated travertine blocks to which the ships were made fast may still be seen. Farther to the east is a circular building in brick with niches called the temple of Portumnus.

Portus eventually captured the main share of the harbour traffic of Rome, and though the importance of Ostia did not at once decrease we find Portus already an episcopal see in Constantine's time not very long after Ostia, and the only harbour in the time of the Gothic wars. Its abandonment dates from the partial silting up of the right arm of the Tiber in the middle ages, which restored to Ostia what little traffic was left. To the west of the harbour is the cathedral of S. Rufina (10th century, but modernized except for the campanile) and the episcopal palace, fortified in the middle ages, and containing a number of ancient inscriptions from the site. On the island (Isola Sacra) just opposite is the church of S. Ippolito, built on the site of a Roman building, with a picturesque 13th century campanile; 2 m. to the west is the modern village of Fiumicino at the mouth of the right arm of the Tiber, 21 m. west-south-west by rail from Rome. It is a portion of the commune of Rome. Three miles to the north is the pumping station by which the lowland (formerly called Stagno di Maccarese, now reclaimed and traversed by many drainage canals) is kept drained (Bonifica di Maccarese).

PORT WINE is a rich, fruity, heavy-bodied sweet wine of the dessert class, usually deep red but sometimes tawny or white in colour. It has numberless variants throughout the world, depending on the varieties of grapes used, the manner of production, the time of bottling and the extent of aging.

Port was developed under English auspices in Portugal. In a treaty of 1703 the British gave preferential duty to Portuguese wines in exchange for free entry into Portugal of English woollens. The wines initially imported from Portugal were found too harsh and sharp to prove popular; but English wine merchants at Oporto discovered that by adding grape brandy before all the grape sugar had fermented out they could please the British taste with a wine that was sweeter. Thenceforth the English drank port increasingly; they sold it throughout the world.

Wine-growers in countries other than Portugal produce ports, stating on their labels the place of origin, but the United Kingdom under a treaty of 1916 with Portugal declines to admit any wine as port except that produced on certain quintas, or acreages in a 30 by 60-mile region of Portugal's upper Douro basin and shipped over the bar of Oporto; that is, from Oporto or its sister port of Vila Nova de Gaia.

In the terraced region thus recognized by the English about 70 grape varieties are cultivated, some because they yield wines of body and character, others because, when blended with these, they impart a deepness of tint which the English like in red ports. Generally 10 to 15 varieties are blended after picking. Fermentation is arrested, when the grapes still retain the desired amount of sweetness, by straining the juice and siphoning it into vats containing some grape brandy.

In the spring the new wines are borne in pipes by sailboat to shippers' lodges at the mouth of the Douro. Testers there decide whether the year's wine is good enough to be a "vintage Port," the highest type. If so, a portion is kept separate, allowed to age about two years in cask and then sent abroad, in most cases to England, for bottling and further aging.

Other ports are marketed as "crusted," "ruby" and "tawny." The last two are blends matured in wood, often as many as 30 ports together; the "tawny" is aged the longer, and as it is repeatedly clarified to remove sediment, it loses some of its red colour. Sometimes the designation "tawny" is applied to ports that owe their lightness of colour to the fact that they were produced from grapes not rich in tint. (*See* WINE.)

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PORUS (4th century B.C.), an Indian prince, ruler of the country between the rivers Hydaspes and Acesines at the time of the invasion of Alexander the Great. In the battle on the banks of the Hydaspes he offered a desperate resistance, and Alexander, struck by his independent spirit, allowed him to retain his kingdom, which he increased by the addition of territory. From this time Porus was a loyal supporter of Alexander. He still held the position of a Macedonian satrap when assassinated some time between 321 and 315 B.C.

See Arrian v. 18, 19; Plutarch, *Alexander*, 60; Quintus Curtius viii. 14.

PORVOO (Swed. *Borgå*), a seaport in the province of Nyland, republic of Finland, situated at the entrance of the river Borgå into the Gulf of Finland, about 33 mi. E.N.E. of Helsinki by rail. Pop. (1940) 7,541. It is the seat of a Lutheran bishopric which extends over the provinces of Viipuri and St. Michel with portions of Tavastehus and Nyland; it possesses a beautiful cathedral and a high school, and is the seat of a court of appeal. Once a city of great dignity, the rapid growth of Helsinki has eclipsed it. In 1809, when the estates of Finland were summoned to a special diet to decide the future of the country, Porvoo was the place of meeting, and it was in the cathedral that the Tsar Alexander I pledged himself as grand duke of Finland to maintain the constitution of the grand duchy.

POSEIDON, in Greek mythology, god of the sea and of water generally, son of Cronus and Rhea, and brother of Zeus and Pluto (perhaps "lord of moisture"; *see* Carnoy in *Musée Belge,* xxviii. p. 175 or connected with πόσις drink, ποταμός a river). When the three brothers deposed their father, Cronus, the kingdom of the sea fell by lot to Poseidon. His home was in a golden palace in the depths of the sea near Aegae in Achaea. In his hand he bore a trident, wherewith he lashed the sea into fury, split the rocks, and caused horses and fountains to spring from them. But, while he caused storms and shipwrecks, he could also send favouring winds; hence he was known as *Sōtēr,* "the preserver." Another of his titles was *Gaieochos,* "holder (*i.e.,* encircler?) of earth." He was the god of navigation and his temples stood especially on headlands and isthmuses. Every occupation connected with the sea was under his protection, and seafaring people, especially the Ionians, regarded themselves as his descendants. As god of the sea he disputed with other deities for the possession of the land. Earthquakes were thought to be produced by Poseidon shaking the earth—hence his epithet of *enosichthon,* "earth-shaker"—and hence he was worshipped even in inland places which had suffered from earthquakes. Several striking seismic and other phenomena in historical times were attributed to him. Poseidon was also the god of springs, which he produced by striking the rock with his trident, as he did on the acropolis of Athens when disputing with Athena for the sovereignty of Athens (Herodotus viii. 55; Apollodorus iii. 14). As such he was called *Nymphagetes,* the leader of the nymphs of springs and fountains, a god of fresh water, probably his original character, and in this connection was φυτάλμιος, a god of vegetation, frequently associated with Demeter. At Athens, he is closely associated with Erechtheus (*q.v.*), with whom many identify him. As he gave, so he could withhold, springs of water; thus the waterless neighbourhood of Argos was supposed to be the result of his anger. Black bulls were sacrificed to him and often thrown alive into rivers; in Ionia and Thessaly bull-fights took place in his honour; at a festival of his at Ephesus the cupbearers were called "bulls," and the god himself was surnamed "Bull Poseidon." The horse was especially associated with his worship. Several legends represent him as creating the first horse; horses were occasionally sacrificed to him; and he is called *Hippios* ("lord of steeds"). In the deme of Colonus he was worshipped with Athena, the reputed inventor of the bridle. Various explanations of the title ἵππιος have been given: (1) that the horse represented the corn-spirit; (2) the resemblance of the crested waves to horses; (3) the impression of horses' hoofs near the god's sacred springs, and the shaking of the earth by them when galloping (*see* Farnell, *Cults of the Greek States,* iv. 20). In the Trojan War he takes the side of the Greeks, because he had been cheated of his reward by Laomedon, king of Troy, for whom he had built the walls of the city. The blinding of his son Polyphemus by Odysseus brings upon the hero the wrath of Poseidon. He is famous for his numerous amours; his offspring were mostly wild and cruel, like the sea—the Laestrygones, Polyphemus, Antaeus, Procrustes, and the like. He was worshipped as a national god by the Ionians, who took his worship over with them from Peloponnesus to Asia Minor. His chief sanctuary was at Mycale, where the Panionia, the national festival of the Ionians, was held. Other seats of his worship were in Thessaly, Boeotia (*see* Farnell, p. 29 ff.) and Peloponnesus. At Taenarum in Laconia he had a famous cave-like temple with an asylum, and on the island of Tenos he was worshipped as the *physician,* probably in reference to the health-giving properties of the sea air. By far the most famous of his festivals was that celebrated every alternate year on the isthmus of Corinth, at which the "Isthmian games" were held. The horse, the dolphin (the symbol of the calm sea) and the pine-tree, with wreaths of which the Isthmian victors were crowned, were sacred to him. His attributes are the trident and dolphin or tunny fish.

As represented in art, Poseidon resembles Zeus, but possesses less of his majestic calm. In modern Greece St. Nicholas has taken the place of Poseidon as patron of sailors. But the Zacynthians have a special sea god, half man, half fish, who dwells under the sea, rides on dolphins or in a car drawn by dolphins, and wields a trident. By the Romans Poseidon was identified with Neptune (*q.v.*).

See Preller-Robert, *Griechische Mythologie,* i. 566 ff. (1894); O. Gruppe, *Griechische Mythologie,* vol. ii. (1906); and especially L. R. Farnell, *Cults of the Greek States,* vol. iv. (1907).

POSEIDONIUS (130?–50 B.C.), nicknamed "the Athlete," Stoic philosopher, the most learned man of his time and perhaps of all the school. A native of Apameia in Syria and a pupil of Panaetius, he spent many years in travel and scientific researches in Spain (particularly at Gades), Africa, Italy, Gaul, Liguria, Sicily and on the eastern shores of the Adriatic. When he settled as a teacher at Rhodes his fame attracted numerous scholars; next to Panaetius he did most, by writings and personal intercourse, to spread Stoicism in the Roman world, and he became well known to many leading men, such as Marius, Rutilius Rufus, Pompey and Cicero. The last-named studied under him (78–77) B.C.), and speaks as his friend.

The titles and subjects of more than twenty of his works, now lost, are known. In common with other Stoics of the middle period, he displayed eclectic tendencies, following the older Stoics, Panaetius, Plato and Aristotle. Unquestionably more of a polymath than a philosopher, he appears uncritical and superficial. But at the time his spirit of inquiry provoked Strabo's criticism as something alien to the school (τὸ αἰτιολογικὸν καὶ τὸ ἀριστοτέλιζον, ὅπερ ἐκκλίνουσιν οἱ ἠμέτεροι). In natural science, geography, natural history, mathematics and astronomy he took a genuine interest. He sought to determine the distance and magnitude of the sun, to calculate the diameter of the earth and the influence of the moon on the tides. His history of the period 146–88 B.C., in 52 books, must have been a valuable storehouse. Cicero made much use of his writings.

See Zeller, *Philosophie der Griechen,* iii. (in Eng. trans., *Eclecticism,* 56–70); C. Müller, *Fragmenta historicorum graecorum,* iii.; J. Blake, *Posidonii Rhodii reliquiae* (Leiden, 1810); R. Scheppig, *De Posidonio rerum gentium terrarum scriptore* (Berlin, 1869); R. Hirzel, *Untersuchungen zu Ciceros philosophischen Schriften,* i.–iii. (Leipzig, 1877); Thiaucourt, *Essai sur les traités philosophiques de Cicéron* (1885); Arnold, *Untersuchungen über Theophanes von Mytilene und Posidonius von Apamea* (1882); Schmekel, *Die Philosophie der mittlern Stoa* (1892); I. Heinemann, *Poseidonios' metaphysische Schriften* (Breslau, 1921); K. Reinhardt, *Poseidonios* (Munich, 1921) and *Kosmos u. Sympathie, Neue Untersuchungen über Poseidonios* (Munich, 1926) and P. Schubert, *Die Eschatologie des Posidonius* (Leipzig, 1927). Full bibliography in Überweg, *Grundriss der Gesch. der Philosophie,* Bd. I. (1926). *See* also STOICS.

POSEN: *see* POZNAN.

POSIDIPPUS (3rd cent. B.C.), Greek dramatist, of Cassandrea in Macedonia, the last and one of the most distinguished of the writers of the new comedy. He began to write for the stage in 289 B.C., and, according to Suïdas, wrote 40 plays, of which 17 titles and some fragments have been preserved. His comedies were frequently imitated by the Romans (Aulus Gellius ii. 23), and it is considered very probable that the *Menaechmi* (a comedy of errors) of Plautus is an adaptation from him. His statue in the Vatican is considered a masterpiece of ancient art.

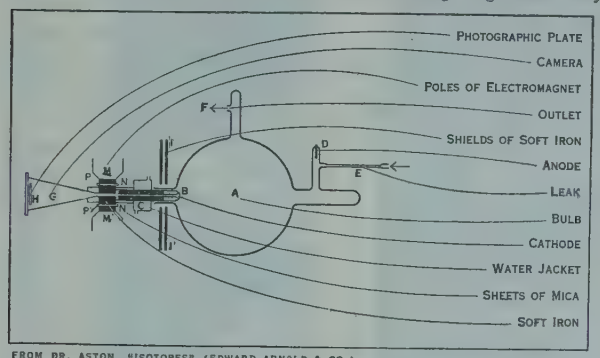
Fragments in A. Meineke, *Poet. comic. graec. fragmenta* (1855).

POSITION ANALYSIS: *see* ANALYSIS SITUS.

POSITIVE (or PORTABLE) **ORGAN,** a mediaeval chamber organ which could be carried from place to place, and when played was placed on a table or stool and required a blower for the bellows, as well as a performer. It was larger and more cumbersome than the portative organ (*q.v.*).

POSITIVE RAYS. In 1886 Goldstein while experimenting with the discharge in gases at low pressures observed luminous streamers passing through perforations in the cathode and illuminating the gas behind it. The luminosity, he assumed, was due to rays of some sort which travelled in the opposite direction to the cathode rays (*q.v.*) and so passed through the aperture in the cathode. On account of the method by which they were obtained he called them "Canalstrahlen." Subsequently Wien showed that they could be deflected by means of a magnetic field. They were very fully investigated by Sir Joseph J. Thomson who called them "Positive Rays" on account of the fact that normally they are positively electrified. Recently they have been included in the

general term "Mass Rays" which covers all swiftly moving particles of matter of atomic or molecular size whether charged electrically or not. The rays may be developed in many different ways, the most general being ionization of a gas at low pressure in a strong electric field. Ionization, which may be due to collision or radiation, means in its simplest case the detachment of one electron from a neutral atom. The two resulting fragments carry



FROM DR. ASTON, "ISOTOPES" (EDWARD ARNOLD & CO.)

FIG. 1.—APPARATUS FOR THOMSON'S "PARABOLA" METHOD OF POSITIVE RAY ANALYSIS, SHOWING PARTS

charges of electricity of equal quantity but of opposite sign. The negatively charged portion is the electron, the atomic unit of negative electricity itself, and is the same whatever the atom ionized. It is extremely light and therefore in the strong electric field rapidly attains a high velocity and becomes a cathode ray. The remaining fragment is clearly dependent on the nature of the atom ionized. It is immensely more massive than the electron, for the mass of the lightest atom, that of hydrogen, is about 1,845 times that of the electron, and so will attain a much lower velocity under the action of the electric field. However, if the field is strong and the pressure so low that it does not collide with other atoms too frequently it will ultimately attain a high speed in a direction opposite to that of the detached electron, and become a "positive ray." The simplest form of positive ray is, therefore, an atom of matter carrying a positive charge and endowed, as a result of falling through a high potential, with sufficient energy to make its presence detectable. Positive rays can be formed from molecules as well as atoms, so that it will at once be seen that any measurement of their mass will give us direct information as to the masses of atoms of elements and molecules of compounds, and that this information will refer to the atoms and molecules individually, not, as in chemistry, to the mean of an immense aggregate. It is on this account that accurate analysis of positive rays is of such fundamental importance in research on the structure of atoms.

For visual effects the rays are best detected by a screen made of powdered willemite, which glows a faint green when bombarded by them. When permanent effects are required this screen is replaced by a photographic plate. The sensitivity of the plate to positive rays bears no particular relation to its sensitivity to light; so far the best results have been obtained from comparatively slow process plates of the type known as "Half Tone."

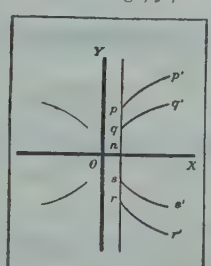
Thomson's "Parabola" Method of Analysis.—The method by which Sir J. J. Thomson investigated the properties of positive rays, and which still remains pre-eminent in respect to the variety of information it supplies, consists essentially in allowing the rays to pass through a very narrow tube and then analysing the fine beam so produced by electric and magnetic fields.

The construction of one of the types of apparatus used is indicated in fig. 1. The discharge by which the rays are generated takes place in the bulb A. The cathode B is placed in the neck of the bulb. Its face is of aluminium and so shaped as to present a hemispherical front provided with a funnel-shaped depression. This hole through which the rays pass is continued as an extremely fine-bore tube, mounted in a thick iron tube forming the continuation of the cathode as indicated. The finer the bore of this tube the more accurate are the results obtained, and tubes have been made as narrow as one-tenth of a millimetre, but as the intensity of the beam of rays falls off with the inverse fourth power of the diameter a practical limit is soon reached. The cathode is cooled by the water-jacket C. The anode D may be placed in a side tube. The gas to be examined is led in through a fine leak E and pumped off at F. The pressure is usually adjusted so that the discharge potential is 30,000 to 50,000 volts.

During the discharge all the conditions necessary for the production of positive rays are present in A. Under the influence of the high potentials they attain high speeds as they fly towards the cathode, and those falling axially pass right through the narrow tube emerging as a fine circular beam. This beam is subjected to analysis by causing it to pass between the pieces of soft iron P,P′ which are placed between the poles M,M′ of a powerful electromagnet. P and P′ constitute the pole pieces of the magnet, but are electrically insulated from it by thin sheets of mica N,N′, and so can be raised to any desired potential by means of the leads shown. The rays then enter the highly exhausted camera G, and finally impinge upon the fluorescent screen or photographic plate H. In order that the stray magnetic field may not interfere with the main discharge in A, shields of soft iron I,I′ are interposed between the magnet and the bulb.

If there is no field between the plates P,P′ the beam of rays will strike the screen at a point in line with the fine tube called the undeflected spot. If an electric field of strength X is now applied between the plates a particle of mass m, charge e, moving with velocity v, will be deflected in the plane of the paper and will no longer strike the screen at the undeflected spot, but at distance x from it. If the angle of deflection is small $x=k\ (Xe/mv^2)$. In the same way if this electric field is now removed and a magnetic field of strength H applied between P and P′ the particle will be deflected at right angles to the plane of the paper and strike the screen at a distance y from the undeflected spot where $y=k'\ (He/mv)$, k and k' being constants depending solely on the form of the apparatus. If now, with the undeflected spot as origin, we take axes of co-ordinates OX, OY along the lines of electric and magnetic deflection, when both fields are applied simultaneously, the particle will strike the screen at the point (x, y) where y/x is a measure of its velocity and y^2/x is a measure of e/m, its ratio of mass to charge.

Now e can only exist as the electronic charge $4{\cdot}77\times10^{-10}$ C.G.S. or a simple multiple of it. Thus if we have a beam of positive rays of constant mass, but moving with velocities varying over a considerable range, y^2/x will be constant and the locus of their impact with the screen will be a parabola pp' (fig. 2). When other rays having a larger mass m' but the same charge are introduced into the beam, they will appear as another parabola qq' having a smaller magnetic displacement. If any straight line p,q,n be drawn parallel to the magnetic axis OY cutting the two parabolas and the electric axis OX in p,q,n it will be seen at once that $m'/m=pn^2/qn^2$. That is to say, the masses of two or more particles can be compared directly by merely measuring lengths the ratio of which is entirely independent of the form of the apparatus and the experimental conditions.



FROM DR. ASTON, "ISOTOPES" (EDWARD ARNOLD & CO.)

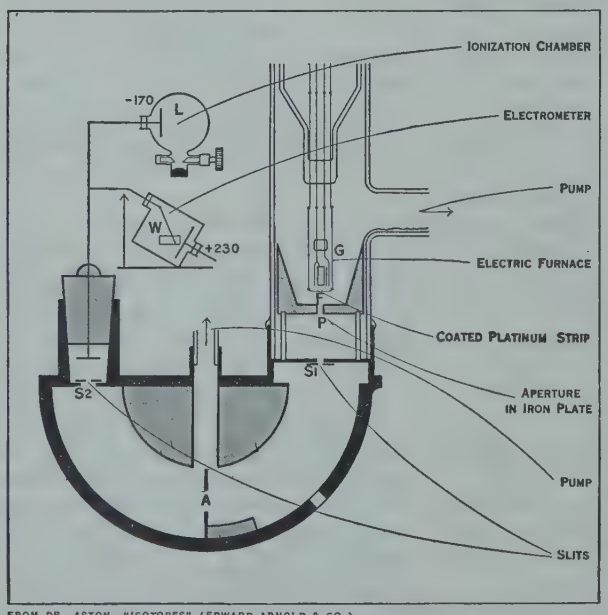
FIG. 2.—PARABOLAS OF POSITIVE RAYS OY is the magnetic, OX the electric, axis

The principle of the method is, therefore, to obtain a photographic record upon which at least one parabola can be identified with particles of known mass; all the other parabolas can then be measured against this one and their masses deduced. In practice, since OX is an imaginary line and has no existence on the photograph, in order that the measurements may be made with greater convenience and accuracy, the magnetic field is reversed during the second half of the exposure, when—in the case we are considering—two new parabolas will appear rr', ss', due to m and m' respectively; the masses can now be compared by the equation $m'/m=pr^2/qs^2$ where p,q,r,s is any straight line cutting the curves approximately parallel to the magnetic axis. The measurement

of these lengths is independent of zero determinations, and if the curves are sharp, can be carried out with considerable accuracy. It has been shown that the electrical displacement is in inverse proportion to the energy of the particle. This energy has a maximum limit determined by the potential of the discharge so that normal parabolas will end fairly sharply at points p,q, etc., equidistant from the magnetic axis This is clearly shown in the photographs reproduced in Plate, figs. 1 and 2.

Negatively Charged Rays.—As there is intense ionization in the fine tube the charged particles may easily collide with and capture electrons in passing through it. A singly charged particle capturing a single electron will, of course, proceed as a neutral ray, and being unaffected by the fields will strike the screen at the central spot. If, however, it makes a second collision and capture it will become a negatively charged ray. Rays of this kind will suffer deflection in both fields in the opposite direction to the normal ones, and will, therefore, give rise to parabolas of a similar nature but situated in the opposite quadrants, as indicated by the fine lines in fig. 2. Such negative parabolas are shown in the photographs. They are always less intense than the corresponding normal ones, and are usually associated with electronegative atoms.

Rays with Multiple Charges.—If during ionization more than one electron is split off, the resulting positive ray will have a double or multiple charge. Taking the case of a doubly charged particle it may give rise to two distinct effects. In the first place if it retains its double charge while passing through the analysing fields its behaviour will be quite indistinguishable from that of a normal ray of half its mass. Thus the effective mass of a doubly charged oxygen atom, written O^{++}, will be 8. Parabolas due to C^{++} and O^{++} may be seen in Plate, fig. 2. In the second place, the



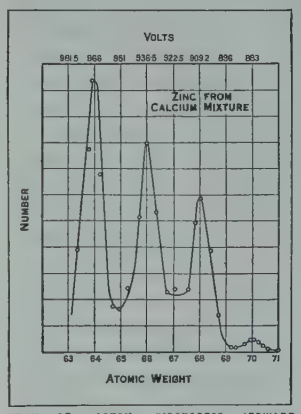
FROM DR. ASTON, "ISOTOPES" (EDWARD ARNOLD & CO.)

FIG. 3.—DIAGRAM OF APPARATUS FOR DEMPSTER'S METHOD OF ANALYSIS

particle may retain its double charge through the whole potential fall of the discharge but capture an electron in the fine tube. It will then constitute a ray of normal ratio of mass to charge but with double the normal energy, so that the normal parabola will show an extension towards the axis OY to a point half way between that axis and the line pq. The extension of the oxygen parabola due to this cause is clearly shown on the photograph.

Most elements are capable of losing two electrons, some, such as krypton, three or more, while mercury can lose no less than eight at a time. The results of the multiple charge on atoms of mercury is beautifully illustrated in Plate, fig. 3. The parabola α corresponding to normal single charge will be seen extended almost to the origin itself, while above a series of parabolas of diminishing intensity β,γ, etc., indicate the atoms which have retained two, three or more charges.

Dempster's Method of Analysis.—This method makes use of the principle first used by Classen and now generally adopted for beta-ray analysis, that a homogeneous beam of charged particles diverging from a narrow slit may be focussed by bending them through 180° in a uniform magnetic field. One form of Dempster's apparatus is shown in fig. 3. The element, the rays of which are to be analysed, is vaporized in a small electric furnace G and its vapour ionized by bombardment with electrons from a coated platinum strip F near the mouth of the furnace. The positive ions so produced pass into an accelerating field through the aperture in the iron plate P. The energy of the rays at this point is regarded as negligible so that all reach the slit S_1 with the same energy which can be controlled by varying the potential between P and S_1, usually 800–1,000 volts. The rays passing down in a narrow beam through S_1 are bent into a semicircle S_1,A,S_2 by the magnetic field, and so focussed upon a second slit S_2. Beyond this they are collected on an insulated plate and their charge measured. This is done by connecting the plate to an electrometer W and balancing the current brought up by the rays against a known and controlled leak produced in the ionization chamber L by means of a constant radioactive source.



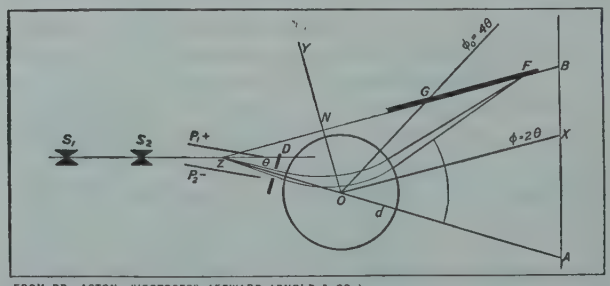
FROM DR. ASTON, "ISOTOPES" (EDWARD ARNOLD & CO.)

FIG. 4.—CURVE OBTAINED FROM ZINC, WITH A PEAK FOR EACH VALUE OF MASS IN BEAM OF RAYS

If V is the accelerating potential and r the radius of curvature it can easily be shown that $e/m = 2V/H^2r^2$. By keeping the magnetic field constant and plotting current against accelerating potential a curve is obtained having a peak for each value of mass present in the beam of rays. The ratios of the masses can be calculated from the voltages corresponding to the peaks. In this way Dempster was able to perform the first analyses of magnesium, calcium and zinc into their isotopes. (*See* ISOTOPES.) Fig. 4 shows a curve obtained from zinc.

The method is unfortunately limited in its application but it has the notable advantage that the relative abundance of the different isotopes can be directly deduced from the heights of their respective peaks.

Aston's Method of Analysis, the Mass-spectrograph.—This instrument was primarily designed to determine the constitution



FROM DR. ASTON, "ISOTOPES" (EDWARD ARNOLD & CO.)

FIG. 5.—DIAGRAM OF THE MASS SPECTROSCOPE USED IN ASTON'S METHOD OF ANALYSIS

of neon, a problem which required considerably greater accuracy than that given by the parabola method by which this element had been previously examined. In it electric and magnetic fields are employed to deflect the rays but they are so arranged that their deflections are at 180° instead of at 90° as used in the parabola method. The principle is indicated in fig. 5. The rays are collimated into an extremely thin ribbon by passing them through the two parallel narrow slits S_1,S_2. They are then deflected by

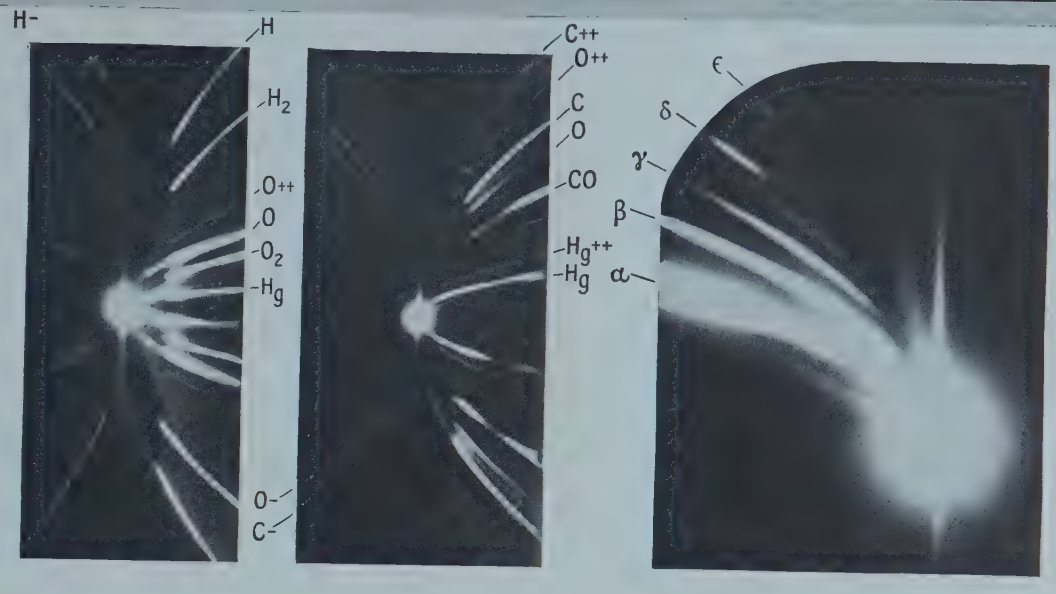


FIG. 1 FIG 2 FIG. 3

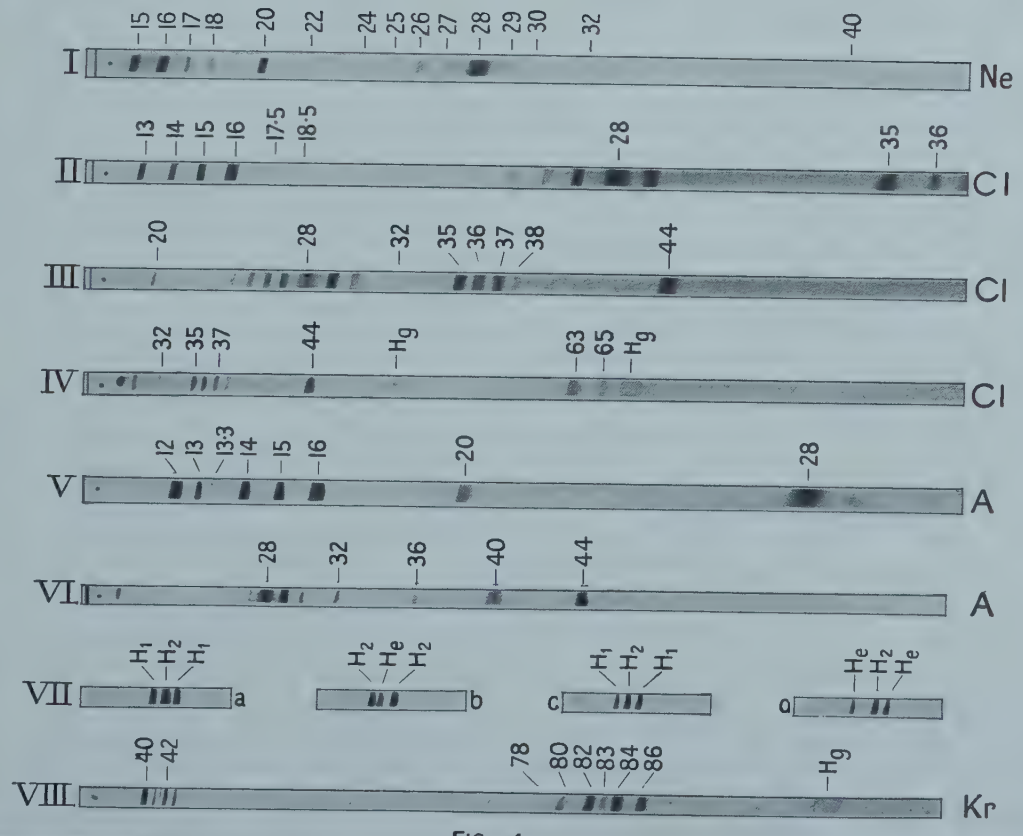


FIG. 4

PHOTOGRAPHS FROM DR. ASTON'S "ISOTOPES," BY COURTESY OF EDWARD ARNOLD AND COMPANY

POSITIVE RAYS

1. Typical positive ray parabola. Particles of like mass and charge, but of different velocities, give parabolic curves
2. Parabolas of carbon, oxygen, mercury, etc.
3. Parabolas of mercury (Hg) atoms with multiple charges
4. Typical Mass Spectra obtained from the mass-spectograph. The dark lines represent images of slits corresponding to particular masses, while the numbers above the line indicate the masses they correspond to on the ordinary chemical scale

the electric field between the plates P_1,P_2. This spreads them out into an electric spectrum in which the deflection of any particular particle is e/mv^2. After emerging from the electric field the rays may be taken, to a first degree of approximation, as radiating from a virtual source Z half way through the field. A group of these rays is now selected by means of the diaphragm D, and allowed to pass between the poles of a powerful electromagnet. For simplicity the poles may be taken as circular, the field between them uniform and of such a sign as to bend the rays in the opposite direction to the foregoing electric field.

If θ and ϕ be the angles through which the selected beam of rays is bent by passing through fields of strength X and H then $\theta v^2=lXe/m$ and $\phi v=LHe/m$ where l,L are the lengths of the paths of the rays in the fields. From these equations it can easily be shown that if the magnetic deflection is greater than double the electric deflection all rays of constant mass, or more precisely of constant m/e, will come to a real focus F, and that the locus of the foci so generated will lie along the line GF passing through Z and parallel to the line $\phi=2\theta$. If a photographic plate is placed at GF a spectrum depending on mass alone will be obtained. On account of its analogy to optical apparatus the instrument has been called a mass-spectrograph and the spectrum it produces a mass-spectrum.

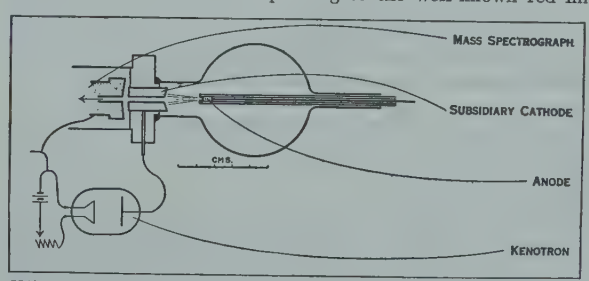
The use of slits instead of a fine circular tube, combined with the enhanced intensity obtained by means of the focussing principle, enables a very much higher resolving power to be used than was possible with the parabola method. Hence, although the photographs obtained do not afford so wide a range of general information upon the rays, the limit of accuracy in comparison of mass is notably increased. The first mass-spectrograph was set up in Cambridge in 1919 and used continually till 1925. In it θ the angle of electric deflection was one twelfth of a radian. It had a resolving power of about 1 in 130 and an accuracy of about 1 in 1,000. By its means over 50 elements were analysed and the "whole number rule" established. (*See* Isotopes.) For details of its construction and technique the reader is referred to the works quoted at the end of this article.

Plate, fig. 4 shows a number of mass-spectra obtained by its means. Each dark line represents the image of the slits corresponding to a particular mass. The number above the line indicates the mass it corresponds to on the ordinary chemical scale O=16. The whole spectrum represents a range of mass of about 3 to 1, and the position of any line on the spectrum can be altered at will by changing the strength of the deflecting fields as shown by the positions of the chlorine group 35,36,37,38 in spectra II., III., IV. It will be noticed that the displacement to the right with increasing mass is roughly linear, a fortunate occurrence of great assistance in making the necessary calibrations. The measurements of mass are not absolute, but relative to certain reference lines which correspond to known masses. Such lines, due to hydrogen, carbon, oxygen and their compounds, are generally present as impurities or purposely added for the smooth working of the discharge tube. The two principal groups of these reference lines are the C_1 group, due to C(12),CH(13),CH_2(14),CH_3(15),CH_4 or O(16), and the C_2 group (24 to 30) containing the very strong line (28) due to CO and other bodies. The latter group and part of the former are well shown in spectrum I., where between them may be seen the lines due to the isotopes of neon 20 and 22. These two groups form with CO_2(44) a good scale of reference. The remarks already made about parabolas due to multiply charged rays apply to the lines obtained by this form of analysis. Lines due to particles carrying one, two, three, or more charges are called lines of the first, second, third or higher order, thus in spectrum II. the faint lines at 17·5 and 18·5 are chlorine lines of the second order. In spectrum V. taken with argon the third order line of its principal isotope (40) is clearly shown at $13\frac{1}{3}$ among the C_1 group of reference lines. Spectrum VIII. shows the six isotopes of krypton; on the left their second order lines can be seen close to the first order line of argon 40.

The remarkable property possessed by the atoms of mercury, of carrying multiple charges is well exhibited in mass-spectra. Mercury is a complex element and the characteristic closely packed group of lines due to its isotopes can be seen, progressively weaker in intensity up to the sixth order. Some of these groups appearing as unresolved blurrs may be recognized in the plate. The lines of mercury have now been satisfactorily resolved and its constituent isotopes determined by a mass-spectrograph of higher power. (*See* Isotopes.)

Method of "Bracketing."—The method of determining masses by the position of lines with regard to known reference lines cannot be conveniently applied to the elements hydrogen and helium as these are too remote from the scale of reference. Their masses were first compared by the following principle which involves change in the deflecting fields. It is not practicable to determine the absolute values of the magnetic field but it can be kept constant without much difficulty. On the other hand, it is easy to apply electric fields whose ratios are known with certainty. From the equations already given it can be shown that for a given position on the spectrum $mv^2\propto X$ and $mv\propto H$. Therefore if H is constant $m\propto X^{-1}$. If, therefore, after taking a spectrum we take another with the same magnetic field and, say, exactly double the electric field, the position due to a mass m on the first will be occupied by a line due to a mass $\frac{1}{2}m$ on the second. Hence if V is the original potential on the plates and v a suitable small voltage, and we take three spectra on the top of each other, one with a potential V, one with $2V+v$, and a third with $2V-v$, the magnetic field being identically the same for all, a line due to a mass m will appear bracketed on each side by lines due to $\frac{1}{2}m$. If the two to one relation between the masses is an exact one the bracket will be symmetrical as in the case of the hydrogen atom and molecule spectrum VII. *c*. If the bracket is not symmetrical the ratio of the masses is not 2 as in the case of the hydrogen molecule and helium atom spectrum VII. *b* and *d*. In this way it was first proved that the hydrogen atom had a mass considerably greater than a whole number on the oxygen scale, the value agreeing with 1·008, that deduced by chemical methods. This result, which has since been amply confirmed, is of great theoretical importance.

Anode Rays.—The usual source of positive rays, as has been stated, is the ordinary discharge in gases at low pressures. For examination by this process a substance must itself be volatile or capable of yielding a stable compound which can be introduced as a vapour into the discharge tube. The majority of elements are metals and do not behave in this manner. To obtain mass rays of these other methods must be used. As long ago as 1906 it was observed that halogen salts when heated and used as anode in a discharge tube behaved in a very remarkable manner giving off pencils of coloured rays. Thus the salts of lithium produced brilliant red streamers corresponding to the well-known red line



FROM DR. ASTON, "ISOTOPES" (EDWARD ARNOLD & CO.)

FIG. 6.—APPARATUS FOR ACCELERATED ANODE RAYS, IN WHICH THE DISCHARGE TAKES PLACE BETWEEN ANODE AND SUBSIDIARY CATHODE

of the lithium spectrum. These were called "Anode Rays" and proved to be positively charged atoms of the metals employed. These rays are usually too slow to be suitable for direct analysis by the mass-spectrograph but they can be made so by the device illustrated in fig. 6, called the method of "accelerated anode rays." The discharge providing the rays takes place between the anode, containing halogen compounds, and a subsidiary cathode as shown. The slow rays passing through the latter are accelerated by introducing between it and the cathode of the mass-spectrograph a kenotron which will only allow a current of a value desired

to pass. Now if the discharge tube becomes too hard the cathode rays from the subsidiary cathode will increase in energy heating the anode and softening the tube. If, on the other hand, the discharge becomes too soft the energy is absorbed in the kenotron, that in the cathode rays decreases and the anode cools down hardening the discharge. Also, whatever the state of the discharge tube, the energy of the rays reaching the mass-spectrograph is roughly constant, for this is governed by the watts in the high tension discharge and the current allowed to pass through the kenotron. By means of this device applied to the original mass-spectrograph the isotopic constitution of a large number of metallic elements was demonstrated. (*See* ISOTOPES.)

Mass-spectrographs of High Precision.—The accuracy and resolving power of the original mass-spectrograph have since been greatly exceeded. Costa, in 1925, described an instrument capable of an accuracy of 1 in 3,000 by which he compared the masses of the atoms of lithium and other light elements by the method of bracketing. The latest model now in use by the writer in the Cavendish laboratory has a resolving power of 1 in 600, more than sufficient to resolve the mass lines of the isotopes of any known element, and, when suitable systems of measurement are used, an accuracy of 1 in 10,000. This instrument has been used to measure the very small divergencies from the whole number rule. (*See* ISOTOPES.) In conclusion, it may be stated that the discovery of positive rays gave a very valuable weapon into the hands of the physical investigator. The study of their analysis is less than 20 years old, yet already it has established facts of revolutionary importance and has provided a means of measuring the weights of atoms, free from ambiguity and of an accuracy equal to that of the finest chemical methods. (*See* also ISOTOPES; ELECTRICITY; ELECTRICITY, CONDUCTION OF; ELECTRON, THE.)

See J. J. Thomson, *Rays of Positive Electricity* (2nd ed.); F. W. Aston, *Isotopes* (2nd ed., 1924) and Bakerian Lecture, *Roy. Soc. Proc.* A. 115 (1927); W. Wien, *Kanalstrahlen* (1923). (F. W. A.)

POSITIVISM, a philosophical term, applied somewhat loosely to any system which confines itself to the data of experience and declines to recognize a priori or metaphysical speculations. In this sense the term may be applied to empirical philosophers in general. Thus Hume is a positivist in the sense that he specifically restricts philosophy to the sphere of observation, and regards the causal relation as being nothing more than what we have been accustomed to expect. Similarly Mill, Spencer and physical scientists generally view the universe from the positivist standpoint. In its commonest acceptation, however, the term is used of the philosophy of Auguste Comte, who applied the term to his system according to which knowledge is based exclusively on the methods and discoveries of the physical or "positive" sciences (*see* COMTE). The outcome of this positivism is the substitution for revealed religion of a religion of humanity—according to Huxley "Catholicism minus Christianity"—in which God is replaced by Humanity. This religion was to have its special priesthood, ritual and organization.

In England a number of prominent Positivists carried out Comte's ideal of a Church of Humanity with ritual and organization. The chief building (in Chapel Street, Lamb's Conduit Street, London) is adorned with busts of the saints of humanity, and regular services are held. Positivist hymns are sung and addresses delivered. Among the leaders of this movement have been Frederic Harrison, Richard Congreve, E. S. Beesly and J. H. Bridges (d. 1906). Services are also held weekly in Essex Hall, London, and there are a few other centres in the provinces, including a prosperous church in Liverpool.

POSSE COMITATUS, a summons to every male in the county, between the ages of 15 and 20, to be ready and apparelled, at the command of the sheriff and the cry of the county, to maintain peace and pursue felons. In England, ecclesiastics, peers and the infirm were not compellable to attend. Owing to the establishment of county police, the sheriff does not now pursue felons, but by the Sheriffs Act, 1887, he is expressly authorized to call out the posse comitatus if he suffers resistance in the execution of a writ. Thus it is no answer by him, for non-execution of a writ, to say that he was resisted.

In the United States, where used in the states, it is the assemblage of males of 15 years and over called by the sheriff to aid him in maintaining peace.

POSSESSION, the supposed control of a human body and mind by an alien spirit, human or non-human; or the occupation by an alien spirit of some portion of a human body, causing sickness, pain, etc. The term *obsession* (Lat. for siege) is sometimes used as equivalent to possession; sometimes it denotes spirit control exercised from without, or it may mean no more than a maniacal monoideism. The spirit is held to have entered the person in order to foretell the future or to proclaim the will of a god; the god himself may be regarded as speaking through the mouth of his devotee. Hence the authority of a prophet. Among peoples in the lower stages of culture possession by spirits of the dead is common and is related to ancestor worship. This kind of possession is found in Africa, Polynesia and Asia. Many of the classical oracles were regarded as due to divine inspiration. The manifestations are often voluntarily induced and are provoked in many different ways; in classical times the eating of laurel leaves, the inhaling of fumes which ascended from a cleft in the rocks of Delphi, the drinking of intoxicating liquors, or of a more widely found means of inducing the phenomena—blood—were all in use. Hypnosis was produced by drugs, draughts of animal blood, or as in Siberia, America and many parts of Africa by drumming, contortions and orgiastic dancing.

The symptoms of supposed possession by a god differ as widely as do those of the hypnotic trance. In Hawaii the god Oro gave his oracles by inspiring the priest, who ceased to speak or act as a voluntary agent, his frenzied utterances being interpreted by the attendant priests. In the Malay peninsula the *pawang*, after censing himself, lay down on his back, with his head shrouded, and awaited the moment of inspiration. The tiger spirit which became the familiar of all Malay *pawangs* manifested its presence by a low lifelike growl, and the *pawang* scratched at the mat, gave a series of catlike leaps and licked up from the floor the handfuls of rice scattered there. But his state seems to be far removed from the ecstasy of the Hawaiian priest, though it must be remembered that no *bona fide* test was possible in either case. In Tahiti another stage was the lofty declamation of the possessed priests, who thus afford a parallel to the utterances of many modern mediums. Finally in Africa, where the frenzied form of possession also became common, at Sofala the manifestations of possession were confined to the simple dramatic imitation of the voice of the dead king, whose soul was believed to give counsel in this manner to his successor.

Demoniacal possession is a common explanation of such psychopathological conditions as epilepsy, somnambulism, hysteria, etc.; especially in the East Indian field lycanthropy (*q.v.*) and magical power (for evil) are commonly attributed to possession. Demoniacal possession is familiar to us from the New Testament narratives, in which those possessed are stated to live among the tombs, to be deaf and dumb, or blind, to be possessed by a multitude of evil spirits or to suffer from high fever as a result of possession; the demons are said to pass into the bodies of animals or to reside in waterless places. The facts recorded are explicable either as symptoms of mental disease or as results of suggestion.

In the lower stages of culture diseases are explained as caused by the invasion of the body by spirits (*see* ANIMISM), but the effects are supposed to be physiological, not psychical. The wrath of an ancestor or other dead person or the malice of a spirit, such as the Malay *hantus*, or of any nonhuman spirit, may set up pathological conditions. Such cases may be distinguished from the inspirational form by their invariably involuntary character and are dealt with by a variety of means such as spells, purifications, sacrifices to the possessing spirit, etc. (*see* EXORCISM).

BIBLIOGRAPHY.—For anthropological data *see* Adolf Bastian, *Der Mensch in der Geschichte* (1860); Naevius, *Demon Possession;* Radloff, *Das Schamanentum;* W. W. Skeat, *Malay Magic* (London, 1900); Otto Stoll, *Suggestion und Hypnotismus,* 2nd ed. (Leipzig, 1904); Sir Edward Tylor, *Primitive Culture,* 7th ed. (1924); Verdun, *Le Diable dans les missions;* Maury, *La Magic,* p. 258 *et seq.;* Chamberlain, *Things Japanese, s.v.* "Fox." Details of the phenomena are given in all good modern ethnographical works. *See* bibliography to ANTHROPOLOGY.

For discussion of New Testament facts *see* W. M. Alexander, *Demoniacal Possession in the New Testament;* Conybeare, in *Jewish Quarterly Review,* vol. viii, 576, vol. ix, 59, 444, 581; Herzog's *Realencyklopädie, s.v.* "Dämonische." For patristic literature *see* J. Bingham, *Antiquities of the Christian Church,* vol. iii.

POSSESSION (IN LAW), a term derived from Roman law. It has been said to be either a right or a fact conferring a right, or both together. The latter is the view of Friedrich Karl von Savigny, the leading authority upon the subject (*Das Recht des Besitzes*). The definition of W. A. Hunter may be accepted: "Possession is the occupation of anything with the intention of exercising the rights of ownership in respect of it" (*Roman Law*). Possession is inchoate or incomplete ownership; it is on its way to become ownership.

In both Roman and English law the possessory tended to supersede the proprietary remedies from their greater convenience—that is to say, the plaintiff based his claim or the defendant his right upon possession rather than property. The English possessory action may have been directly suggested by the interdict. Henry de Bracton (103b) identifies the assise of novel disseisin, the most common form of possessory action, with the interdict *unde vi.* In England ejectment had practically superseded other real actions before the latter were (with the exception of dower, writ of dower and *quare impedit*) expressly abolished by the Real Property Limitation act, 1833, s. 36. The action for the recovery of land, introduced by the Judicature acts, is the modern representative of the action of ejectment.

Possession gives in English law, speaking generally, much the same rights as in Roman law. Thus it serves to found a title (*see* LIMITATION, STATUTES OF; PRESCRIPTION), and to throw the onus of proof upon the claimant. In an action for the recovery of land the defendant need only allege that he is in possession by himself or by his tenant, and (where such an allegation is necessary) that he had no notice to quit. In English law the doctrine of possession becomes practically important in the following cases: (1) Possession serves as a convenient means of division of estates. (*See* LAWS RELATING TO REAL PROPERTY AND CONVEYANCING.) One of the divisions of estates is into estates in possession and estates in reversion or remainder. It also serves as a division of personal property (*q.v.*). A chose in action is said to be reduced into possession when the right of recovery by legal proceedings has become a right of enjoyment. (2) Possession gives a title against a wrongdoer. In the case of real property it is regarded as prima facie evidence of seisin.[1] In the case of personal property the mere possession of a finder is sufficient to enable him to maintain an action of trover against one who deprives him of the chattel.[2] (3) What is called "unity of possession" is one of the means whereby an easement is extinguished. (4) Possession is very important as an element in determining the title to goods under 13 Eliz. c. 5, the Bills of Sale act, 1878, and the Bankruptcy acts, 1883 to 1890. (5) Possession of goods or documents of title to goods is generally sufficient to enable agents and others to give a good title under the Factors' acts. (*See* FACTOR.) (6) In criminal law the question of possession is important in founding the distinction between larceny and embezzlement. (*See* Sir James Stephen, *Digest of the Criminal Law,* note xi.) (7) Actions of possession of ships fall within the jurisdiction of the admiralty division. This jurisdiction in the case of British vessels depends upon the Admiralty Court act, 1861 (24 Vict. c. 10, s. 8), in the case of foreign vessels (in which the jurisdiction is rarely exercised) upon the general powers of the court as a maritime court. Under the Statutes of Limitation the only question now is, not whether possession has been adverse or not, but whether 12 years have elapsed since the right accrued.

Scotland.—In Scotland possessory actions still exist *eo nomine.* Actions of molestation, of removing and of maills (payments) and duties are examples. A possessory judgment is one which entitles a person who has been in possession under a written title for seven years to continue his possession (Watson, *Law Dict., s.v.* "Possessory Judgment").

United States.—In U.S. law possession carries much the same important significance that it does in English law. Except in Louisiana, where the civil law prevails, possession is commonly divided into actual and constructive possession. The former concerns actual occupancy or the exercise of dominion over a thing; the latter occurs where there is no actual possession but simply ownership and the possession is either vacant or consistent with the outstanding ownership, such as possession by a servant or bailee. The doctrine of possession has an outstanding importance in practically every branch of the law, especially in the numerous cases where ownership to realty or personalty is in issue. Especially significant are the doctrines of adverse possession, where long continued and uninterrupted possession of chattels or realty under a claim of right and hostile to the true owner ripens after the statutory period into indefeasible ownership.

In addition to the authorities cited may be mentioned W. A. Hunter, *Exposition of Roman Law,* 4th ed. (1903); O. W. Holmes, *The Common Law* (1882); F. Pollock and R. S. Wright, *Possession in the Common Law* (1888); W. Markby, *Elements of Law* (1905); T. H. Holland, *Elements of Jurisprudence,* 13th ed. (1924).

POST, GEORGE BROWNE (1837–1913), U.S. architect, was born in New York, N.Y., on Dec. 15, 1837. He attended Churchill's Military school, Ossining, N.Y., and graduated with a degree in civil engineering from New York university in 1858. Post was a student draftsman under Richard Hunt until 1860, when he and Charles D. Gambrill formed a partnership.

During the Civil War Post served as an officer with the New York national guard, 22nd regiment. After the war Post opened his own office, and in 1868 he resigned his commission as a colonel in order to devote more time to the business. In 1869 he was consulting architect for the New York Equitable building, designed by Arthur Delevan Gilman, in which elevators, then an innovation for business buildings, were installed.

Numerous commercial buildings designed by Post include the Williamsburgh Savings bank, New York city (1874), in Renaissance style; the New York Cotton exchange (1883–86), with curved towers; the original *New York Times* building (1889), Romanesque; the St. Paul building, New York city (1897–99), a 22-story structure using applied classic orders; and the New York Stock exchange (1904). Post was president of the American Institute of Architects, 1896–99, and president of the New York chapter in 1905. He died on Nov. 28, 1913, at Bernardsville, N.J.

POST, MELVILLE DAVISSON (1871–1930), U.S. author, born at Romines Mills, near Clarksburg, W.Va., April 19, 1871, studied at rural schools and an academy at Buckhannon, W.Va. He graduated from West Virginia university in 1891 and in the following year received a law degree. Post practised criminal law and later corporate law in West Virginia, forming a partnership with John T. McGraw, a leader of the state Democratic party. Post became active in politics and in 1898 was named chairman of the Democratic congressional committee in West Virginia.

In 1896 he published *The Strange Schemes of Randolph Mason,* a collection of short stories featuring a lawyer who unscrupulously took advantage of loopholes in the law. In the following year a sequel, *The Man of Last Resort,* was published. Post's Randolph Mason worked for the ends of justice in *Randolph Mason, Corrector of Destinies* (1909). Post became best known for his series of magazine stories about a rural sleuth in early Virginia. In 1918 a selection of the tales was published as a book entitled *Uncle Abner: Master of Mysteries.* Other mystery stories include *The Sleuth of St. James's Square* (1920); *Monsieur Jonquelle* (1923); *The Bradmoor Murder* (1929); and *The Silent Witness* (1930).

He also wrote *Dwellers in the Hills* (1901), a long story of West Virginia cattlemen; *The Gilded Chair* (1910), an adventure story; and *The Mountain School-Teacher* (1922), an allegory based on Christ's life. On June 29, 1903, Post was married to Ann Bloomfield Gamble of Roanoke, W.Va., who died in 1919. He died at Clarksburg on June 23, 1930.

[1] "Seisin" and "possession" are used sometimes as synonyms, as generally by Bracton; at other times they are distinguished: thus there can be possession of a term of years, but no seisin (Noy, *Maxims,* p. 2). It seems doubtful, however, how far in English law a tenant for years has true possession, for he is in law only a bailiff or servant of the landlord. But he certainly has possessory remedies.

[2] Compare the *Code Napoleon,* art. 2,279: "En fait de meubles la possession vaut titre."

POST, PIETER (1608–1669), Dutch architect, was born at Haarlem and died at The Hague. His works, together with those of Jacob van Campen, mark the height of Dutch classicism. Post began his career as a painter but from 1633 onward was known as an architect. In that year he designed, possibly with Campen in whose work he often collaborated, the Mauritshuis at The Hague and showed himself already a master. In 1645 he became architect to the stadholder Frederick Henry. With Campen he designed the House-in-the-Wood at The Hague (1645–47) and, independently, Swanenburg house (1645), Nieuwkoop almshouses at The Hague (1658) and the weighhouse in Leyden (1658). Post's town hall at Maastricht (1656 *et seq.*) is one of the outstanding buildings of the 17th century in the Netherlands. Greater freedom in the grouping of masses and the treatment of façades distinguish his works from Campen's. Post influenced many of his younger contemporaries.

BIBLIOGRAPHY.—*Les ouvrages de Pierre Post,* engravings (Leyden, 1715); G. A. C. Blok, *Pieter Post* (Siegen, 1937); F. A. J. Vermeulen, *Handboek tot de geschiedenis der Nederlandsche bouwkunst,* vol. 3 (The Hague, 1941). (A. NH.)

POST, WILEY (1899–1935), U.S. aviator, was born on a farm near Grand Plain, Tex., on Nov. 22, 1899. When he was about eight years of age his family moved to Oklahoma and later settled on a farm near Maysville. While still a boy Post showed a decided mechanical inclination; he tinkered on his father's farm and did odd jobs for neighbours. At the age of 13 he bought a bicycle, and a year later he took his first automobile ride and saw his first aeroplane, exhibited at a county fair. Post attended an automobile school in Kansas City, and in 1917 was a radio student at an army training camp at Norman, Okla. After World War I, he became an oil driller in the Oklahoma oil fields. In 1924, while learning to fly, he began his career as a featured parachute jumper; by the time of his death, he had made almost 100 jumps. When he returned to his job as an oil driller two years later, his left eye was injured in an accident and had to be removed. With part of the compensation he received, Post bought a used aeroplane and began to give exhibitions and fly passengers.

In 1928 he became the pilot of an Oklahoma oil man, F. C. Hall, and was later employed in California as a test pilot for an aeroplane manufacturer. In 1930, when Post again became Hall's pilot, he won the Los Angeles, Calif., to Chicago, Ill., air derby in 9 hr. 9 min. 4 sec. He flew Hall's aeroplane the "Winnie Mae," named after Hall's daughter.

With Harold Gatty, who served as navigator, Post started in the "Winnie Mae" from New York city on June 23, 1931, and flew around the world, over England, the U.S.S.R. and Alaska, returning to New York on July 1. He covered the 15,500 mi. in 8 days 15 hr. 51 min. In 1933 Post was the first to fly around the world alone. Following the same route in the "Winnie Mae," which he then owned, he flew 15,600 mi. in 7 days 18 hr. 50 min. (July 15–22). Wiley Post and Will Rogers, U.S. humourist and motion-picture actor, were killed on Aug. 15, 1935, when Post's plane crashed in northern Alaska.

POSTAL INSURANCE: *see* INSURANCE: POST OFFICE FACILITIES.

POSTAL ORDER, in the United Kingdom, is a post-office facility for making small remittances. The postal order is a voucher which can be bought at any post office and is payable at any other post office either to its bearer or to the nominee if a name is filled in. Orders are sold for sums from 6*d.* to 21*s.*, and odd pence can be filled in by affixing postage stamps. The poundage charge ranges from 1*d.* to 2*d.* Larger sums can be made up by buying several orders. Thus £3 17*s.* 4*d.* can be remitted by buying three 20*s.* orders and one 17*s.* order and affixing 4*d.* in postage stamps to one of the orders. If the order is crossed it is only paid through a banker as in the case of a cheque. About £100,000,000 a year is remitted by this means. *See* POST AND POSTAL SERVICES.

United States Postal Notes.—By an act of congress signed March 3, 1883, a form of postal order known as the postal note was authorized for use in transmitting through the mails any amount less than $5. This postal note, for which a fee of three cents was charged, became immediately popular, but as it was payable to bearer many complaints of loss and theft were received. Notwithstanding the increasing number of such losses and depredations the use of the note was continued until Jan. 1894, when it was abolished and, a lower fee having been prescribed for the regular money order of small amount, the latter took the place of the postal note without any serious confusion or complaint.

POST AND POSTAL SERVICES. The history of postal services goes back to the early days of the great empires of the east, when the permanent maintenance of control over a wide area was seen to depend on the organization and maintenance of rapid and frequent communication. The posts of the Persian empire under the successors of Cyrus are the first great example. The Roman empire brought the official postal service to a very high degree of perfection, but with the collapse of the western empire there was a long eclipse of this as of the rest of the machinery of the imperial government.

During the middle ages such posts as existed were maintained by the universities or by the guilds of merchants. With the Renaissance the need for private communication forced itself inevitably upon the notice of the governments of the day. In its gradual growth and expansion the policy followed can be traced to three distinct motives. These are the desire to ensure an official control or censorship, mainly of international correspondence; the search for additional sources of revenue; and the wish to provide an efficient service.

The first motive is prominent in a proclamation of Queen Elizabeth I dated 1591, which prohibits the carriage of letters to and from "the Countreys beyond the seas" except by messengers duly authorized by the master of the posts. This was directed at the private posts maintained by the foreign merchants in London and seems to have been effective at the moment in bringing them to an end. In 1609 James I extended the prohibition to the inland as well as the foreign post, but in this case the motive may have been the protection of the postmaster general's revenue. The importance of state control emerged again during the protectorate, and in Oliver Cromwell's Post Office act of 1657 stress is laid on the importance of a centralized post office as a means not only of promoting trade but of discovering and preventing "many dangerous and wicked designs which have been and are daily contrived against the peace and welfare of this Commonwealth, the intelligence whereof cannot well be communicated but by letter of escript." Postal censorship, long discontinued, was revived for both World Wars I and II.

The growth in knowledge and prosperity which marked the 17th century soon led to deep dissatisfaction with the limited and somewhat inefficient services which prevailed under Elizabeth I and James I, and the reign of Charles I saw the first of the great postal reformers in the person of Thomas Witherings. Witherings began his career as "postmaster of England for foreign parts" and carried out sweeping reforms of the foreign post. In 1635 he was authorized to bring into operation a reorganization of the inland posts, which he proposed to make self-supporting, instead of being a charge to the crown, by the simple method of making them efficient and cheap. Witherings' scheme consisted in the organization of posts travelling night and day on each of the great post roads and covering a minimum distance of 120 mi. a day, with branch posts working to and from the post towns on the way. A letter could thus be sent to Edinburgh and a reply received in six days—an enormous improvement on anything previously attempted. A regular tariff of rates was established, based on the "single letter"; *i.e.,* one sheet of paper. This method of charging and the zone system of postage rates remained as the underlying principles of the postal service until the reforms of Rowland Hill.

Witherings' rates on the single letter were as follows: less than 80 mi., 2*d.*; 80 to 140 mi., 4*d.*; more than 140 mi., 6*d.*; on the borders and in Scotland, 8*d.*; in Ireland, 9*d.*

For letters carried on the branch posts an additional 2*d.* was charged. In 1653 the government decided, for revenue purposes, to let the posts out to farm. The successful tenderer paid £10,000 a year, and the system was continued under the Restoration until 1667. The revenue of the post office, however, was not considered

simply as a contribution to the general expenses of government. In 1663 it was settled on the duke of York and his male heirs, and somewhat later was charged with a number of pensions, which in 1713 amounted to £22,120, or one-third the total net revenue. The last of these pensions, that payable to the duke of Grafton, was continued until 1856, when it was commuted for £91,000.

London Penny Post, 1680.—In 1653 Louis XIV had authorized the establishment of a local post in Paris at a charge of one sou. Profiting no doubt by this example, a London merchant, William Dockwra, brought into existence in 1680 the London penny post. A rate of 1*d.*, to be prepaid, was charged on all packets up to one pound in weight, the packets being insured up to £10. Several hundred receiving offices were opened, from which an hourly collection was made, the letters being brought into six central offices, where they were sorted, date stamped and sent out for delivery. There were 4 to 8 deliveries a day in the greater part of London and 10 or 12 in the business centres. The area covered by this service extended from Hackney to Lambeth and from Blackwall to Westminster, and there was also a daily delivery, for which an additional 1*d.* was charged, to places 10 or 15 mi. from London.

For some time Dockwra struggled with serious financial difficulties, but no sooner had the penny post begun to show a profit than the duke of York, on whom the post-office revenues were settled, asserted his monopoly. Dockwra was condemned to pay damages and his undertaking was incorporated in the general post office.

The First Postmaster General.—The act of 1657 was the first comprehensive attempt to regulate the postal service by statute. It established a government monopoly, provided for the post of postmaster general, regulated the treatment of letters brought by private ship and prescribed the rates of postage, both inland and foreign. The act was renewed with practically no alteration immediately after the Restoration. The inland rates were somewhat lower than those charged by Witherings, the maximum rate being 6*d.* for a single letter to or from Ireland.

Another Post Office act was passed in 1711, uniting the post offices of England and Scotland, which had been separated in 1695; regulating the postal service in New York, the West Indies and the other American colonies; prohibiting post-office officials from taking part in politics; and increasing substantially the rates of postage in order to provide for the expenses of the war with France.

The development of the posts since the reforms of Witherings had now raised a difficult administrative problem; viz., that of the "crossposts," or letters exchanged between one town and another without passing through London. At this juncture another reformer appeared in the person of Ralph Allen, postmaster of Bath. Allen, who had been in the postal service since his boyhood, was convinced that with proper management the crossposts could be turned into a source of revenue. In 1719 he offered to farm them for £6,000 a year, or 50% more than the net receipts at that time, and in 1721 this offer was accepted for a term of seven years. Allen's farm was successful and the contract was renewed, at a constantly increasing rent, until his death in 1769. The net revenue of the post office increased from £96,000 in 1724 to £165,000 in 1769.

The later years of the 18th century were marked by a great development of the main roads and a consequent improvement in speed of communication. Regular stagecoach services began to be established. The establishment of the mail coach service was the work of John Palmer of Bath. The coaches were all to leave London at the same time—8 P.M.—and to return together as far as possible. The security of the mails was to be provided for by armed guards.

First Mail Coach, 1784.—Palmer succeeded in bringing this project under the personal notice of Pitt, who saw its merits and ordered its adoption. The first mail coach was established between London and Bath in 1784, and within two years coaches were running to Norwich, Nottingham, Liverpool, Manchester, Leeds, Milford Haven, Holyhead, Exeter and other places. By 1797 there were 42 mail coach routes in operation. Examples of times taken are: London to Holyhead 27 hours, to Edinburgh 43 hours, to Falmouth 29 hours. The development of the post was hampered by the necessity of obtaining revenue to finance the war with France, and the rates of postage were periodically increased until in 1812 they attained the highest point they had ever reached, and at which they remained until the reforms of Rowland Hill.

It is surprising that these rates were retained for 25 years after Waterloo, and when Rowland Hill published his pamphlet on postage in 1836 he had behind him a substantial volume of public discontent. Hill argued that the postal administration was conducted on principles which were in effect an obstacle to the development of postal business. The principal features of the scheme put forward were the abolition of the method of charging postage on the basis of distance and the number of sheets, and substitution of rates based simply on weight; the prepayment of letters by postage stamps; and the adoption of a uniform minimum rate of 1*d.*

Rowland Hill's Success, 1840.—It was only after four years of agitation and parliamentary inquiry that penny postage was finally established in 1840. This was the most signal service Great Britain rendered to the cause of postal progress, and from the point of view of developing social relations and business communications it was an unqualified success; it established a standard to which it became the ambition of the rest of the world to attain.

This success, however, had to be paid for in another direction. Cheap postage rates were not in themselves the gold mine that certain of their enthusiastic supporters imagined. It is significant to note that the post-office revenue, which in 1839 was more than £1,600,000, dropped to £500,000 in the following year. It was not until 35 years after the introduction of Rowland Hill's reform that the revenue was again as much as it had been in 1839.

BRITISH POST OFFICE IN MODERN TIMES

For several years after the introduction of penny postage the post office abstained from introducing more reforms and devoted itself to developing its existing services. The effect of the new rate on the volume of correspondence was immediate and continuous. In 1840 the number of letters posted was 169,000,000, or more than double that posted in the previous year. In ten years it had almost quadrupled, and by 1870 had reached the total of nearly 880,000,000. The initial weight of one-half ounce for a letter adopted by Rowland Hill remained unchanged for more than 30 years; it was raised in 1871 to one ounce, at which it remained until the Jubilee reform of 1897, when the weight carried for 1*d.* was raised to four ounces. In 1897 the postage on all weights above the initial 1*d.* was fixed at ½*d.* per two ounces.

World War I, among its other retrogressive results, brought about the abolition of penny postage 78 years after its first establishment. From 1918, when the basic rate was 1½*d.*, there were various changes up and down, until in 1952 it was 2½*d.* for the first two ounces, 3*d.* for four ounces and 1*d.* for each additional two ounces.

Newspapers.—The newspaper post had a varied and anomalous history. In 1840 newspapers were by statute carried free of postage. This, however, was not equivalent to the free postage which has been given on a more or less extended scale in other countries, as from the time of Queen Anne all newspapers had contributed to the revenue by the stamp duty which was levied on every copy. This state of things continued until 1855 when the duty was made optional, the privilege of free postage being continued to such newspapers and even to such periodicals as chose to pay it. Unstamped papers were forwarded by book post (*see* below). In 1870 the position was altered by act of parliament, which established a rate of ½*d.* for each newspaper irrespective of weight, the privilege being confined to papers published at intervals of not more than seven days and complying with certain specified conditions. The principle of a flat rate irrespective of weight was abandoned in 1915, when the rate was increased. Later alterations brought the rate (in 1950) to 1½*d.* per copy for the first four ounces and ½*d.* per copy for each additional four ounces, the maximum being two pounds.

Book (Now Printed Paper) Post.—The first special rate of postage introduced after 1840 was the book post, instituted in 1848. This was intended to benefit education and literature and

was fixed at 6*d.* a pound. Various reductions were made in the scale until in 1870 it was reduced to ½*d.* per two ounces. From 1915 various changes took place; in 1952 the rate was 1½*d.* for the first four ounces and ½*d.* for each additional two ounces, the maximum being two pounds. This post comprises practically all kinds of commercial documents wholly or partly printed. It is not remunerative but is extremely popular.

Post Cards.—The next reform was not of British growth. The Austrian post office introduced the inland post card in 1869; it won immediate success, and was adopted in England in 1870, the rate being fixed at ½*d.* For many years only official post cards were allowed; the admission of private cards paid at the post-card rate, first allowed in 1894, was the origin of that notable development, the picture post card. The rate for post cards was increased in 1918 and again later. In 1952 it was 2*d.*

Sample Post.—This was established in 1863 to allow a special rate to bona fide trade patterns and samples. The rate fixed at that time was 3*d.* for 4 oz. rising to 1*s.* 6*d.* per 24 oz., this being the maximum weight permitted. After various reductions the rate in 1870 was ½*d.* per two ounces. Because of the rule that the sample post should be restricted to bona fide samples, it was always found in practice to be extremely difficult to work, and, at various times, it was abolished, only to be reinstituted at a later date. The service is still not very much used. The maximum weight in 1950 was eight ounces and the charge was: not over four ounces, 1½*d.*; not over six ounces, 2*d.*; and not over eight ounces, 2½*d.*

Registration.—The system of granting compensation for the loss of a packet in the post was a feature of the original London penny post of 1680. A parliamentary commission in 1838 recommended a uniform system of registration at a charge of 2*d.*, liability being accepted up to £5. The reform of postage rates, however, caused the postponement of the scheme and it was not until 1841 that a general registration system came into being, and then only in an attenuated form, a fee of 1*s.* being charged and no responsibility being accepted in the event of loss. The service was not attractive, and little traffic was obtained; but though the fee was reduced, it was not until 1878 that the principle of compensation was adopted. The amount was originally fixed at £2, but was gradually increased. In 1906 the present system was introduced under which the minimum fee (in 1952, 6*d.*, as compared with the earlier 2*d.*) covers compensation up to £5, and the maximum fee £400. The service is very popular, about 146,000,000 registered letters and parcels being sent in 1950.

Business.—The growth of postings is of considerable interest as an indication of the expansion of trade, the spread of education and, of course, of the extension of postal facilities. Table I gives for each decade since the establishment of penny postage the total number of packets of all kinds sent by post and the number per head of the population in Great Britain.

TABLE I.—*British Postal Statistics*

Year	Number of postal packets of all kinds	Percentage of increase or decrease	Number per head of the population
1839	82,000,000	—	3.1
1849	169,000,000	+106	6.4
1850	327,000,000	+ 93.5	13.2
1860	646,000,000	+ 97.6	22.2
1870	877,000,000	+ 35.7	28.0
1880	1,662,000,000	+ 89.5	47.5
1890	2,620,000,000	+ 57.6	69.4
1900	3,723,000,000	+ 42.1	89.7
1910	5,281,000,000	+ 41.8	116.7
1920	5,716,000,000	+ 8.2	127.0
1930	6,959,000,000	+ 21.7	152.0
1940	6,579,000,000	− 5.5	137.0
1950	8,732,000,000	+ 32.7	163.7

BRITISH RAILWAY MAIL SERVICE

Letter Mails.—The first regular railway service to be established was that between Manchester and Liverpool in 1830, and the first Conveyance of Mails act was passed in 1838. Under this act, the provisions of which still govern in essentials the relations between the post office and the railways, the postmaster general was given powers to call on the railway companies to convey his mails and guards in all trains, ordinary and special, and to provide if required the use of a whole carriage for the purpose of sorting letters. The only financial provision in the act was that the railway companies should receive "reasonable remuneration" for their services, any negotiations which could not be settled amicably being referred to arbitration.

Even at this early stage it was seen that the value of the railways lay not only in their superior speed but in the facilities they afforded for doing in a swiftly moving railway carriage the work of sorting letters which would otherwise fall on a stationary office, and so of securing a very considerable advantage in time of delivery. The first travelling post office was established between Birmingham and Liverpool in 1838. Later in the same year another travelling post office was established between London and Preston, leaving Euston station at 8:30 P.M. At mid-20th century it still left Euston at 8:30 P.M. but terminated at Aberdeen. The speeds on the earlier railways were comparatively slow. The journey from London to Birmingham occupied five and one-half hours, and from London to Manchester or Liverpool nine and one-half. These times were, however, less than half those occupied by the stagecoaches. The last coach was not withdrawn until 1847.

In spite of the great improvements which they offered in the mail service, however, the railways entailed a much heavier cost on the post office than their predecessors, and for several years after their establishment there were difficulties between the companies and the post office on the question of payment.

At the outset mails not carried in a travelling post office were dispatched by train in charge of a post-office guard. The system worked satisfactorily enough for the small mails of the 1830s; but the great growth in the number of letters which followed the introduction of penny postage soon made this method of transmission inconvenient and unnecessarily costly, and in 1848 statutory powers were obtained under which the railway companies were obliged to convey mails by train in charge of their own guards, which remained the normal method of transmission for the great bulk of the mails sent by railway.

Far reaching as are the statutory powers of the postmaster general with regard to the railways, in practice they are never invoked, and the details of the postal service are settled by contracts negotiated with the railway authorities. The main requirement of the post office in the contract is the running of trains at times convenient to the mail service, which cannot be altered without the consent of the postmaster general. Great Britain is covered by an intricate network of mail trains providing complete and direct communication between the different divisions and between all parts of the country, the speed of which is equal to or, in some cases, better than that of the best passenger trains. On the west coast route to Scotland, on which one of the first travelling post offices was established, there is a special train devoted entirely to the post office, running nightly in each direction between London and Edinburgh, Glasgow and Aberdeen. This is the trunk main-line mail service of Great Britain, and the staff working in the train varies between 50 and 70 at different times on the run. A similar special train runs in each direction between London and Penzance. In all other cases the mail trains convey passengers as well as mails.

A special feature of the English mail-train service is what is known as the mailbag apparatus, a mechanical contrivance by which mailbags can be dispatched from and received in travelling post offices while the train is travelling at full speed.

Inland Air Mails.—The internal air services provided for passengers and freight are utilized for the conveyance of letter mails wherever this method of transport provides an earlier delivery than otherwise obtainable. No additional postage is payable for this air conveyance.

The Parcel Post.—An international parcel post was established at the Postal Union congress in Paris in 1878. The Post Office Parcels act of 1882 was passed, establishing an inland parcel service in Great Britain which came into operation in the following year. The maximum weight of parcels was fixed at seven pounds, with a scale of postage varying from 3*d.* to 1*s.*, according to weight. No individual contracts were made with the separate railway companies, but the post office paid to the railway clearinghouse

55% of the postage received on all parcels conveyed by railway, the distribution of the sums thus received among the railway companies being undertaken by the clearinghouse. This arrangement enabled the post office to maintain the principle of a flat rate of postage for the whole country.

It soon became evident that for short distances it was possible to convey parcels by road at a lower cost than the payment to the railway companies provided under the act, and very shortly after the establishment of the parcel post parcel coaches were established by the post office. These road services took on a new development with the coming of the internal-combustion engine. The higher speed and greater capacity of the motor van made a large extension of the coach system practicable, and at the outbreak of World War I it had reached considerable dimensions, parcels being carried by road during the night between large towns up to a distance of 120 mi. Following fresh negotiations with the railway companies, it was enacted by the Post Office Parcels act of 1922 that the percentage of the postage payable to the railway companies should be reduced from 55% to 40%, the post office for its part agreeing that the railway companies should be entitled to claim a revision of their remuneration if the number of parcels conveyed otherwise than by railway exceeded 10% of the total number transmitted by post. Under these arrangements many of the road services were terminated as being no longer remunerative.

Since the establishment of the service, the maximum weight has been raised from 7 lb. to 15 lb., and the postage rates have been varied from time to time. The rates in 1952 were 11*d.*; 1*s.*, 1*d.*; 1*s.*, 3*d.*; 1*s.*, 5*d.*; 1*s.*, 7*d.*; 1*s.*, 9*d.*; 1*s.*, 10*d.*; 1*s.*, 11*d.*; and 2*s.* for parcels not over 2 lb., 3 lb., 4 lb., 5 lb., 6 lb., 7 lb., 8 lb., 11 lb. and 15 lb. respectively.

BRITISH MAIL PACKET SERVICE

The first regular government mail packet service was established by Queen Elizabeth I in 1598 between Holyhead and Dublin. At that period, however, foreign communications were of greater postal importance than those with Ireland, and when James I reaffirmed the post-office monopoly in the case of foreign letters and appointed a postmaster for foreign parts, it clearly became incumbent on the post office to provide a regular means of communication with foreign countries. Witherings, who subsequently reformed the inland post, began his career by establishing efficient and regular communication with France by means of hired boatmen engaged to carry the mail between Dover and Calais. For the next 50 years the service appears to have been somewhat unsatisfactory and development slow; but in 1686 a regular service was established by government packet between Harwich and the Netherlands, which was followed in 1688 by a service from Falmouth to Corunna, Sp., and in 1703 by a weekly service from Falmouth to Lisbon, Port. The growth of the British oversea possessions in the 18th century led to further developments. After an unsuccessful attempt at the beginning of the century, regular packets were put on from Falmouth to the West Indies in 1745; packets also ran to North America, and by the end of the 18th century they served a great part of the world. The packets themselves were small, being only 70 tons on the shorter services and on the ocean routes 150, vessels of the latter tonnage being, according to a report of 1788, considered fit to go to any part of the world.

The next important event in the history of the packets was the introduction of the steamship. Steamship communication with Ireland was established in 1816, and in 1821 a mail packet of 205 tons burden was put on this service, being followed in the next year by a steamship on the Dover–Calais route. It soon became evident, however, that mails could be carried more advantageously by private companies than by the government, and in 1831 the principle of inviting tenders for the mail service from private companies was introduced.

In the earlier part of this period the government definitely adopted the policy of subsidizing steamship companies in order to establish regular communication on routes where ordinary traffic would not have justified the requisite expenditure, and to ensure the provision of a better type of vessel than would otherwise have been forthcoming. The first contract was made with Samuel Cunard in 1839 for a subsidy of £55,000 a year and was speedily followed by others. The subsidy policy, however, proved in practice very costly, the expenditure having by 1853, when it became the subject of a parliamentary inquiry, reached the very considerable sum of £853,000. After that time the principle of the subsidy gradually disappeared; its object had been fulfilled by the establishment of such far-reaching mail services as those of the Peninsular and Oriental company, the Royal Mail Steam Packet company and the Cunard White Star line.

The use of noncontract ships for providing the mail service was, in fact, a return to an earlier epoch in the history of the overseas mail service. The government packets in the 17th and 18th centuries were far from covering the whole field; for example, Africa and Asia were never touched by them, and for correspondence to and from a great part of the world the only means of transport was the private ship. The post office for a long period made only a feeble attempt to secure control of this means of communication. The measures taken were not effective, and as late as 1827 certain coffeehouses, which had customarily kept bags for the acceptance of overseas mail, were still collecting letters in defiance of the law. The general improvement in the postal service, and in particular the effective measures taken to establish regular mail services by private ships whenever such a course was advantageous, gradually abolished the incentive to forward letters by other means than by the post office.

AIR MAILS

The history of air mails in Great Britain begins in 1911, when to celebrate the coronation of King George V an air-mail service was run between Hendon and Windsor. Twenty-one trips were performed and a considerable number of picture post cards, etc., carried; but the service was very irregular and did not hold out much promise of the development which came a few years later, thanks to the great progress made by aviation during World War I. After the Armistice, an experimental service between Folkestone and Cologne, set up for the benefit of the army of occupation, was followed in Nov. 1919 by a regular service between London and Paris, on which the air fee, originally fixed at the high rate of 2*s.* 6*d.* an ounce in addition to postage, was soon reduced to 2*d.* an ounce. Other regular services to European countries followed (including an air parcel service between London and Paris in 1921); air-mail services spread further afield, the inauguration of the England-India service in March 1929 being the first stage in extending air-mail services from the United Kingdom to the commonwealth.

During the decade preceding 1939 the United Kingdom post office introduced the so-called "all-up" system, whereby first-class mail was sent by air at normal rates of postage whenever it would thereby secure earlier delivery, in the service to many European countries. An all-up system at a postage rate of 1½*d.* per one-half ounce was also introduced, under the Empire Air Mail scheme, on the British Commonwealth air routes to the Union of South Africa and Australia.

The outbreak of World War II led to the suspension of many air-mail services and the reintroduction of surcharge services on other routes. Aircraft capacity was at a premium and, to meet the urgent needs of forces personnel in particular, an "airgraph" service, both from and to the United Kingdom, was introduced in 1941. A lightweight air letter service to the United Kingdom was also introduced in 1941, but did not commence in the outward direction till Dec. 1942. In the airgraph service the messages were written on special forms which were handed in at post offices. The form was photographed on a strip of film 100 ft. long by 16 mm. wide. The film strip, containing 1,700 messages, when enclosed in a cardboard container weighed only 5½ oz., whereas a similar number of letters by ordinary post would have weighed about 50 lb. On receipt at their destination by air, prints prepared from the photographed messages were delivered to the addressees in the ordinary way. More than 350,000,000 airgraph messages were conveyed during the four years in which the service operated.

With the termination of the war, steps were taken to reintroduce air-mail services throughout the world, and it was made possible not only for first-class mail but for second-class mail (at a reduced rate of postage) to be sent from the United Kingdom to practically anywhere. The air letter form was retained as a specially cheap form of air-mail service. The all-up service to European destinations was reintroduced and extended, but the high cost of air transport in the postwar period precluded its introduction on the intercontinental routes. Air parcel services were introduced to many destinations.

MISCELLANEOUS SERVICES

In addition to the general postal service placed at the disposal of the public, a certain number of special facilities may be obtained by those who wish to have a more rapid or convenient method of delivery. The most important is the express delivery, which was established in 1891. There are several varieties of express delivery, the most useful of which perhaps is that by which a letter or packet may, at any time at which messengers are on duty, be dispatched by special messenger to its destination on payment of a small mileage fee. Living animals are accepted for express delivery if a suitable receptacle or lead is supplied and provided the sender takes precautions to safeguard the postal official from injury. A further service provides for the delivery, immediately on arrival, of letters or parcels received by the ordinary mail, at the request of the sender; and the same facility is given at the request of an addressee who is expecting an important letter.

When a quicker transmission is desired than that afforded by ordinary mail, letters can be accepted at many post offices for conveyance by messenger to the railway station for dispatch by the next available train. A messenger will meet the train and deliver the packet to the addressee. For certain addresses in Great Britain this arrangement applies to inland air services.

When a regular early delivery of correspondence is desired, any firm or person may rent a private box at the post office, from which he or his messenger may obtain his letters and parcels on application. If, again, his postings are on so considerable a scale that the application of postage stamps becomes inconvenient and expensive, he may on certain conditions arrange to pay the postage in cash; large users of the post may have their correspondence or parcels collected from their premises by the post office. Another method of avoiding the use of postage stamps is the employment of postal franking machines, which are licensed by the post office. These machines impress the correspondence with a red franking stamp which is accepted as the equivalent of a postage stamp. Each machine is provided with a meter, which is set from time to time at the post office, postage being prepaid in cash on the number of impressions which the meter is set to register.

THE BRITISH POST OFFICE AS BANKER

Savings Bank.—The British Post Office Savings bank was set up in 1861, as a result of legislation introduced by William Ewart Gladstone. The object was to encourage thrift among the lower-income classes, and limits were therefore set to the amount of money which could be deposited. The maximum amount which may be deposited in one year by any individual is £500 and the maximum balance which may be held is £3,000. Interest is allowed on complete pounds at the rate of 2½% and is added to the balance at the end of each calendar year. All accounting is centralized, but a depositor may pay in or withdraw money at any post office in the country at which savings bank business is transacted. There were about 18,500 of these offices at mid-20th century. A withdrawal on demand up to £3 at a time may be made at any savings bank post office. To make larger withdrawals a notice has to be sent to headquarters and an authority to pay is issued to the office named by the depositor. Within certain limits withdrawals may be made by telegram. All deposits are handed over to the national debt commissioners, by whom they are invested for the Post Office Savings Bank fund. The post office draws on the fund to cover withdrawals, and the interest earned by the investments of the fund is set against the interest due to depositors and management expenses. The Post Office Savings bank has enjoyed increasing popularity through the years. The appeal for savings to help finance World War I gave it an additional impetus, but the accretion of business during World War II passed all records. In 1938 the number of active accounts was about 11,000,000 with a total balance of more than £500,000,000. By the end of 1951 the active accounts numbered more than 22,450,000 and the balance due was more than £1,875,000,000. Since 1945 more than 6,500,000 accounts had been set up with initial credits of £370,000,000 in respect of war gratuities and postwar credits for personnel of the fighting and civil defense services but many of these accounts were short-lived.

Insurance and Annuity Business.—In 1864 the post office was authorized to set up an insurance and annuity business through the savings bank, but this business has never been of more than moderate dimensions. Insurance business was discontinued on Dec. 31, 1928.

Post-Office Stock Register.—A much more successful development was instituted in 1880 when facilities were given to depositors in the savings bank to purchase government stock up to a limit of £300. A simple method of purchase was devised at a low rate of commission, and dividends were credited to the purchaser's savings bank account. At a later date the link between the savings bank and the post-office stock system was loosened, and it was no longer necessary to be a savings bank depositor in order to hold stock through the post office, nor need dividends be paid into a savings bank account. During World War I the machinery proved of great value to the government in making it possible for the small investor to purchase or subscribe to government stock. For many kinds of government stock there was a post-office as well as a Bank of England issue, and subscriptions could be made at most post offices. The most outstanding development of the post-office register occurred during World War II, when a special issue of defense bonds, restricted to the post-office register, was made. The bonds made an appeal to all classes; although a maximum limit of £1,000 (later increased to £3,500) was set to each holding, the peak holdings of the bonds reached a total of more than £1,000,000,000. The issue open to subscription from Sept. 1, 1952, bore interest at 3½% per annum and individual holdings were limited to £1,000. Including other stocks the total of investments on the post-office register at the end of 1951 was £997,743,000 and the number of stock and bond holders was 2,954,000.

Savings Certificates.—A further simple and popular method of investment managed by the post office is the national savings certificate. Originally issued in 1916, it proved attractive to all classes during World War I as a means of helping the war finance, and at the end of 1918 the value of the certificates held had reached £207,000,000. During World War II the sale of certificates was phenomenal, and the value of the certificates held increased from £381,000,000 in 1938 to £1,720,000,000 at the end of 1951. These figures are exclusive of accrued interest. The number of holders was about 18,751,000.

The early certificates were based on a unit of £1, which was the value given to the certificate after it had been held for a number of years. The purchase price of the certificate varied from time to time according to the rate of growth and the number of years before the value reached £1. For the first issue of certificates the purchase price was 15*s.* 6*d.* and the value of £1 was reached in five years. The purchase price of the ninth issue was 15*s.*, with an increase to £1.0*s.*, 3*d.* after ten years. Interest on the certificates is not paid separately but is included in the value when the certificate is repaid. Certificates are repayable at any time after a few days' notice. The accrued interest is free from income tax. Limits are imposed on the number of certificates which may be held by one individual.

Savings Stamps.—Various aids have been introduced from time to time to encourage the saving of quite small sums (*e.g.*, home safes and slips to which postage stamps could be affixed), but the method of national savings stamps became the main as well as the most popular method. The stamps are issued in de-

nominations of 6*d.* and 2*s.* 6*d.* The stamps can be used for the purchase of savings certificates or stock or for deposit in the savings bank, but they can also be cashed freely at post offices.

Savings Department.—The conduct of the savings bank, savings certificate and stock business of the post office is concentrated in the post-office savings department, which is thus responsible for accounts containing about £4,600,000,000 of the public's money. There are few, if any, families in the United Kingdom which have not a share in these savings in some form or other.

Money Orders.—The original establishment of the money order service was a result of the desire of the postmasters general toward the end of the 18th century to prevent the theft of money carried in letters in the post. There was some doubt whether such a service could be established by the post office under its existing powers, so by a curious compromise certain officers of the post office were allowed in 1792 to set up a service on their own account, the cost of advertising it being borne by the postmaster general, who also allowed the relative advices to pass free of postage under the post-office frank. The money order service was taken over by the government in 1838. The rates of commission charged to the public have varied from time to time, and the maximum amount for which a single order may be issued increased until by 1950 the maximum for an inland order was £50. Notwithstanding the competition of the cheaper postal order, the money order still appeals because of the security afforded by the special feature of the service—the advice note which is sent to the office of payment and against which the order is checked before payment. In 1951–52, 20,000,000 ordinary inland money orders were issued representing £168,000,000. The telegraph money order service came into operation in 1889 and is utilized to a considerable extent; in 1951–52, 2,500,000 inland orders were telegraphed to the total value of £19,500,000.

The overseas money order service came into being in 1856, when arrangements were made for an inward service to Britain from army post offices at Constantinople, Scutari and Balaclava, this plan being extended to Gibraltar and Malta the following year. The first two-way service was with Canada in 1859, and services with other colonies soon followed. In 1868 the first foreign money order service was started with Switzerland. The service was extended gradually to cover most parts of the world in which an inland money order service operated. A telegraph money order service was started with Germany in 1898 and was subsequently extended to many other countries.

World Wars I and II brought considerable difficulty in maintaining a money order service with foreign countries. At the start of war in 1939 the control of foreign exchange was applied to the overseas money order service, and this control was still operated at mid-century. The number of overseas money orders (including those sent by telegraph) in 1951–52 was 980,000 representing £5,300,000.

Postal Orders.—A reduction in 1871 of the commission charged on money orders under £1 was followed by an increased demand for the low-value orders, and by 1875 the service was being run at a loss. The comparatively high charges which would have been necessary to avoid this loss caused the post office to consider the possibility of introducing a new method of remittance for smaller amounts which would dispense with the advice, an expensive feature of the money order service. As a result the postal order (originally styled postal note) was introduced in 1881. These orders were for fixed denominations up to 21*s.* and in 1951 an order for 40*s.* was added to the range. Odd amounts not less than 1*d.* can be made up by fixing postage stamps to the orders. They must be made payable to a particular person and preferably at a particular office and can be crossed for payment through a bank. The simplicity, cheapness and convenience of the postal order made it an immediate success. In the first two years the number grew from 4,500,000 to 33,000,000 and in 1951–52 the figure was 534,000,000, representing £172,000,000. Considerable use is made of this form of remittance in connection with football pools and newspaper competitions.

The convenience of the postal order soon led to a proposal to extend its use throughout the empire, and in 1903 all dominions, colonies and dependencies were invited to adhere to a scheme for making postal orders available for remittances to and from the United Kingdom, between one part of the empire and another and within the participating country. Most of the commonwealth, with the notable exceptions of Australia and Canada, operates this scheme, and in 1951–52 about 8,400,000 orders were supplied to overseas countries under the arrangement.

BRITISH POST OFFICE AND SOCIAL SERVICES

One of the most striking developments of post-office activities in the 20th century was its assumption of functions which had no connection whatever with its primary purpose but which flowed from its possession of a widespread network of local offices having day-to-day financial dealings with the public. This development began many years ago in the use of the post office for the collection of local or national revenue by means of licence duties. For example, dog, gun and game licences, excise licences and motor vehicle licences are obtainable from the post office, £7,000,000 being collected by this means in 1948–49.

This, however, was a comparatively small item of business and it was far exceeded by business connected with the social services established from time to time. When the Old Age Pension act of 1908 came into operation, the post office became the paying agent. This arrangement was extended to payments under the Widows', Orphans' and Old Age Contributory Pensions act of 1925 and under the National Insurance act which came into operation in 1948. Similarly, war pensions, separation allowances, national assistance allowances and family allowances are paid by the post office. In 1948–49, 560,000,000 orders of these kinds were paid to the total value of £496,000,000. In addition, during the last nine months of 1948–49, 29,000,000 payments representing £50,000,000 were made in respect of sickness benefits due under the National Insurance act.

A considerable number of stamps are sold for other than postal purposes. Certain inland revenue duties may be paid by postage stamps (*e.g.*, receipt duty), but, in addition, the post office has long assisted the inland revenue authorities by selling such inland revenue and fee stamps as are in general use, as well as entertainment duty stamps. There was also a large sale of stamps for the various state insurance schemes culminating in the National Insurance act, 1946. The value of the insurance stamps sold in 1948–49 was £346,000,000.

Revenue is also collected by the sale of broadcast (sound and television) receiving licences. Records are maintained of the persons who hold such licences and steps taken to ensure that the licences are renewed after their validity has expired. During 1948–49, 11,600,000 broadcast receiving licences (sound and television) were issued to the value of £11,800,000. The post office also sells amateur transmitting licences.

BRITISH ARMY POSTAL SERVICE

The British army postal service dates back to the Napoleonic Wars. In 1792 a post-office official went to the Netherlands to organize a private communications service for the British troops there. Similar arrangements were made for the Crimea in 1854, but a military postal service as such first operated in the Egyptian campaign of 1882 when a company of the 24th Middlesex volunteer regiment (post-office rifles) undertook postal duties. Since the beginning of the 20th century at least a nucleus army postal service has existed on an army reserve basis. After 1914 it operated abroad continuously in larger or smaller numbers both in peace and war, and ran services for the air force as well as the army.

Modern British army postal technique began to emerge during the South African War, and it was naturally greatly developed during World War I when large-scale army postal services were needed for the first time. In 1918 the personnel both at home and overseas numbered nearly 6,000, of whom about one-third were women, some being sent to base offices in France for sorting work. Excluding peak traffic at Christmas time the maximum dispatches from home were about 12,000,000 letters and 1,000,000 parcels a week. The services to and from the continent attained

an efficiency and regularity comparable with civil ones of peacetime.

World War II with its various phases and events, extensive and rapid movements of large armies, the closing of the Mediterranean, the world-wide dispersal of British forces, etc., presented postal problems of an entirely new and complicated character. However, a far greater range of postal facilities was provided, largely of necessity, than in any previous war: surface letters and parcels, ordinary air letters, lightweight post cards, lightweight air letters, airgraphs and various types of telegrams. The overseas destinations where the army postal service distributed mail were more than 25 in number, and the maximum traffic amounted to about 17,000,000 letters, newspapers and parcels a week, although during Christmas pressure periods it was much greater. The staff abroad and in the United Kingdom numbered more than 7,000, of whom about 2,500 were women of the Auxiliary Territorial service who performed most of the sorting work at the home postal depot. Liaison and co-operation with British Commonwealth and Allied military postal services necessarily grew to great dimensions by 1944. For the first time, army postal facilities were provided for the army and air force at home. This began soon after the evacuation from Dunkirk and later was greatly used for security purposes for troops who were detailed for the Normandy invasion in 1944. Toward the end of the war extensive air-mail services were provided, and in difficult areas such as Burma parachute dropping of mails was practised extensively.

At the end of 1951 there were still more than 1,200 military and foreign civilian personnel employed in the army post office, mostly overseas.

BRITISH POSTAL STAFF

At the beginning of 1950 the staff of the British post office—postal, clerical, telegraph, telephone and engineering—numbered 353,000, including about 100,000 women, 72,000 industrial engineering staff and 45,000 part-time staff, figures which were increased by between 3,500 and 4,000 in April 1950 by the transfer of staff from the nationalized company, Cable and Wireless Ltd.

The chief administrative questions arising are recruitment, pay, training, welfare and other conditions of the staff, productivity and staff consultation. The bulk of the staff enjoys the usual civil service conditions of permanence of employment and pensionability. Clerical and professional staff generally belong to grades common to the civil service as a whole. Manipulative staff—postmen, telegraphists, telephonists and postal and telegraph officers—are recruited either by interview and selection or by competition; at least half of postmen vacancies are assigned to ex-servicemen. The manipulative staff have opportunities of advancement both by competition and by promotion to higher rank, including clerical appointments. Pay and major conditions of service are settled generally by negotiations with the staff associations or, failing agreement, by awards of the civil service arbitration tribunal, subject to the overriding authority of parliament.

The day-to-day staff administration is eased as much as possible by the organization of the post office into seven functional headquarter departments, apart from administrative headquarters, and ten territorial regions, subordinate to which are about 450 head post offices and 55 telephone managers' areas, and by the utmost possible decentralization of authority to regional directors, head postmasters and telephone managers.

British Postal Trade Unions.—The difficulties which trade unionism has met in outside employment were reflected in the history of the postal staff, and it was not until 1899, after two partial strikes, that the duke of Norfolk consented to receive representations from the Postmen's federation. Thereafter many associations were formed in the post office, indicating the variety of work and the consequent multiplicity of grades. At mid-20th century there were 33 separate associations officially recognized, with an aggregate membership of 275,279. The largest associations and their membership were in 1949 as shown in Table II.

TABLE II.—*Chief British Postal Trade Unions, 1949*

Title	Membership
Union of Post Office Workers	147,508
Post Office Engineering union	50,410
Civil Service Clerical association (post-office section)	22,881
National Federation of Sub-Postmasters	17,200
Federation of Post Office Supervising Officers	12,961
National Guild of Telephonists	11,870

In 1920 relations between the administration and the staff entered on a new phase with the establishment of Whitley councils. General questions common to the post office and the rest of the civil service are discussed on the national Whitley council, but the post office has its own headquarters departmental councils (working largely through smaller joint committees) to discuss general matters affecting the staff, and local committees in head post offices, etc., to discuss local matters. The Whitley machinery has on the whole worked smoothly and disagreements are comparatively rare. Whitleyism has in no way superseded the separate unions, which continue to act as independent negotiating bodies on matters such as wages.

In 1947 machinery for joint consultation on productivity was set up on the engineering side to discuss measures to increase output, and in 1949 similar but more elaborate machinery was established for the nonengineering grades. The Trade Unions act of 1927 forced the post-office unions to sever their connection with the Trades Union congress, but, with the passing of the Trade Disputes and Trade Unions act 1946, three of the unions mentioned above were reaffiliated to the T.U.C. The Union of Post Office Workers also became affiliated to the Labour party.

INTERNATIONAL POSTAL SERVICE

The importance of the international service is evident from the earliest days of post-office history, but the working of the service is somewhat obscure. In the 16th century a regular service seems to have been provided between London and Calais, which was the port on which foreign communications mainly centred. The outward letters seem to have been carried to their destination by English post-office messengers, while inward letters were brought by foreign messengers as far as Calais.

Witherings reorganized the foreign service, and shortly after his time (1670) a regular postal treaty was concluded between England and France. This was renewed in 1698 after the conclusion of the Treaty of Ryswick. The treaty provided that the mail from London for Paris and from Paris for London was to leave twice a week. Between Dover and Calais the English post office provided the mail packets in both directions; the service beyond Calais was provided by France. Letters could be prepaid only to a limited number of destinations—Paris, Rouen or Lyons; any charges for further transmission were collected from the addressee.

This treaty, soon interrupted by further hostilities, was again renewed in 1713. The new version is interesting as containing the germ of the international system of accounting for transit mails which lasted with but slight alteration until the latter part of the 19th century. On letters for Italy, which could be franked to Turin, France was to be paid at the rate of 21 sols per single letter; on letters for Spain franked to Bayonne the payment was 19 sols; on letters for Turkey franked to Marseilles, 17 sols. Double letters were charged approximately twice, and letters weighing one ounce four times the single rate. The accounting between the two offices was based on the sum of the amounts due on the separate letters, mail by mail. The principles adopted in the 17th century show little change in the 18th, and a treaty concluded with France in 1802 shows comparatively little variation from its predecessors of more than a century before.

As time went on the postal treaties required for the establishment of a gradually expanding foreign service became more and more numerous and complicated. The postage depended on the sums payable to the various post offices concerned in the transit of the letters, and these were often based on their own internal rates and units of weight. The result was an extraordinary variety of rates—often differing materially for the same destination according to the route employed—and a considerable variety in the weight

covered by the initial postage rate. Moreover, prepayment was in some cases compulsory, in some cases optional; but compulsory prepayment covered conveyance only up to a certain point, all charges beyond that point being collected from the addressee. The unit of weight was in a large number of cases one-fourth ounce, any letter above that weight being charged pro rata. The lowest postage in force was that to France, which was 4*d.* per one-fourth ounce. A letter from England to Belgrade via France, weighing one ounce, cost 5*s.*; a half-ounce letter to California via Panamá cost 4*s.* 8*d.*, in addition to a further charge on delivery. Even to Spain the postage was 2*s.* 2*d.* per one-half ounce, plus a charge on delivery.

From the point of view of post-office management, the complexity of the service was, with the industrial development of the 19th century and the constant growth of correspondence, reaching a point at which the rapid and accurate handling of the mails became practically impossible. Almost the only advance made over the procedure in force in the 17th century was that letters were weighed in bulk instead of singly. The example of a simple and uniform tariff had been set by the establishment of penny postage, but the principle which underlay Rowland Hill's scheme for obtaining uniformity (viz., that the cost of conveyance of a letter represented only a small fraction of the total cost of its treatment) was far from being applicable to the conditions of the international post.

Formation of the Universal Postal Union.—The first step in the direction of reform was taken by the United States, which in 1862 suggested a conference for the purpose of considering the improvement and simplification of international postal relations. This met in Paris in 1863 and adopted a code of 31 articles, intended to serve as the basis of international conventions. Further progress was delayed first by the American Civil War and then by the Franco-German War. In the meantime, however, another great postal reformer, Heinrich von Stephan of the North German Postal confederation, had prepared a project for a universal postal union, based in part on the conclusions of the conference and in part on the experience of Germany, which had several years before formed a postal union including Prussia, Austria and all the other German states, nearly 20 in number. The Swiss government, at the instance of Germany, summoned a conference to meet at Berne to consider the proposal to form a general postal union.

The Congress of Berne in Sept. 1874 was attended by the representatives of 22 states, including the whole of Europe, the United States and Egypt. The result of the congress was the signature of the first International Postal convention, which remained from 1875, with comparatively little modification, the foundation of the international postal service.

The fundamental principle of the union is contained in a striking article which lays down that for the purposes of postal communication all the signatory countries form a single territory. The practical application of this principle lies in the doctrine of liberty of transit; every member of the union binds itself to transmit the mails entrusted to it by every other member by the best means of communication which it employs for its own letters. Thus each country has in effect the full and unrestricted use of the railway and steamship services of the whole world, and any improvement made by any member of the union is placed at the disposal of any other which desires to utilize it.

The membership of the union was at first somewhat limited, and was mainly European, although from the first the United States, Asiatic Russia and Asiatic Turkey were included. Extensions of membership were, however, rapid. Ten years after its foundation the union included 86 postal administrations; by 1900 there were 113 and at mid-century there was hardly any part of the world remaining outside.

The Postal Union Organization.—The organization of the union is simple but effective. Most questions are settled directly between the countries immediately concerned, but for matters in which the whole union is concerned an international bureau is maintained at Berne. The bureau collects and distributes information of common interest, publishes statistical returns, a monthly journal, lists of steamship and air services, etc., and acts if required as a clearinghouse for the settlement of accounts. The cost of the bureau is apportioned in a ratio corresponding to their importance between the various members of the union.

The Universal Postal convention and the subordinate agreements are reviewed periodically, usually at intervals of five years, by a congress to which every member is invited to send delegates. In cases of dispute between postal administrations, the union has adopted the principle of compulsory arbitration. Serious disputes are infrequent, but when they occur the arbitration machinery has invariably been effective.

Four Chief Principles.—The first principle was the uniformity of postage rates and of units of weight. The Congress of Berne adopted the rate of 25 gold centimes per 15 g. for letters, but permitted a certain variation within a definite maximum and minimum, and the rate of 7 gold centimes, with a similar variation, per 50 g. of printed papers. In 1878, however, standard uniform rates in gold centimes were adopted for letters, post cards and printed papers and were retained unaltered until 1920. The only variation allowed was the addition of a surtax in cases where heavy costs for sea transport were incurred. The conditions which followed World War I swept away the uniformity which had prevailed for 40 years and brought about a reversion to the original principle of a maximum and a minimum rate which has been maintained ever since. The only change in the units of weight has been the raising of the letter unit from 15 g. to 20 g., or to one ounce for English-speaking countries.

The second basic principle is the classification of postal correspondence into three groups—letters, post cards and printed papers (including commercial papers and samples). Definite conditions of acceptance, as well as separate rates of postage, were adopted; the delicate distinctions between what can be sent at the cheap rate and what must be charged as a letter, which are often puzzling to the public, depend on international decisions which no individual country is in a position to vary.

The third principle was the adoption of definite payments to be made by the country which dispatches mails by the trains or steamships of another country for the use of those services, with the exception that no payment is made to the country of destination, the flow of correspondence in each direction being assumed to be approximately equal. Here there has been no continuity of practice. Rates for sea services in particular were at the outset extremely high. Over the years the rates for sea and land services have been adjusted from time to time to meet changing circumstances.

The fourth principle was the universal adoption of a system of registration and compensation. International registration differs from internal registration in one important particular, which often puzzles and annoys the sender of a letter. The compensation payable is a fixed amount and is allowed only in the event of the entire loss of the registered packet and not for damage or loss of contents. This principle the union has steadily maintained from its inception.

Later Changes.—The original convention applied only to letter mails, but from an early date supplementary agreements were adopted at successive congresses for various extensions of the postal service. In 1878 an agreement for an international money order service was signed by a considerable number of countries; at the same time an insurance service, which provided for payment of compensation for loss or damage of letters containing documents of value (paper money, etc.), was established. This was later extended to cover insured boxes containing valuables such as gold or jewellery. The amount insured varies with the fee paid, and the maximum varies in different countries.

A further considerable advance was made in 1880, when 19 countries concluded a parcel-post agreement. The original agreement was limited to parcels not exceeding three kilograms; it prescribed a simple procedure and fixed rates of payment both for terminal and for transit countries. The scope of the service expanded considerably and provides both for an insurance and a cash-on-delivery service. The agreements above mentioned are not adopted universally throughout the union; for example, neither Great Britain nor the United States has adhered to the

parcel-post and money order agreements; but where separate agreements have to be concluded, they generally follow with only slight variations the principles sanctioned by the union.

At the Congress of Paris in 1947 the union accepted a relationship agreement with the United Nations under which it became a specialized agency.

Commonwealth Preferential Postage.—The idea of adopting preferential postage rates on political grounds began to develop in the era following the establishment of the Universal Postal union, and it was decided by the Postal Congress of Washington in 1897 that the postal union convention should permit the establishment, by agreement, of rates below the standard postage. This decision, coinciding with a growth of the feeling of the unity of the British Commonwealth, led to the introduction in 1899, following a special conference, of "imperial penny postage" at a rate of 1*d.* per one-half ounce to Canada, India, South Africa and the crown colonies generally; it was extended to New Zealand in 1901 and Australia in 1905. A few years later (1908) the United States was included in the scheme. Throughout the various changes in letter postage brought about by World Wars I and II the principle of maintaining the initial imperial letter rate at the same point as the initial inland rate has been uniformly observed.

POSTAL SERVICE OF THE COMMONWEALTH OF NATIONS

In the early days of colonial expansion the postal services established overseas were in theory and to a large extent in practice under the direct control of the postmaster general of Great Britain. Reasons of practical convenience and the development of autonomy in the dominions and colonies gradually led to the establishment of independent postal services.

Australia.—Australia's largest business undertaking, the department of the postmaster general, had its beginning in the colony of New South Wales with the establishment of the first post office in Sydney in 1809.

The Australian post office serves the public through 10,000 offices and employs more than 80,000 persons. The postal system covers not only the handling of mails and the transmission of money, but extends to the management of telephone and telegraph systems of the country and to the maintenance of the technical side of the national broadcasting service.

An overland mail service between Sydney and Melbourne commenced in 1838. Sydney and Melbourne were further linked by telegraph in 1858, and telegraphic communication between Australia and other countries was established in 1872. The telephone was introduced only two years after its invention in 1876, and the first telephone exchange (in Melbourne) was opened in 1880.

Australia's first official air-mail service was established in 1921 between Geraldton and Derby in Western Australia, and was extended through to Perth two years later. At mid-century more than 50 internal networks linked all states with subsidiary services to many parts of the interior, covering a route distance of about 39,000 mi. In addition, overseas air-mail services operate several times weekly, bringing Europe and America within a few days' distance by correspondence.

Before federation in 1901, each of the six colonies had maintained its own postal, telegraph and telephone services, but with the passing of the Post and Telegraph act, 1901, by the new federal parliament, the six separate postal services were combined into one federal system. In 1901–02, the first full financial year of operation under the control of the commonwealth, the expenditure of the Australian post office was less than £2,500,000. Expenditure had reached £10,000,000 by 1921–22 and £20,000,000 by 1941–42. Six years later, expenditure had again doubled to reach £40,000,000. In 1948–49 it amounted to £53,400,000.

Canada.—Postal service dates from the French regime when in 1705 a courier first carried official and private mails between Quebec, Trois Rivières and Montreal. The post office was established under the British crown by Benjamin Franklin in about 1763 and formed part of the North American system until the American Revolution. In 1851 the separate Canadian provinces assumed control of their postal services, which were merged into a centralized Canada post office at the time of confederation. At mid-20th century Canada operated approximately 12,000 post offices, with revenue reported at $95,957,469 for the year 1948–49 —a 300% increase in 15 years. Ordinary letters up to one ounce in weight, posted in Canada to a domestic address, are carried by air by all-up service whenever delivery can thus be effected more quickly. Canada's air-mail service connects with U.S. and world air networks and operates directly to the United Kingdom, the West Indies, Australasia, Japan and Hong Kong. Its money order service has an annual turnover exceeding $415,703,000, and its Post Office Savings bank does a considerable business.

India and Pakistan.—From time immemorial communication between the different parts of India was maintained by means of couriers both on horse and on foot by the rulers, but this was limited to the carriage of the rulers' mail. After the occupation of India by the British, a somewhat similar postal service was established by Robert Clive in 1766; but this was also mainly intended for official correspondence, and the same principle was followed for many years during the gradual extension of British rule in India.

The post was first made available to the public in 1774 when a regular organization was set up. It was not until 1837 that it was considered to be sufficiently developed to warrant the establishment of a monopoly in favour of the official post.

The Indian post office prior to partition in 1947 was governed by legislation called the Indian Post Office act. The area to be served is immense, and the cost of transport relatively heavy; moreover, the policy of uniform rates irrespective of distance, adopted in England in 1840, was accepted in India as early as 1854, and the aim of the government was to fix the rate as low as possible, the post office never having been expected to make any considerable profit. India became a founder member of the Universal Postal union in 1876.

The number of letters delivered annually is about 1,837,000,000, an average of six letters a head each year. Post-office work has shown a steady and considerable increase, the volume having doubled in a period of about 20 years by 1950, when the inland letter postage was 2 annas (2*d.*), the post-card rate ¾ anna, the newspaper charge for a weight of ten tolas only ½ anna. A considerable parcel-post service was maintained at comparatively low rates, a parcel of 40 tolas (1 lb.) being conveyed for any distance for the low charge of 6 annas (6*d.*).

A money order service with an annual turnover of nearly Rs. 1,180,000,000 is maintained, and the value payable (cash or delivery) post, which by 1950 had been established in India for more than 70 years, was also highly developed, the annual value being more than Rs. 340,000,000.

India is one of the few countries where first-class mail is carried by air at night and carried on the all-up basis without any surcharge. India was the first country in the world to use aerial post (in 1911) and also the first country in the commonwealth to issue a special set of air-mail stamps (in 1929).

In Pakistan, air-mail service between the eastern and western parts of the nation was set up soon after the partition of India in 1947. Air-mail links were also established with the United States and practically all other foreign countries. Pakistan also joined the Universal Postal union.

New Zealand.—The New Zealand post office, ministerially controlled by a postmaster general with cabinet rank and the permanent head of which is the director general, not only provides all kinds of postal service but also controls the telegraph, telephone and radio services. In addition it acts as agent for many other departments; *e.g.*, the land and income tax department, the social security department, the public trust office, the State Advances corporation and the registrar of births, deaths and marriages.

The first post office was established at Kororareka (Bay of Islands) in 1840, and the first postage stamps were issued in 1855. The postal department and the telegraph department were amalgamated in 1881. In 1901 New Zealand introduced penny postage not only inland but with all countries of the empire and also with every foreign country which would accept it, submitting to the

Postal Union congress of Rome in 1906 a proposition, which was not successful, for the introduction of penny postage on a universal basis. The initial letter postage rate was *2d.* in 1950.

Scattered throughout the country were 1,933 post, telegraph and telephone offices in 1949. In addition, an extensive rural system of mail delivery was operated. Altogether there were 50,000 rural box holders. Postal traffic is heavy in relation to the population. During the year ended March 31, 1949, 319,229,000 articles of all kinds were posted, an average of 180 a head.

Union of South Africa.—The first regular postal service was introduced in South Africa in 1806 when communication was established between Capetown and the important centres by Hottentot postboys. These foot messengers were replaced by horsed post orderlies, and subsequently the development of the railways made rapid communication possible on an extensive scale. Later the internal air service became a normal means of transmission for letters.

The four states of South Africa maintained their separate post offices until the formation of the Union in 1910, when a centralized postal administration was formed. By 1949 there were 3,400 post offices in the Union employing a staff of more than 30,000 persons. The total volume of postal traffic for 1947 amounted to 605,669,000 articles of all kinds.

The inland letter rate in 1949 was 1½*d.* for the first ounce and 1*d.* for each additional ounce, and the post-card rate was 1*d.* Parcels were charged for at the following rates: up to four ounces in weight, *2d.*; up to eight ounces, *4d.*; and thereafter, *6d.* a pound. An interesting feature is the agricultural parcel post for the conveyance of primary products of the soil, horticultural and dairy produce and foodstuffs produced within the Union. The rates range from *3d.* for 1¼ lb. to *1s.* for 11 lb. Cash on delivery and insured parcel services also operate.

South Africa, alone among the commonwealth countries, is the contracting party for the regular sea conveyance of the mails exchanged with the United Kingdom.

POSTAL SERVICE IN OTHER COUNTRIES

France.—The creation of a state post in France is generally held to go back to the edict of Luxies issued by Louis XI in 1464, the authenticity of which is, however, disputed by certain historians.

In the course of the centuries, modifications in organization were introduced by different sovereigns. They all aimed at reducing the existing privileges enjoyed by private messengers and at increasing the control of the royal power over the postal service. The culmination of this policy is the edict of the consuls of the 27th *Prairial*, year IX (June 16, 1801), the provisions of which, fixing the basis of the postal monopoly, are still in force.

The system of "farming" the posts which was tried in England for a short period during the 17th century was maintained in France up to the time of the Revolution. In 1792 the system was suppressed and the posts raised to the status of a national agency. In year III (1794–95) this was replaced by an administration-general of posts and stagecoaches, which was transformed in 1804 by Napoleon I into a directorate-general placed under the authority of the minister of finance. Later, by reason of the importance which the postal service had come to assume in the general economy of the country, the control of the postal administration was entrusted, sometimes to an undersecretary of state attached to a minister, sometimes to a minister. The postal administration is now generally placed under the authority of a secretary of state or of a minister.

In the course of the 19th century and the first half of the 20th century, various services were attached to the postal administration—money orders, telegraphs, telephones, postal cheques, etc. Moreover, in view of the number of post offices (20,000), which permits contact with the mass of the population, the postal service has been given the task of carrying out various operations on behalf of other organizations or administrations (National Savings bank, National Bank for Old-Age Pensions, payment of civil and military pensions, investment of state loans, payment of dividend warrants, etc.).

The following figures will give an idea of the importance of the postal traffic. In 1948 the French posts transported about 4,500,000,000 items of ordinary correspondence and 160,000,000 registered and insured items. Moreover, 137,000,000 money and postal orders were issued representing 1,500,000,000,000 fr.

The economic and financial conditions resulting from World Wars I and II made it difficult to stabilize postal charges. These charges are fixed generally in relation to cost. However, with a view to aiding the development of commerce and of public information, certain charges are fixed below cost—in particular, those for printed matter and newspapers. Similarly, for easily comprehensible reasons, the charges for the internal service are applied *in toto* to items for the territories of the French union.

The parcel-post service, as in all countries, is the responsibility of the postal administration. In France, however, the operation of the service is entrusted to the French National railways (S.N.C.F.). The relations between the postal administration and the railways are laid down in various documents, notably in a convention signed in 1945.

The National Savings bank created in 1881 operates under state guarantee; it is placed under the authority of the minister of posts, telegraphs and telephones, and is represented in its relations with depositors by the postal administration. On June 30, 1949, there were 12,800,000 National Savings bank accounts in existence and the amount standing to the credit of depositors amounted to 208,000,000,000 fr.

Finally, the postal cheque service created in 1918 enjoys an increasing popularity with the French public. At the end of 1948 there were 2,600,000 current accounts in operation, and the total amount of the transactions, debit and credit, carried out in the course of that year reached 15,000,000,000,000 fr.

Germany.—In 1919 postal and telecommunications matters in Germany became the exclusive affair of the German reich—the head of the *Reichspost* being the *Reichspostminister* responsible to the reichstag. The *Reichspostfinanzgesetz* (Imperial Post Office Finance act) of 1924 established the post office on an independent financial basis analogous to that of a commercial company, so that apart from a tax on revenue the treasury had no claims on post-office finances and vice versa. The post-office administration fixed the estimates of expenditure, decided on questions of borrowing for post-office purposes, redemption of debt, investment of postal cheque office balances, rates of pay, classes of business and rate of postage and telegraph and telephone charges.

The *Reichspostminister* was assisted by an administrative council, and decisions of the council were implemented by ordinances issued by him. In 1934 the council was replaced by an advisory committee, a change intended only to simplify procedures and reduce administrative costs. At the capitulation in May 1945 the *Reichspostministerium* completely disintegrated and only the *Reichspostdirektion* (regional headquarters) and subordinate offices remained in any more or less organized form. By order of the Allied military government all post-office services were suspended. At this time 70% of the post-office buildings had been seriously damaged and 17% totally destroyed, and the staff and transport were dispersed and disorganized. During 1945 a zonal administration was set up in each of the British and U.S. zones of occupation, but these were replaced by a bizonal administration early in 1947. With the creation in Sept. 1949 of a federal republic covering the British, French and U.S. zones, the bizonal administration gave way to a federal ministry for posts and telecommunications. At the end of 1949 the new federal ministry employed in all services, including postal, telecommunications, savings bank, *Postcheck*, etc., about 272,000 people serving a population of 41,500,000.

Despite the serious setback during and immediately after World War II, the volume of business in 1949 approached the 1938 figures with an annual postal traffic amounting to 3,400,000,000 letters, 99,000,000 parcels and 656,000,000 papers and periodicals. The savings bank, which remained in business throughout the whole of the financial chaos following the capitulation, had 37,000,000 transactions (deposits and withdrawals) in 1949 with a

turnover of 220,000,000 DM., while the *Postcheck* service transacted business to the value of 132,700,000,000 DM. The number of telegrams reached a peak of 4,000,000 a month in May 1948 but settled down to an average of 1,800,000 per month or 21,000,000 a year—a figure 50% greater than 1938.

The number of telephone installations totalled 1,750,000 or 5% less than in 1938, but the traffic at 112,000,000 local calls and 21,000,000 long-distance calls per month exceeded the 1938 traffic by about 10%. The revenue from posts and telecommunications operations for the year 1949 was of the order of 1,700,000,000 DM.

Transmitting stations for radio broadcasting were provided and maintained by the *Deutschepost* until 1948, in which year they were transferred to the several broadcasting corporations then in existence. The number of listeners' licences at the end of 1949 totalled 6,250,000—20% more than in 1938.

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UNITED STATES

The first system of posts in the United States was legalized in 1639 by the general court of Massachusetts. The ordinance directed that all mail brought from overseas was to be left at the home of Richard Fairbanks in Boston, who would have it transmitted onward to destination. Fairbanks was allowed a penny for the transmission of each letter. In 1672 Gov. Francis Lovelace of New York established a monthly post between New York city and Boston over what later became the Boston post road—U.S. highway route no. 1. In 1683 Gov. William Penn of Pennsylvania established a post office in Philadelphia, where Henry Waldy, the first postmaster, was authorized to send mail weekly between Philadelphia and Newcastle, Del., and to supply the riders with horses to serve the routes. A post route extending from Maine to Georgia was established in this same year; these old routes later became the trunk highways serving the eastern U.S. seaboard.

In 1691 Andrew Hamilton of Edinburgh, Scot., was appointed by the British crown as postmaster general for the American Colonies. The first advance toward an organized intercolonial service was made by the granting of a patent to Thomas Neale on Feb. 17, 1692, to establish post offices in North America. An office was established at Philadelphia and rates were fixed to most of the Colonies, but receipts did not cover expenses and in 1707 the government purchased the rights.

In 1753 Benjamin Franklin became joint postmaster general for the North British Colonies in America and served until 1774, when he was dismissed by the crown because of his sympathies with the cause of the American colonists. Many improvements in the colonial postal system were made under his administration. Despite poor roads and great distances between centres of population, Franklin made the postal service an efficient and reliable means of communication. Service between New York city and Philadelphia was increased from once to three times a week in summer and from twice a month to once a week in winter; post roads were in operation from Maine to Florida and from New York to Canada, and mail between the Colonies and the mother country was operated on a monthly schedule.

Franklin was appointed head of the American postal system by the Continental Congress on July 26, 1775, at a salary of $1,000 a year, and served until Nov. 7, 1776. To Franklin, in great measure, belongs the credit for the establishment of a sound U.S. postal system.

Following ratification of the constitution, George Washington on Sept. 26, 1789, appointed Samuel Osgood of Massachusetts to serve as postmaster general. At that time the postal service was a part of the treasury department and it remained so until 1829, when the postmaster general became a member of the president's cabinet. In 1789 there were only 75 post offices; by mid-20th century there were more than 41,500 post offices. In 1790 there were only 1,875 mi. of post routes; by 1950 there were more than 2,100,000 mi. of post routes.

The postal grant under the constitution gave to congress much wider powers, and a vast and important public service was established and developed. Post offices were established as rapidly as possible, speedy transportation of mails was provided and service was extended to distant parts of the country.

In colonial times the policy was to make a profit from the postal service. But after the post office was made a separate department of government this policy was changed; it was felt that the department should render good service to the public consistent with due regard for cost, but it was maintained that such service should not always be self-sustaining. Deficits, therefore, became common in the conduct of the department throughout the years. By mid-20th century revenues of the U.S. post-office department amounted to more than $1,500,000,000 annually. Expenditures amounted to more than $2,100,000,000, resulting in a gross operating deficit of accrual of between $500,000,000 and $600,000,000.

Estimated postage that would have been collected if the service had been on a regular pay basis in the case of penalty and franked mail, free-in-county mail, differentials in second-class mail matter and free matter for the blind, and the cost of aircraft service over the postage revenues derived from air mail, amounted to approximately $120,000,000.

Post offices are established in every city, town and village in the United States for the receipt and delivery of mail matter and the performance of such special services appropriate to their size and importance. These offices, each with a postmaster, are of four classes. Postmasters of the first three classes are appointed by the president with the advice and consent of the senate and those of the fourth class by the postmaster general. There were at mid-20th century more than 2,500 first-class, 5,700 second-class, 12,700 third-class and 20,400 fourth-class postmasters. More than 237,000 persons were employed in offices of the first and second class, not including postmasters, rural carriers and motor service employees.

One of the first major advances in the postal service was the use of adhesive postage stamps for prepayment of postage on mail matter. Legislation was enacted on March 3, 1847, authorizing the postmaster general to issue stamps, and they were first placed on sale in New York city on July 1, 1847. Until that time the rate of postage for a letter weighing less than one ounce and composed of a single sheet of paper for a distance not exceeding 30 mi. was six cents. The rate was increased to a maximum of 25 cents for more than 400 mi.

Transportation.—The earliest methods of transportation were by horseback riders, stagecoaches and steamboats. The opening of the west and the movement of settlers to new lands broadened the scope of the postal service, and in the following years services were inaugurated which became an integral part of the postal establishment. The advent of railroads in 1834 marked the beginning of a vast change in mail transportation. By mid-20th century mails were carried over more than 165,000 mi. of railroads.

With the discovery of gold in California in Jan. 1848 and the rush of thousands westward, the postal service kept pace by sending mail overland to Monterey, Calif., by way of Fort Leavenworth, Kan., and Santa Fe, N.M.; the first overland mail arrived in Los Angeles in May 1848. The pony express, a private enterprise, was inaugurated between St. Joseph, Mo., and Sacramento, Calif., on April 3, 1860, to give faster mail transportation to and from the Pacific coast. The first mail took 10½ days and 75 ponies were used; the fastest time made was 7 days 17 hours to deliver the inaugural address of Pres. Abraham Lincoln in 1861. The

company charged $5 for each one-half ounce at the beginning of the pony express, but later reduced the rate to $1. Service was discontinued in Oct. 1861. "Buffalo Bill" Cody was one of the early pony express riders.

Expansion of Services.—Following adoption of adhesive postage stamps for prepayment of postage on mail matter, the next new service to be adopted by the post office was the registry system, established in 1855 to afford greater security in sending money and valuables through the mails. The system was applied to first, second and third classes of mail matter and extended to foreign as well as domestic mails; domestic third- and fourth-class matter could also be insured. This insurance service was established on Jan. 1, 1913. Domestic third- and fourth-class matter and sealed domestic mail matter of any class bearing postage at the first-class rate could be sent collect-on-delivery (service inaugurated on July 1, 1913) on the payment of a special fee.

In 1858 street letter boxes were introduced so that postal patrons would not have to call at post offices to mail their letters. In 1863 free delivery of mail was inaugurated in 49 cities, with 440 carriers so employed the first year. By mid-20th century there were more than 4,500 cities throughout the country enjoying this service, with 90,000 carriers. Village delivery service was established at certain second- and third-class offices in 1912 and was developed rapidly until most such services were consolidated with city services. Rural free delivery, generally regarded as one of the most far-reaching developments in the mail service, was inaugurated Oct. 1, 1896, when five routes were placed in operation in West Virginia. During the first week patrons on the routes received 214 letters, 290 papers, 33 postal cards and 2 packages. At mid-20th century there were more than 32,000 routes, serving 8,200,000 families or 30,500,000 individuals.

Until 1862 all mail carried on trains was distributed in post offices; in that year the postmaster of St. Joseph, Mo., tried out a method of sorting and distributing mail on a moving train between Hannibal and St. Joseph, in an attempt to avoid delays in mail departures for the west. The experiment was successful, and on Aug. 28, 1864, the first officially sponsored test of a railway post-office car was made between Chicago, Ill., and Clinton, Ia. On Dec. 22 of that year the post-office department appointed a deputy in charge of railway post offices and railway mails. This marked the beginning of the railway mail service.

There had long been a demand for means of sending funds safely through the mails, and in 1864 the money order system was placed in operation in 139 post offices, mainly to accommodate soldiers who were desirous of sending money to their homes. Money order service was extended to foreign countries in 1867.

Postal notes, which were placed on sale for the first time at post offices throughout the country on Feb. 1, 1945, as an experiment as to whether card money orders would be feasible, were withdrawn from sale on March 31, 1951. It was found that the method of bookkeeping that had been employed to keep track of postal notes received and sold at post offices was too complicated to make their continuance desirable.

Under an order issued by the post-office department money orders could be cashed at any post office throughout the country instead of the initiating office. This resulted in greater convenience to those sending and receiving money orders in the transaction of their business.

Postal cards were first used in 1873. In 1885, to accommodate persons who wanted prompt delivery of mail upon receipt at the post office, the special-delivery service was established. One million of these transactions were handled the first year.

The postal savings system was established in 1911 as a convenient and safe depository for the accumulation of savings and to encourage thrift. Originally the maximum that could be placed in a postal savings account was $500; at mid-20th century the maximum was $2,500. Postal savings depositors at mid-century numbered about 4,000,000, with deposits of more than $3,000,000,000 and accrued interest of more than $113,000,000. Postal savings certificates were on sale at 8,200 depositories, including about 1,000 branches and stations, and savings stamps were on sale at all post offices and practically all branches and stations.

Parcel post, one of the most widely used services of the postal establishment, was inaugurated in 1913 and resulted in a greatly increased exchange of farm products and goods between the rural and urban areas. By 1950 the post-office department was handling more than 1,200,000,000 parcels annually, with a weight of 7,600,000,000 lb.

Air Mail.—The aeroplane, since the days of its humble beginning at Kitty Hawk, N.C., in 1903, when the Wright brothers flew the first heavier-than-air machine, was integrated into the transportation scheme of the United States postal system in ever-increasing measure. Air mail became commonplace—an essential link in communications and a vital part of the economy. Established on May 15, 1918, in co-operation with the war department, which furnished the planes and the pilots, the mails were first flown between Washington, D.C., and New York city, a distance of 216 mi. Great interest was aroused, and Pres. Woodrow Wilson left the White House to witness the departure of the first mail plane from the nation's capital. On May 15, 1919, service was established between Cleveland, O., and Chicago, with a stop at Bryan, O., the first step in what later became the initial transcontinental route linking New York city and San Francisco, Calif. By May 15, 1920, it was possible to send a letter by air from New York city to San Francisco. The first transcontinental night flight started from San Francisco on Feb. 22, 1921, and ended at Hazelhurst field on Long Island, N.Y., 33 hr. 21 min. later. By July 1924 regular 24-hr. transcontinental air mail was in operation. Shortly after the completion of the coast-to-coast air route, the postal service awarded its first contract for the carriage of mails to a foreign country. The route ran between Seattle, Wash., and Victoria, B.C., a distance of 74 mi., and the service was inaugurated on Oct. 15, 1920, although it was not until 1927 that regular foreign air-mail service was in operation. In 1935 another milestone in overseas air transport was marked with the inauguration of transpacific air-mail service, from San Francisco to the Philippine Islands by way of Hawaii, Midway, Wake and Guam. This route was extended to Hong Kong on April 21, 1937, and to Singapore on May 3, 1941. Transatlantic air-mail service was inaugurated on May 20, 1939, from New York city via Bermuda and Portugal to Marseilles, Fr. Another route between New York city and Great Britain by way of Canada and Newfoundland began operation on June 24, 1941. Direct air service to Africa was made possible by the establishment of a route from Miami, Fla., to the Belgian Congo. After World War II there was a tremendous increase in foreign air transport, and direct air-mail service to every continent was afforded by United States carriers.

To increase the use of air-mail routes, overseas postage rates to foreign countries were materially reduced. With the exception of Mexico and Canada, where a six-cent-an-ounce rate was in effect, and Cuba, where the rate was eight cents per one-half ounce, air mail at mid-century could be sent to all countries in the western hemisphere for ten cents a one-half ounce. To Europe and countries surrounding the Mediterranean the rate was 15 cents per one-half ounce, and to all other countries a rate of 25 cents per one-half ounce was in effect. On April 29, 1947, the ten-cent air letter sheet, mailable to any country in the world, was made available to postal patrons by the post-office department as a convenient, economical means of sending communications to foreign lands.

Large metropolitan areas continued to present a problem in dispatching mail to and from the airport. In numerous instances the time saved in sending mail long distances by air was lost by the time consumed in surface transportation. It was thought that the helicopter, because of its ability to land in a small area, on the ground or rooftop, might prove the solution to the problem, and exhaustive tests of the carriage of mail by helicopter were conducted in the Los Angeles area in July 1946. Further tests were made at Chicago in Oct. 1946 and at New York city in Feb. 1947. As a result, the world's first experimental helicopter air-mail service was inaugurated in the Los Angeles area on Oct. 1, 1947, over a route linking communities to the

north directly with the airport. Shuttle service between the airport and the Los Angeles terminal annex post office was instituted the same day. The route was expanded until by mid-century it served approximately 50 cities and towns in the Los Angeles metropolitan area. Similar service was inaugurated in the Chicago area on Aug. 20, 1949.

International air parcel-post service was inaugurated March 15, 1948, between the United States and 21 countries in Europe and the North Atlantic area. Service to South America was instituted on Sept. 4, 1948, and to the Pacific area on Sept. 11, 1948. Air parcel-post service became available to more than 60 countries throughout the world. Hundreds of planes flown by United States carriers were operating on frequent schedules over 120,000 mi. of foreign routes, carrying air mail to every corner of the globe and transporting in a matter of hours mail that less than 15 years before took weeks to deliver.

Domestic air parcel-post service to the United States and its territories and possessions was begun Sept. 1, 1948, including all mail carried by air weighing more than 8 oz. and not more than 70 lb. Zone rates varied from 55 cents to 80 cents for the first pound, and from 4 cents to 65 cents for additional pounds, according to the distance flown.

Other Developments.—In 1943 the postal zoning system was placed in operation in 124 of the larger post offices. This method of addressing mail had been in use in other countries, and it was found that it permitted faster distribution and sorting of the mail, especially by less experienced personnel, and particularly during the Christmas season when large numbers of temporary clerks were employed at the larger post offices throughout the country.

As early as 1930, officials of the post-office department, anticipating the continuing withdrawal of trains and foreseeing the need of providing an effective substitute for railway post-office service, prevailed upon congress for the necessary legislation to establish highway post offices throughout the country. Operated on the same basis as the railway mail service, the mails on these highway post offices are transported in large bus-type vehicles and equipped with all facilities for sorting, handling and dispatch of mail that are found in railway postal cars. Manned by highly trained railway postal clerks, these post offices give swift and efficient service to post offices along the line of the various routes. The first route, established Feb. 10, 1941, was between Washington, D.C., and Harrisonburg, Va. By 1950 there were 55 government-owned highway post offices and 10 operated under contract. The system proved satisfactory in every respect and justified its continued existence and growth; the cost compared favourably with service by railroads.

Mail Matter.—The act of 1792, first after the adoption of the constitution, recognized letters, packets and newspapers as mail matter. Magazines and pamphlets were recognized in 1799 and unbound journals of the several states in 1825. Lithographed circulars, handbills or advertisements and every other kind or description of printed or other matter were recognized as mailable in 1845. In 1851 bound books were made mailable, with an early weight limit of four pounds. In 1861 maps, engravings, photographic prints, photographic paper, letter envelopes, cards, blanks, seeds and cuttings were made mailable and the weight limit was fixed at four pounds. The act of 1863 excepted books circulated by order of congress from the weight limit. Mail matter was classified in 1863 and again in 1872 into three classes; in 1879 it was reclassified into four classes as follows: first class, written matter; second class, periodical publications; third class, miscellaneous printed matter; and fourth class, merchandise and matter not included in the other classes and not in form or nature likely to injure the contents of the mailbag or harm those engaged in the postal service, and not exceeding four pounds in weight for each package. By the Parcel Post act of Aug. 24, 1912, the scope of fourth-class matter was enlarged. On third-class mail matter circulars and other miscellaneous printed matter and merchandise weighing not more than eight ounces were admitted to the mails. On fourth-class mail matter the limit of weight was increased to 70 lb., with the limit of size not more than 100 in. in length and girth combined.

Congress vested in the post-office department a monopoly in the conveyance of letters, but did not extend this monopoly to any other class of mail matter.

Dead-Letter Office.—Letters or parcels which cannot be delivered because of defect of address or other cause are sent to the division of dead letters and dead parcel post. They are carefully examined on both front and back for the name and address of the sender; if these are found, they are returned to the sender. If the sender's address is lacking, they are kept for a period, after which dead letters are destroyed while dead parcels are sold at auction. During 1949, a rather typical year, it was impossible to deliver more than 18,100,000 letters, of which 4,075,000 were returned to the senders. Letters containing valuables enclosed numbered 375,000, of which 102,000 contained money amounting to $202,000. There were also 718,000 unclaimed parcels and articles found loose in the mails; 593,000 were returned to the senders. The remaining 125,000 parcels were sold at public auction and $136,000 was realized.

Staff.—The post-office department is administered by the postmaster general, a member of the president's cabinet, assisted by a deputy postmaster general and four assistant postmasters general, an executive assistant, director of budget and administrative planning, commissioner of the budget, chief clerk and director of personnel, purchasing agent, solicitor, chief inspector and comptroller. The inspection service is supervised by the chief and inspectors in charge of divisions throughout the country.

On Nov. 1, 1949, the postal transportation service was created under a reorganization plan in the post-office department to displace the railway mail service. The new organization consisted of a deputy assistant postmaster general and 15 divisions, each under a general superintendent. The divisions were further divided into 119 districts, each in charge of a district superintendent and an assistant. The distribution of mail in railway post-office cars and highway post offices is primarily for first-class mail, air mail, newspapers and special delivery, special circulars, ordinary papers and parcel post. These are distributed mostly in terminals of the postal transportation service, located at strategic points throughout the country; mail for certain states is routed to these terminals and redistributed and redispatched to its destination.

National Association of Letter Carriers.—The National Association of Letter Carriers was organized at Milwaukee, Wis., in 1889. It affiliated with the American Federation of Labor on Sept. 20, 1917, and with the government employees council of the federation in 1945. In 1950 it affiliated with the postal telegraph and telephone international. Its membership at mid-century was slightly in excess of 100,000, with 4,200 local branches located in cities throughout the 48 states, Puerto Rico and Hawaii. Qualification for membership in the association is that the applicant must be a city, village or rural letter carrier on a classified civil service register.

The association maintains its own sick and accident insurance with headquarters in Boston, Mass., in addition to its own life insurance headquarters in Nashville, Tenn.

Relationship with International Postal Service.—In 1844 congress enacted legislation authorizing the postmaster general to enter into formal agreements with other countries for the exchange of mails, and the first agreement was concluded in 1847 with the Hanseatic republic of Bremen. This was followed in 1848 by an agreement with Great Britain. Another postal union known as the Postal Union of the Americas and Spain was formed by the republics of North, Central and South America, Canada and Spain.

(I. Gg.)

POSTER. A poster is a printed, written or illustrated announcement publicly exhibited. Its usual function is to call attention to goods or service; but, to fulfil that object completely, it has not merely to arouse attention; it must provoke interest and create a desire for purchase. However attractive pictorially or textually a modern poster may be, commerce, the chief patron of poster art, finally judges a design by its value as a link in the chain of salesmanship.

The poster is seldom given entire responsibility for influencing the public; rather is it regarded as a form of "reminder" advertising—an ally of the press advertisement, the creator of a favourable atmosphere. The average "commercial" poster is intended to influence two groups—the retailer, who, it is hoped will stock the advertiser's goods, and the public who will purchase them. Posters have a very wide range of duties to perform in addition to selling goods. They deliver every kind of message, to every type of "audience," in an infinite variety of styles. Actually, the poster or placard can trace its ancestry back almost to the dawn of civilization.

History.—Egyptian wall-paintings, mural decorations and inscriptions, produced over 3,000 years B.C., have been discovered by archaeologists, much of this work, together with that of the early-Babylonian, Assyrian, Greek and Roman craftsmen, displaying a precision of line and a decorative beauty which are the envy and despair of the modern poster-designer. Tablets of wood, papyrus and parchment were also used, in ancient Egypt, Greece or Rome, for the purpose of issuing announcements, while it is the lettering of the Trajan column which has inspired the finest types of poster lettering of to-day.

Later Developments.—In later days, the sign-board was adopted as a form of advertisement, the hanging sign being a picturesque feature of mediaeval architecture throughout Europe. Written handbills were an additional means of enabling the shopkeeper to bring his goods and service to the notice of the public, and vast possibilities were suddenly presented to him by the invention of printing, by Gutenberg, before 1450, and by its introduction into England by Caxton in 1476.

The first letterpress poster soon made its appearance in England; and shortly afterwards, in France, a royal proclamation was issued in poster form. During the 17th century, the general use of posters was forbidden, but in time their value to the community was recognized, official restrictions were removed, and the first pictorial posters made their appearance. These were illustrated by wood-cuts. Pedlars and packmen, hucksters and showmen, strolling players and proprietors of booths, also used handbills and miniature posters, decorated by wood-cuts; and these simple, primitive illustrations have formed part of the artistic inspiration of the leading poster designers of to-day.

The wood-cut was, however, destined to be superseded by lithography (*q.v.*) as a medium for the designing and printing of posters. Invented in 1796, and developed for printing purposes by Senefelder, the new art of drawing and engraving on stone, metal plates and "transfer" papers, opened up possibilities almost as vast as those which followed the invention of the printing press.

The first lithographed posters are interesting as historical curiosities only, the earlier wood-cuts possessing infinitely more character. Lithography was seized upon as a means of producing a more elaborate, "highly-finished" form of illustration, and it is to France that we have to turn for the earliest lithographed posters of quality.

The modern poster began with Jules Chéret, a Frenchman, born in Paris in 1836, self taught as a draughtsman. He served his apprenticeship as a lithographer in England, and when 30 years old became interested in announcements of theatrical managers and placards put out about that time urging recruiting for armies. In 1867 the world saw the first modern poster of Chéret's, an announcement of a play enacted by a young woman, then 22 years old, who was to make her name immortal—Sarah Bernhardt. The poster announced a fairy play, entitled: *La Biche au Bois.*

The first Chéret posters, with their filmy female figures seemingly floating in space and flaming colours, excited interest, held attention, and caused favourable comment. Orders for Chéret's posters came from music halls, dealers in cigarettes, drinks, toilet articles, newspapers, circuses, charity fêtes, and the streets were gladdened with merrily dancing figures. Chéret designed more than 1,000 posters, the best of which can be found in books devoted to the art.

The poster spread from France to Germany. Later it travelled across the Pyrenees to Spain, and from France to Switzerland, and over the Alps into Italy, from France to Belgium, and across the English channel to England, across the North sea to Holland, and from Germany it found its way to Austria-Hungary, the poster invasion finally reaching Russia and travelling across the Baltic sea to Norway and Sweden. From the British Isles and the Continent of Europe, the poster went to the United States, and later to Canada, thence to Australia.

In England the first to attract attention by his posters was Frederick Walker, who in 1871 made a poster for the dramatized version of *The Woman in White.* Members of the Royal academy were attracted to the newly discovered medium, and Sir John Millais exhibited "Bubbles," advertising a soap. This poster pleased England immensely. Then followed Aubrey Beardsley, with his weird posters, Walter Crane, R. Anning Bell, the "Beggarstaff Brothers" (James Pryde and William Nicholson), J. W. Simpson, Gordon Craig, Dudley Hardy, Maurice Greiffenhagen, J. Hassall, Will Owen and others.

In Germany Ludwig Hohlwein won not only a national, but an international reputation, and books of his posters are sold throughout Europe and America; his posters are so compelling that he is regarded as a master of his craft. Other German poster artists whose work reached the highest standards include Otto Fischer, Sattler, Speyer, T. T. Heine, Max Klinger, Dasio, Hofmann, Franz Stück and L. Zumbrusch.

Leon Bakst, the Russian genius, and H. Cassiers, Belgian, have done much to bring renown to their native lands by their posters of distinction. Japan's greatest poster artist is Toyókuni.

The poster, as it is known to-day, did not exist in the United States previous to 1889, except for the theatrical and circus posters made by Matt Morgan. Posters began in the United States in the '90s, when Louis Rhead and Will H. Bradley began to produce their decorative placards. These were used principally for the announcements of magazines and the books of publishers. Later business and commerce saw the great value of poster advertising, and enlisted the services of Maxfield Parrish, Ethel Reed, Will Carqueville, J. J. Gould, Howard Chandler Christy, J. C. Leyendecker, Frank Hazenpflug, James Montgomery Flagg, Charles Dana Gibson, and others.

Among other recognized U.S. artists who also did work on posters were Harrison Fisher, Linn Ball, G. C. Beall, Norman Rockwell, Fred Stanley, William Oberhardt, Fred Mizen, Clarence F. Underwood, Karl Johnson, F. Nelson Abbott, Arthur von Frankenberg, John E. Sheridan, Harry Morse Mayers, Hadon Sundblum, John O. Brubaker, Charles E. Chambers, McClelland Barclay and Lucille P. Marsh.

With the outbreak of World War I posters took on a new significance in all nations actively engaged in the struggle. In countries where there was not conscription, posters were most effectively used to stimulate recruiting. Before conscription in England (during the first stages of the war), more than 2,500,000 posters were posted in the British Isles alone to get men to enlist, the posters representing the work of about 100 artists. Taking a lesson from Great Britain, the governments of the countries actively engaged in the war spoke to their nationals through the medium of the poster, appealing to the civilian population in behalf of subscriptions to the war loans, the conservation of food, aid for the organizations engaged in war work (such as hospitals), milk funds, destitute dependents, the Red Cross, the Y.M.C.A. and other activities that war entails.

Brangwyn and Spencer Pryse produced work for Britain and Belgium which was full of dignity and nobility. In France, Steinlen, Faivre, Willette, Poulbot and Fouqueray appealed to the patriotism of their countrymen. In Germany the belief in force and might was hammered into pictures by Engelhard, Louis Oppenheim, Puchinger, Otto Leonard and Wohlfeld. Austria's actions were justified or defended and its causes championed by Krafter, Arpellus, Buo and Kurthy.

Standards.—After the latter part of the 19th century, when the poster became a popular means of outdoor publicity, women were predominant in many of the posters displayed. The charm of childhood illumined many posters. Birds and animals were also favourites with poster designers. But whatever is pictured on a poster, this courier of commerce must have these

important features: it must be new and interesting, have attention-value, simplicity of design, brevity of text, good composition, pleasing colours, and "selling power"—the latter usually achieved through expression of a basic link of interest between the product and the public.

Great strides have been made in the development of the poster as an organized advertising medium. Modern business in America has discarded the old-fashioned and unkempt "billboard," and posters of various sizes are no longer made. Due to the Outdoor Advertising Association of America, there has come the standard structure in two sizes surrounded by a green moulding as a frame for the poster. These standard panels are found in over 16,000 cities and towns in the United States. Many of these structures are illuminated.

In Great Britain, hoardings, though not standardized, have greatly improved in character and design, under the influence of the British Poster Advertising Association. In Germany a poster hoarding is practically unknown, the design being shown on special advertising kiosks or pillars. France uses both kiosks and hoardings. (*See* PAINTING; ADVERTISING.)

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POSTE RESTANTE, a facility, generally provided at post offices, for the receipt and care of postal packets addressed to be called for. There are usually strict regulations to prevent abuse or fraud. In the United Kingdom, it is stipulated that the words "to be called for" or "Poste Restante" should appear in the address, and it is notified that the facility is intended solely for the accommodation of strangers and travellers, and that even they may not use it for more than three months. Postal packets addressed to initials, or to fictitious names, or to a Christian name without a surname, are not taken in at the Poste Restante. Postal packets may not be re-directed from one Poste Restante to another in the same town or from a private address to a Poste Restante in the same town. Re-direction from a Poste Restante is not undertaken for more than 14 days, unless a longer period, not exceeding three months, is specified on the form of application. All persons applying at a Poste Restante are required to furnish sufficient particulars to prevent mistakes and to ensure delivery to the proper person. Where a ship is in question the name of the vessel should always be mentioned.

The words "General Delivery" in the United States are synonymous with the words "Poste Restante." A general delivery window is maintained at every post office in the United States and is used for handling mail bearing as a part of its address the endorsement "Transient," "To be called for," "General Delivery," or other words indicating that it is intended for a transient person, such mail to be delivered upon application and identification.

At those post offices where delivery carrier service is maintained, residents who use the general delivery window are required to furnish in writing their names and addresses and the reasons for desiring to use the general delivery instead of the carrier service. Minors are required to furnish the names of their parents or their guardians whose written consent must accompany the application.

POSTGATE, JOHN PERCIVAL (1853–1926), English classical scholar and Fellow of the British Academy, was the son of Dr. John Postgate (1820–81), the initiator of the laws against the adulteration of food. He was educated at King Edward's school, Birmingham, and Trinity college, Cambridge, where he took his degree in 1876. He was elected to a fellowship at the college, where he was classical lecturer (1884–1909). He was professor of comparative philology at London (1880–1910) and Latin professor at Liverpool university (1909–20). He was accidentally killed in Cambridge by a steam lorry on July 14, 1926.

Postgate ranks very high among Latin scholars, but some of his due reputation was lost him by his vehement methods. Of these an example is to be found in his great *Corpus Poetarum Latinorum.* He expelled the writings of Ausonius from the *Corpus* on grounds which, though stated in mellifluous Latin, amount to little more than that he thought him a bad poet. Some have seen traces of the same vehemence in certain of the emendations in his Propertius (1894) and Tibullus (1905); he was, however, undoubtedly a very eminent critic and his article on TEXTUAL CRITICISM (written for the 11th edition of the *Encyclopædia Britannica,* and substantially retained in this) is a classic upon its subject.

His greatest successes were achieved in reforming the teaching of Latin. His *New Latin Primer* (1888, last ed. 1918) and his *Sermo Latinus* (1889, 1913) became widely used because of their simple methods. In particular he took a leading part in chasing out the old Victorian pronunciation of Latin—a mass of false quantities and mispronunciations which had no relation to the established facts of ancient pronunciation. He was largely responsible, not only for the adoption of the reformed scheme by the Classical Association, but for the organization and propaganda which secured its general acceptance.

Before his death Postgate had the pleasure of knowing that the old pronunciation had been practically entirely wiped out of British scholastic and learned life and, as he said, that "even a lawyer had been known to pronounce *nisi prius* without making a false quantity."

Postgate's chief works, besides those mentioned above, were editions of Catullus (1894), Virgil (1912), Phaedrus (1920) and part of Lucan (1896, 1917); *How to Pronounce Latin* (1907); *Translation and Translations* (1922); *Prosodia Latina* (1923); *Guide to the Accentuation of Greek* (1925). The *Corpus* was published in parts in 1893, 1894, 1904 and 1905. *See* S. G. Owen, *J. P. Postgate* (British Academy, 1927).

POST-IMPRESSIONISM. The essential difference between impressionism and post-impressionism is perhaps best explained by the description of the former as an objective outlook which results in the rendering of the image received on the retina, and of the latter as the mental image expressed in accordance with a subjective outlook. In other words, whilst impressionism is based on strict fidelity to natural appearances, the need of post-impressionism consists, in the main, of absolute attachment to the personal vision, and, in reality, is the expression of the matter received through the glass of impressionism to be subsequently subjected to an individual thought process. The statement which emerges from the artist as a result of this process might well be termed expressionism, were it not that this name is more exclusively reserved for the excessively brutal German contribution to the movement under consideration. Post-impressionism (a term coined on the occasion of the first exhibition of the work of Cézanne, van Gogh and Gauguin in London, in 1911) provides an alternative which, if less apt, has the merit of being safe.

Post-impressionism was as much a revolt against the naturalism of the impressionists, as impressionism was a revolt against the tyrannical academic formula. It replaced analysis by synthesis. It despised representation and gave the artist unbridled licence to amplify and distort the forms of nature, acknowledging no law but the artist's sense of fitness in arranging and organizing the contents of his picture so as to express with the greatest possible directness and intensity the material and spiritual significance of his subject—the "treeness" of the tree, as Roger Fry has it, and the "wallness" of the wall. Delivered from all restraint and rules, the post-impressionists were able to proceed by leaps and bounds on their excursions into the realms of synthesis and abstraction, to the utter bewilderment of a public which, accustomed to judging art by the degree of its verisimilitude to nature, were left floundering hopelessly when attempting to fathom the meaning of these startling artistic manifestations.

A quarter of a century was enough to secure for the initiators and leaders of post-impressionism a position among the beacon-lights of European art. Cézanne, van Gogh and Gauguin are now referred to as "the glorious triumvirate" and "the old masters of

BY COURTESY OF (UPPER LEFT) FINNISH TRAVEL INFORMATION BUREAU, ILMARI SYSTIMETSÄ, ARTIST, (UPPER RIGHT) S. L. ALLEN CO. AND SASCHA MAURER, ARTIST, (LOWER LEFT) ROYAL NETHERLANDS STEAMSHIP CO., JEAN WALTHER, ARTIST, (LOWER RIGHT) MEXICAN TOURIST ASSOCIATION, C. URELÀ, ARTIST

POSTER ADVERTISEMENTS

Four examples of poster design, illustrating the adaptation of art and colour printing to the uses of publicity

POST-IMPRESSIONISM

BY COURTESY OF (3) THE REID AND LEFEVRE GALLERY, LTD., IN THE COLLECTION OF MR. AND MRS. S. COURTAULD; PHOTOGRAPHS, (1, 2, 4, 5, 6) COPR. H. BONNAIRE

POST-IMPRESSIONISM AND CUBISM

1. "Nude' by Georges Braque (1881–), French painter, in his early days a follower of Picasso, and a prominent leader in Cubist research
2. "Les Baigneuses" by Paul Gauguin (1848–1903), French, one of the three leading painters in the post-impressionist movement. His revolt against impressionism took the form of a return to decorative pattern, and to the two-dimensional design characteristic of Far Eastern Art. The painting illustrated is an example of the work of Gauguin's later years, which were spent in the Marquesas Islands
3. "L'Homme à la Pipe" by Paul Cézanne (1839–1906), French painter, one of the so-called "Glorious Triumvirate" (Gauguin, Cézanne and Van Gogh) who were the initiators of post-impressionism. Cézanne's endeavour in portraiture and still life as well as in landscape painting was to make more clearly perceptible than it is in nature the sense of the third dimension, of volume and weight. In the collection of Mr. and Mrs. S. Courtauld
4. "The Yellow Chair" by Vincent Van Gogh (1853–90), a Dutch painter who derived his technique from the Impressionists but went on to more abstract and subjective methods of expression
5. "Arlequin au Violon" by Pablo Picasso (1881–), Spanish painter, famous as one of the leading exponents of Cubism. His work is characterized by abstraction of form and an aesthetic expression entirely separated from the physical appearance of objects
6. "La Jeune Fille à la poupée" by Paul Cézanne

post-impressionism." Their once despised, numerous, and by no means invariably successful paintings are in most of the galleries of modern art, and thousands of pounds are willingly paid for canvases for which the artists, during their lifetime would willingly have accepted a few hundred francs.

Cézanne.—Cézanne, who at the beginning of his career threw in his lot with the Impressionists, upon whose technique he formed his own, was among the first to realize the limitations imposed by the Impressionists' scientifically truthful rendering of colour and atmosphere. His dissatisfaction with what he considered the superficiality of impressionist productions led him to express, more basically and with greater structural firmness, the essential character of the countryside which forever offered him new vistas, new wonders for his interpretation. His endeavour, in portraiture and still life, as well as in landscape painting, was to accentuate volume and weight—to make the third dimension more clearly and immediately perceptible to the beholder's eye than it is in actual nature, where we are left to guess by experience and by memory of touch. To him is due the dictum that all forms in nature can be reduced to the cube, the cylinder and the pyramid.

Van Gogh.—Like Cézanne, van Gogh derived his technique from the impressionists; and like Cézanne, he was anything but a facile worker, his heavy hand being but an inadequate instrument for conveying his passionate aesthetic reaction to the thing seen. Of him it may truly be said that he did not paint, but rather battled with colour and essential line with a frenzy that took no count of finished execution. His pictures are executed in furiously energetic cross-hatchings of pure Prussian blue, emerald green, orange and yellow, with a daring justified only by the brilliant harmonies evolved from a palette on which he found no room for neutral tints. His brushwork can only be likened to vigorous hatchet-strokes, corresponding to the elemental force of his emotions. There was something uncanny in his power to perceive and to express the essential nature of any object or scene or person by which his aesthetic impulse was stirred. Inanimate things became somehow invested with a soul and with a life of their own—a sunflower, a wicker-chair, a cypress tree, or whatever it happened to be. He was a visionary who found a deep meaning in the humblest objects which his art invested with his own tortured spirit, and which he made eloquent of his own emotions. Van Gogh was the precursor of expressionism.

Gauguin.—The third member of the great triumvirate, Paul Gauguin, was a close friend of van Gogh, but of a less impulsive and more reflective turn of mind. Where van Gogh would shout and even shriek, Gauguin was content to talk, and his words carried more weight, for they were more considered. If Cézanne devoted his life to the search for volume, and van Gogh for material and spiritual significance, Gauguin's revolt against impressionism took the form of a return to decorative pattern, to two-dimensional design as practised by the artists of the Far East. He based his effects on abstract form and colour, not on representational truth or on over-accentuation of some particular truth. Ignoring the colour of nature, and relying, for the expression of his ideas upon his memory more than upon models, he produced first in Brittany, then in Tahiti, those splendours of harmonious decoration against which no arguments founded on convention can ever prevail. It was his belief that, before the spirit of a place could be interpreted, it needed study in all its parts during what he called a "period of incubation." Some proof of the peace Gauguin found in his retreat can be seen in the restful nature of his paintings.

Matisse.—Of the second generation of post-impressionists, Henri Matisse went farther even than Gauguin in reconciling Western art with the Chinese. He aims "at convincing us of the reality of his forms by the continuity and flow of his rhythmic line, by the logic of his space relations, and, above all by an entirely new use of colour." His is an art of extreme synthetic simplification, reducing objects almost to symbols, and disdaining any approach to make-believe of reality. It depends entirely on arabesque and is not concerned with the third dimension.

Cubism.—Cézanne had used colour in block form because, by that means, he could best express his feeling for the weight of whatever he depicted, and its relation to other things presented with it, but he kept to the accepted ideas of representation, which were discarded by his cubist followers, Picasso, Braque, Dérain and Leger, who evolved a new language from Cézanne's suggestion of space. It was a form of art that had nothing whatever to do with realism, and demanded concentration on aesthetic matters to the absolute exclusion of outside practical appearances and accepted canons of judgment. Cubism bears out Ruskin's theory that an artist may deny other truths to the end that one truth may be more apparent.

Like impressionism, the name "cubism" was first used in a derogatory sense; it was Henri Matisse who, in 1908, applied it to a painting in which the subject had received treatment of a markedly cubical character. About as far from the impressionist objective approach as anything could possibly be, cubism is really a stride—albeit a long stride, beyond the subjective outlook of the post-impressionists, in that it takes no heed of visual appearance, and renders what are thought to be essential realities in pure abstract form. Picasso, the most prominent follower of the cubist gospel, and, indeed, the creator of certain of its elements, is the exponent of scientific cubism in its purest sense. Another form of cubism, less pure, is that which is best described as physical, since its fundamentals are culled from visualized realities.

For example, in those of Picasso's works which are based on physical appearances, the objects are presented in a way at least sufficiently realistic to enable their perception by the ordinary beholder, although he may be at a loss to account for the shapes which they assume. Their recognition, incidentally, at once displaces the work from the category of cubism in its strict sense, for that entails matters of line and colour wholly unrelated to objects and figures, since the cult does not intend realism to enter into the question.

Braque stands, to some extent, as the codifier of Picasso's inventions, acting as an editor of his snipe-like movements. Thus, the products of Picasso are sobered down and reduced to a state of uncompromising logic before being handed on as standardized material.

The art of Fernand Leger is concentrated upon the mechanical age into which we are advancing. Working in the gay colours of contemporary life, he extracts excellent design from the solid strength of the mechanized world by which he finds himself enveloped.

Albert Gleizes is a devotee of two-dimensional treatment, and his attitude to a flat surface is that it has no need of the addition of a sculptural third, for the presence of such constitutes a denial of its very nature. This painter, too, does not regard painting as a form of representation, but of presentation of the spirit of the artist, and not of physical matter. Metzinger, Herbin and Lhote are others of the cubist persuasion, which has demanded, in its time, every conceivable form of liberty. Orphism, purism, synchronism, simultaneism, integralism, dadaism and numeralism, all have had their day, and now the parent bids fair to follow them into oblivion. But although cubism may prove to have been a blind alley, it has been, and still is, an invaluable discipline for artists in general and had its definite use in saving art from the rut of academic pedantry.

Futurism.—Italian futurism, initiated, heralded and extolled by the eloquent poet Marinetti, and practised by Boccioni, Severini, Carrà, Russolo, Balla, and other disciples of the founder, was really an offshoot of cubism, although the connection was not admitted in the futurist manifestos. It differs from cubism in so far as cubism is concerned with static conditions, whilst futurism is essentially dynamic. This dynamism aims at cinematographic effects, oblivious of the impossibility of creating on a flat surface the illusion of the sequence of movement. Thus, by depicting a horse with 20 legs in various positions to indicate the movement of the gallop, the futurist endeavours to express the action of the gallop, but does not get beyond the representation of a static horse with 20 legs. Any attempt to change an art of space into an art of time must needs prove abortive. The dynamic intention of the futurists also finds expression in "force-lines," that is to say in lines, radiating, swirling, wedge-shaped, to indicate either

the direction of movement, or the manner in which objects would disintegrate in obedience to the force indicated by their form.

Another tenet of futurism denies the validity of the resemblance of a portrait to the sitter. To the futurist, a painting of one object covered by another in such a manner that both are visible is a method of indicating his total disbelief in opacity, while a dozen people can be, at the same time, and in turn, ten, three, five in number, as well as simultaneously mobile and immobile. Paintings of a box, firmly shut but at the same time disclosing its contents, also are admissible. Pictures must be looked not at, but through, and the spectator must feel himself to be in the midst of them.

In England, F. T. Marinetti's fiery eloquence enlisted for a time a small following, which included C. R. W. Nevinson, who adapted with great skill the futurist formula for a series of remarkable war paintings.

Vorticism.—The chief English contribution to post-impressionism was, however, the work of the short-lived group of "Vorticists" who, led by Wyndham Lewis, adopted a modified method of cubism, and included among their number William Roberts, Edward Wadsworth and F. Etchells. In England, as in most countries, these innovators were regarded as incompetent cranks and charlatans, until their employment in connection with the Canadian war memorials and the Imperial War museum brought them official recognition and public fame.

Expressionism.—In Germany the post-impressionist movement took root and spread with surprising rapidity. Its most abstract form is to be found in the art of the Russian-born W. Kandinsky, who explained his outlook in a book entitled *The Art of Spiritual Harmony*. Max Pechstein, F. Marc, E. Nolde, Oskar Kokoschka and L. Corinth are the most prominent figures among the German expressionists, among whom must also be counted Marc Chagall, notwithstanding his Russian birth.

Certainly it would seem that the German activities which correspond to those of the post-impressionist painters in other European countries should be accorded some distinguishing title of their own. The term "expressionism," therefore, serves the purpose as well as any other, unless one were found which denotes a combination of truth, bestiality, creation and destruction—all expressed in a manner in which a snarling brutality obscures many finer feelings. At the same time it must be admitted that the artist to whom the expressionists owe so much, the Swiss, Ferdinand Hodler, cannot very well be held responsible for the excesses committed by his imitators or contemporaries.

Man and his relation to the world which contains him were subjected by Hodler to every thought process of which his clear brain was capable, and the resulting statements are models of simplicity, precision and originality. Hodler did not attempt to put the unreasoning at ease by being intimate with them, but compelled them, rather by an almost holy power, to use their own imagination. Another artist, who with Hodler, Cézanne and Van Gogh left his mark upon the evolution of German expressionism, was the Norwegian Edward Munch, whose achievement in painting leads from the subjective naturalism of the late 19th century to the post-impressionist tendencies of the present day.

In the U.S. the new art-gospel of post-impressionism or expressionism was popularized mainly by the activity of Jules Pascin (1885–1930), a Bulgarian by birth, who had been working from 1905 onward for *Simplicissimus* and living in France until 1914, when World War I made him seek a new home in the United States. He was equally distinguished as an illustrator and as a painter, and his work, though always maintaining a very personal note, showed in turn the influence of Daumier, Cézanne, Degas, Renoir and Picasso. He resorted extensively to distortion for the definite purpose of forceful emphasis, and is in this respect related to the German expressionists.

Effect on Other Arts.—Post-impressionism, in its attempts at synthesis, drew on the past to as great an extent as any other movement, but, ignoring the representational tricks discovered by succeeding generations, adopted only the basic, elementary facts of the unsophisticated and consequently more sincere primitive races. Exploration has brought to light comparatively modern work, in the form of sculpture, pottery and mat designs, by peoples who, throughout the ages, have known no art teaching or influences save those, possibly, of a conquering but equally primitive tribe. From the Congo, Bakota, Benin and other districts of lesser-known Africa, masks and figures have found their way to Europe, there to reveal, to eager searchers for a means of expressing much without complication, wonders of form and rhythm which were bound to receive the investigation of serious artists. In the same way that Gauguin found stimulation in the vibrant colours of the Polynesian matmakers, so Jacob Epstein and, to a lesser degree, Ossip Tadkine have been helped to fuller expression by deep study of Negro sculpture.

In almost everything—buildings, furniture, dress, design in the home or theatre and especially, perhaps, in that powerful modern factor, advertising—the effect of post-impressionism and its more successful descendants is very marked, while the benefits accruing to sculpture and the minor arts—woodcuts, engravings, posters, wallpapers and others—have already altered the trend of public thought, and freed it, to such extent as slow and inartistic officialdom will allow, from the morass of insincerity and vulgarity which had all but swallowed it up. (*See* IMPRESSIONISM; PAINTING.)

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POST-MORTEM: *see* AUTOPSY.

POSTULATE, in philosophy, is now generally used in the wide sense of any fundamental assumption that is indemonstrable and yet necessary if the requirements of knowledge or of practical life are to be satisfied. In this sense Kant, for example, spoke of the postulates of the practical reason; and nowadays the so-called Laws of Thought are commonly described as postulates. The usage in mathematics is, or used to be, rather different. In philosophy, too, people sometimes employed the term "axiom" rather than postulate for the Laws of Thought and similar theoretical principles, the term "axiom" being defined as "a self-evident truth." But there is no virtue in claiming self-evidence for what is recognized to be indemonstrable. *See* AXIOM; KANTIAN PHILOSOPHY; THOUGHT, LAWS OF.

POSTUMIA, VIA, an ancient highroad of northern Italy, constructed in 148 B.C. by the consul Spurius Postumius Albinus. It ran from the coast at Genoa through the mountains to Dertona, Placentia (the termination of the Via Aemilia Lepidi) and Cremona, just east of the point where it crossed the Po. From Cremona the road ran eastward to Bedriacum, where one branch ran left to Verona and thence to the Brenner, the other right to Mantua, Altinum and Aquileia. The military occupation of Liguria depended upon this road, and several of the more important towns owed their origin largely to it. Cremona was its central point, the distances being reckoned from it both eastward and westward.

POSTUMIA-GROTTE (formerly Adelsberg, Slovene *Postojina*), a town in the province of Trieste, Italy (from which it is 51 mi. E. by rail). Pop. (1936) 3,804 (town), 6,596 (commune). It is the frontier town of Italy on the railway to Ljubljana, Graz and Vienna. A mile from the town is the entrance to the stalactite cavern of Postumia, largest in Europe. The cavern is divided into several branches. The river Piuca enters the cavern 60 ft. below its mouth. In the *sala da ballo* (ballroom) grotto a great ball is annually held on Whit-Monday, when the chamber is brilliantly illuminated. A mile from the entrance, the so-called Elysian fields are reached, from which a view of more than 200 yd. in length can be obtained. The finest of all, however, is the Grotta del Paradiso. These caves are now joined by a tunnel to the Grotta Vera, and with the abyss of the Piuca, which can be

traversed in a boat. The stalactite formations assume fantastic shapes. The length of the passages known is nearly 14 miles. These subterranean wonders were known as far back as 1213 (the earliest names found in it date from 1250) and were probably visited by Dante, who certainly knew the lake of Circonio (Cerkniza) in which the Javornik is reflected. But the cavern remained undiscovered in modern times until 1818. The Magdalene grotto is celebrated for the extraordinary subterranean amphibian, *Proteus anguinus*, first discovered there. It is about a foot in length, lives on snails and worms and is provided with both lungs and gills.

POTASHES, the crude potassium carbonate obtained by lixiviating wood ashes and evaporating the solution to dryness, an operation at one time carried out in iron pots—hence the name from "pot" and "ashes." The term potash or caustic potash is frequently used for potassium hydroxide, whilst such a phrase as sulphate of potash is now appropriately replaced by potassium sulphate. (*See* POTASSIUM.)

POTASSIUM [symbol K (from *kalium*), atomic number 19, atomic weight 39·105], a metallic chemical element, belonging to the group termed the metals of the alkalis. Although never found free in nature, in combination the metal is abundantly and widely distributed. In the oceans alone there are estimated to be $1{,}141\times10^{12}$ tons of sulphate, K_2SO_4, but this inexhaustible store is not much drawn upon; and the "salt gardens" on the coast of France lost their industrial importance as potash-producers when the deposits at Stassfurt in Germany came to be worked. These deposits, in addition to common salt, include the following minerals: sylvine, KCl; carnallite, $KCl{\cdot}MgCl_2{\cdot}6H_2O$ (transparent, deliquescent crystals, often red with diffused oxide of iron); kainite, $K_2SO_4{\cdot}MgSO_4{\cdot}MgCl_2{\cdot}6H_2O$ (hard crystalline masses, permanent in the air); kieserite $MgSO_4{\cdot}H_2O$ (only very slowly dissolved by water); besides polyhalite,

$$MgSO_4{\cdot}K_2SO_4{\cdot}2CaSO_4{\cdot}2H_2O,$$

and anhydrite, $CaSO_4$; salt, NaCl, and some minor components. These potassium minerals are not confined to Stassfurt; larger quantities of sylvine and kainite are met with in the salt mines of Kalusz in the eastern Carpathian Mountains. Important deposits are being worked in Thuringia and Baden, and others occur at Wittelsheim (Alsace) and at Suria (Catalonia, Spain). There are also undeveloped resources in Chile, Peru and Brazil. The Stassfurt minerals owe their industrial importance to their solubility in water and consequent ready amenability to chemical operations. In point of absolute mass they are insignificant compared with the abundance and variety of potassiferous silicates, which occur everywhere in the earth's crust; orthoclase (potash felspar) and potash mica may be quoted as prominent examples. Such potassiferous silicates are found in almost all rocks, both as normal and as accessory components; and their disintegration furnishes the soluble potassium salts which are found in all fertile soils. These salts are sucked up by the roots of plants, and by taking part in the process of nutrition are partly converted into oxalate, tartrate, and other organic salts, which, when the plants are burned, are converted into the carbonate, K_2CO_3. The "vinasse" of beet-sugar factories, *i.e.*, the material left in the retorts after the distillation of the fermented molasses, also consists largely of potassium salts (chiefly the carbonate) and the potash is either utilized directly as a manure or in the manufacture of soft soaps, or it is refined by fractional crystallization. It is a remarkable fact that, although in a given soil the soda-content may predominate largely over the potash salts, the plants growing in the soil take up the latter: in the ashes of most land plants the potash (calculated as K_2O) forms upwards of 90% of the total alkali. The proposition holds, in its general sense, for sea plants likewise. In ocean water the ratio of soda (Na_2O) to potash (K_2O) is 100:3·23 (Dittmar); in kelp it is, on the average, 100:5·26 (Richardson). Ashes particularly rich in potash are those of burning nettles, wormwood (*Artemisia absinthium*), tansy (*Tanacetum vulgare*), fumitory (*Fumaria officinalis*) and tobacco. According to Liebig, potassium is the essential alkali of the animal body; and it may be noted that sheep excrete most of the potassium which they take from the land as sweat, one-third of the weight of raw merino consisting of potassium compounds.

Sir Humphry Davy's Experiment.—To Sir Humphry Davy belongs the merit of isolating this element from potash, which itself had previously been considered an element. On placing a piece of potash on a platinum plate, connected to the negative of a powerful electric battery, and bringing a platinum wire, connected to the positive of the battery, to the surface of the potassium a vivid action was observed: gas was evolved at the upper surface of the fused globule of potash, whilst at the lower surface, adjacent to the platinum plate, minute metallic globules were formed, some of which immediately inflamed, whilst others merely tarnished. In 1808 Gay-Lussac and Thénard obtained the metal by passing melted potash down a clay tube containing iron turnings or wire heated to whiteness, and Caradau effected the same decomposition with charcoal at a white heat. Electrolytic methods are now generally employed for the manufacture of potassium. The Castner process used for sodium (*q.v.*) is somewhat unsatisfactory for potassium, but has been rendered more suitable by various modifications. Fused potassium hydroxide is electrolysed by means of a sheet-iron anode and an iron-wire cathode, the latter being surrounded by a cylinder of magnesite in order to prevent metallic potassium diffusing into the hydroxide in which it tends to dissolve. The temperature is kept as low as possible and air is excluded. The molten hydroxide may be replaced by a readily fusible mixture of potassium chloride and fluoride. The metal, however, is not in great demand, for it is generally found that sodium (*q.v.*), which is cheaper, and, weight for weight, more reactive, will fulfil any purpose for which potassium may be desired.

Pure Potassium.—Pure potassium is a silvery white metal tinged with blue; but on exposure to air it at once forms a film of oxide, and on prolonged exposure deliquesces into a solution of hydrate and carbonate. Perfectly dry oxygen, however, has no action upon it. (*See* DRYNESS, CHEMICAL.) At temperatures below 0° C it is hard and brittle; at the ordinary temperature it is so soft that it can be kneaded between the fingers and cut with a blunt knife. Its specific gravity is 0·865; hence it is the lightest metal known except lithium. It fuses at 62·5° C and boils at about 760°, emitting an intensely green vapour. It may be obtained crystallized in quadratic octahedra of a greenish-blue colour, by melting in a sealed tube containing an inert gas, and inverting the tube when the metal has partially solidified. When heated in air it fuses and then takes fire, burning into a mixture of oxides. Most remarkable, and characteristic for the group it represents, is its action on water. A pellet of potassium when thrown on water at once bursts out into a violet flame and the burning metal fizzes about on the surface, its extremely high temperature precluding absolute contact with the liquid, except at the very end, when the last remnant, through loss of temperature, is wetted by the water and bursts with explosive violence. The reaction may be written $2K+2H_2O=2KOH+H_2$, and the flame is due to the combustion of the hydrogen, the violet colour being occasioned by the potassium vapour. The metal also reacts with alcohol to form potassium ethoxide, while hydrogen escapes, this time without inflammation:

$$K+C_2H_5{\cdot}OH=C_2H_5{\cdot}OK+H.$$

When the oxide-free metal is heated gently in dry ammonia it is gradually transformed into a blue liquid, which on cooling freezes into a yellowish-brown or flesh-coloured solid, potassamide, KNH_2. When heated to redness the amide is decomposed into ammonia and potassium nitride, NK_3, which is an almost black solid. Both it and the amide decompose water readily with formation of ammonia and caustic potash. The metal dissolves in liquid ammonia to give a blue solution. Potassium at temperatures from 200° to 400° C occludes hydrogen gas, the highest degree of saturation corresponding approximately to the formula K_2H, but it seems probable that KH is the only compound formed. In a vacuum or in sufficiently dilute hydrogen the compound from 200° upwards loses hydrogen, until the tension of the free gas has arrived at the maximum value characteristic of that temperature. The hydride is used for the manufacture of potassium formate which results from the action of moist carbon dioxide: $KH+CO_2=H{\cdot}CO_2K$.

COMPOUNDS

Oxides and Hydroxide.—Potassium forms two well-defined oxides, K_2O and K_2O_4, whilst several others, of less certain existence, have been described. The monoxide, K_2O, may be obtained by strongly heating the product or burning the metal in slightly moist air; by heating the hydroxide with the metal:

$$2KOH+2K=2K_2O+H_2;$$

or by passing pure and almost dry air over the molten metal. It forms a grey brittle mass, having a conchoidal fracture; it is very deliquescent, combining very energetically with water to form caustic potash.

Potassium hydroxide or caustic potash, KOH, formerly considered to be an oxide, may be obtained by dissolving the metal or monoxide in water, but is manufactured by double decomposition from potassium carbonate and slaked lime:

$$K_2CO_3+Ca(OH)_2=2KOH+CaCO_3,$$

or by electrolytic methods similar to those used for sodium hydroxide. (*See* ALKALI MANUFACTURE.) In the former case, a solution of one part of the carbonate in 12 parts of water is heated to boiling in a cast-iron vessel by means of steam-pipes and the milk of lime added in instalments until a sample of the filtered mixture no longer effervesces with an excess of acid. The mixture is then allowed to settle in the iron vessel, access of air being prevented as much as practicable, and the clear liquor is syphoned off. The liquors after concentration in iron vessels are evaporated in a silver dish, and the residual oily liquid is then poured out into a polished iron tray, or into an iron mould to produce the customary form of "sticks," and allowed to cool. The solid must be at once bottled, because it attracts the moisture and carbonic acid of the air with great avidity and deliquesces. Nickel basins are better adapted than iron basins for the preliminary concentration of potash lye. The latter begin to oxidize before the lye has come up to the traditional strength of specific gravity 1·333 when cold, while nickel is not attacked so long as the percentage of real KOH is short of 60. For the fusion of the dry hydrate nickel vessels cannot be used; in fact, even silver is perceptibly attacked as soon as all the excess of water is away; absolutely pure KOH can be produced only in gold vessels. Glass and (to a less extent) porcelain are attacked by caustic potash lye, slowly in the cold, more readily on boiling.

Solid Caustic Potash.—Solid caustic potash forms an opaque, white, stone-like mass of dense granular fracture; specific gravity 2·1. It fuses considerably below and is perceptibly volatile at a red heat. At a white heat the vapour breaks down into potassium, hydrogen and oxygen. It is extremely soluble in even cold water, and in any proportion of water on boiling. On crystallizing a solution, the hydrate $KOH·2H_2O$ is deposited; $2KOH·9H_2O$ and $2KOH·5H_2O$ have also been obtained. The solution is intensely "alkaline" to test-papers. It readily dissolves the epidermis of the skin and many other kinds of animal tissue—hence the former application of the "sticks" in surgery. A dilute potash readily emulsionizes fats, and on boiling saponifies them with formation of a soap and glycerin. All commercial caustic potash is contaminated with excess of water (over and above that in the KOH) and with potassium carbonate and chloride; sulphate, as a rule, is absent. A preparation sufficing for most purposes is obtained by digesting the commercial article in absolute alcohol, decanting and evaporating the solution to dryness and fusing in silver vessels.

The *peroxide,* K_2O_4, discovered by Gay-Lussac and Thénard, is obtained by heating the metal in an excess of slightly moist air or oxygen, or better by melting the metal in a flask filled with nitrogen and gradually displacing this gas by oxygen; the first formed grey film on the metal changes to a deep blue, and then the gas is rapidly absorbed, the film becoming white and afterwards yellow. It is a dark yellow powder, which fuses at a high temperature, the liquid on cooling depositing shining tabular crystals; at a white heat it loses oxygen and yields the monoxide. Exposed to moist air it loses oxygen, possibly giving the dioxide, K_2O_2; water reacts with it, evolving much heat and giving caustic potash, hydrogen peroxide and oxygen; whilst carbon monoxide gives potassium carbonate and oxygen at temperatures below 100°. A violent reaction ensues with phosphorus and sulphur, and many metals are oxidized by it, some with incandescence.

Halogen Compounds.—Potassium fluoride, KF, is a very deliquescent salt, crystallizing in cubes and having a sharp saline taste; it is formed by neutralizing potassium carbonate or hydroxide with hydrofluoric acid and concentrating in platinum vessels. It forms the acid fluoride KHF_2 when dissolved in aqueous hydrofluoric acid, a salt which at a red heat gives the normal fluoride and hydrofluoric acid. Other salts of composition $KF·2HF$ and $KF·3HF$, have been described by Moissan.

Potassium chloride, KCl, also known as muriate of potash, closely resembles ordinary salt. It is produced in immense quantities at Stassfurt from the so-called "Abraumsalze" (waste salts). When hydrogen chloride is passed into a solution of potassium chloride the salt is completely precipitated as a fine powder. If the original solution contained the chlorides of magnesium or calcium or sulphate of potassium, all impurities remain in the mother-liquor (the sulphur as $KHSO_4$), and can be removed by washing the precipitate with strong hydrochloric acid. The salt crystallizes in cubes of specific gravity 1·995; it melts at about 800° and volatilizes at a bright red heat. It is extensively employed for the preparation of other potassium salts, but the largest quantity (especially of the impure product) is used in the production of artificial manures.

Potassium bromide, KBr, may be obtained by dissolving bromine in potash, whereupon bromide and bromate are first formed, evaporating and igniting the product in order to decompose the bromate:

$$6KOH+3Br_2=5KBr+KBrO_3+3H_2O;\quad 2KBrO_3=2KBr+3O_2;$$

but it is manufactured by acting with bromine water on iron filings and decomposing the iron bromide thus formed with potassium carbonate. In appearance it closely resembles the chloride, forming colourless cubes which readily dissolve in water and melt at 722°. It combines with bromine to form an unstable tribromide, KBr_3.

Potassium Iodide.—Potassium iodide, KI, is obtained by dissolving iodine in potash, the deoxidation of the iodate being facilitated by the addition of charcoal before ignition, proceeding as with the bromide. The commercial salt usually has an alkaline reaction; it may be purified by dissolving in the minimum amount of water, and neutralizing with dilute sulphuric acid; alcohol is now added to precipitate the potassium sulphate, the solution filtered and crystallized. It forms colourless cubes which are readily soluble in water, melt at 685° and yield a vapour of normal density. It is sparingly soluble in absolute alcohol. Both the iodide and bromide are used in photography. Iodine dissolves in an aqueous solution of the salt to form a dark brown liquid, which on evaporation over sulphuric acid gives black acicular crystals of the tri-iodide, KI_3. The salt is very deliquescent; it melts at 45°, and at 100° decomposes into iodine and potassium iodide. For the oxyhalogen salts *see* CHLORATES; CHLORINE; BROMINE and IODINE.

Carbonate of Potash, popularly known as "potashes," was originally obtained in countries where wood was cheap by lixiviating wood ashes in wooden tubs, evaporating the solution to dryness in iron pots and calcining the residue; in more recent practice the calcination is carried out in reverberatory furnaces. This product, known as "crude potashes," contains, in addition to carbonate, varying amounts of sulphate and chloride and also insoluble matter. Crude potash is used for the manufacture of glass, and, after being causticized, for the making of soft soap. For many other purposes it must be refined, which is done by treating the crude product with the minimum of cold water required to dissolve the carbonate, removing the undissolved part (which consists chiefly of sulphate), and evaporating the clear liquor to dryness in an iron pan. The purified carbonate (which still contains most of the chloride of the raw material and other impurities) is known as "pearl ashes." Most of the carbonate which occurs in commerce is made from the chloride of the Stassfurt beds by an adaptation of the "Leblanc process" for conver-

sion of common salt into soda ash. (*See* ALKALI MANUFACTURE.)

Chemically pure carbonate of potash is best prepared by igniting pure bicarbonate in iron or (better) in silver or platinum vessels, or else by calcining pure cream of tartar. The latter operation furnishes an intimate mixture of the carbonate with charcoal, from which the carbonate is extracted by lixiviation with water and filtration. The filtrate is evaporated to dryness (in iron or platinum vessels) and the residue fully dehydrated by gentle ignition. The salt is thus obtained as a white porous mass, fusible at a red heat (838° C) into a colourless liquid, which solidifies into a white opaque mass. The dry salt is very hygroscopic; it deliquesces into an oily solution ("oleum tartari") in ordinary air. The most saturated solution contains 205 parts of the salt to 100 of water and boils at 135°. On crystallizing a solution monoclinic crystals of $2K_2CO_3{\cdot}3H_2O$ are deposited, which at 100° lose water and give a white powder of $K_2CO_3{\cdot}H_2O$; this is completely dehydrated at 130°. The carbonate, being insoluble in strong alcohol (and many other liquid organic compounds), is much used for dehydration of the corresponding aqueous preparations. The pure carbonate is constantly used in the laboratory as a basic substance generally, for the disintegration of silicates, and as a precipitant. The industrial preparation serves for the making of flint glass, of potash soap (soft soap) and of caustic potash.

Potassium bicarbonate, $KHCO_3$, is obtained when carbonic acid is passed through a cold solution of the ordinary carbonate as long as it is absorbed. Any silicate present is also converted into bicarbonate with elimination of silica, which must be filtered off. The filtrate is evaporated at a temperature not exceeding 65°; after sufficient concentration it deposits on cooling anhydrous crystals of the salt, while the potassium chloride, which may be present as an impurity, remains mostly in the mother-liquor; the rest is easily removed by repeated recrystallization. The bicarbonate forms large monoclinic prisms, permanent in the air. When the dry salt is heated to 190° it decomposes into normal carbonate, carbon dioxide and water.

Sulphur Compounds.—Potassium sulphide, K_2S, was obtained by Berzelius in pale red crystals by passing hydrogen over potassium sulphate, and by Berthier as a flesh-coloured mass by heating the sulphate with carbon. When it is prepared by treating potash with sulphuretted hydrogen and adding a second equivalent of alkali, a solution is obtained which on evaporation in a vacuum deposits crystals of $K_2S{\cdot}5H_2O$. The solution is strongly caustic. It turns yellow on exposure to air, absorbing oxygen and carbon dioxide and forming thiosulphate and potassium carbonate and liberating sulphuretted hydrogen, which decomposes into water and sulphur, the latter combining with the monosulphide to form higher salts. The solution also decomposes on boiling. The hydrosulphide, KHS, was obtained by Gay-Lussac on heating the metal in sulphuretted hydrogen, and by Berzelius on acting with sulphuretted hydrogen on potassium carbonate at a dull red heat. It forms a yellowish-white deliquescent mass, which melts on heating, and at a sufficiently high temperature it yields a dark red liquid. It is readily soluble in water, and on evaporation in a vacuum over caustic lime it deposits colourless, rhombohedral crystals of $2KHS{\cdot}H_2O$. The solution is more easily prepared by saturating potash solution with sulphuretted hydrogen. The solution has a bitter taste, and on exposure to the air turns yellow, but on long exposure it recovers its original colourless appearance owing to the formation of thiosulphate. *Liver of sulphur* or *hepar sulphuris*, a medicine known to the alchemists, is a mixture of various polysulphides with the sulphate and thiosulphate, in variable proportions, obtained by gently heating the carbonate with sulphur in covered vessels. It forms a liver-coloured mass. In the pharmacopoeia it is designated *potassa sulphurata*.

Potassium sulphite, K_2SO_3, is prepared by saturating a potash solution with sulphur dioxide, adding a second equivalent of potash, and crystallizing in a vacuum, when the salt separates as small deliquescent, hexagonal crystals. The salt $K_2SO_3{\cdot}H_2O$ may be obtained by crystallizing the metabisulphite, $K_2S_2O_5$ (from sulphur dioxide and a hot saturated solution of the carbonate, or from sulphur dioxide and a mixture of milk of lime and potassium sulphate) with an equivalent amount of potash. The salt $K_2SO_3{\cdot}2H_2O$ is obtained as oblique rhombic octahedra by crystallizing the solution over sulphuric acid.

Potassium sulphate, K_2SO_4, a salt known early in the 14th century, was styled in the 17th century *arcanum* or *sal duplicatum*, being regarded as a combination of an acid salt with an alkaline salt. It was obtained as a by-product in many chemical reactions, and subsequently used to be extracted from kainite, one of the Stassfurt minerals, but the process is now given up because the salt can be produced cheaply enough from the chloride by decomposing it with sulphuric acid and calcining the residue. To purify the crude product it is dissolved in hot water and the solution filtered and allowed to cool, when the bulk of the dissolved salt crystallizes out with characteristic promptitude. The very beautiful (anhydrous) crystals have the habit of a double six-sided pyramid, but really belong to the rhombic system. They are transparent, very hard and absolutely permanent in the air. They have a bitter, salty taste. The salt is soluble in water, but insoluble in caustic potash of sp.gr. 1·35, and in absolute alcohol. It fuses at 1,078°. The crude salt is used occasionally in the manufacture of glass. The acid sulphate or bisulphate, $KHSO_4$, is readily produced by fusing thirteen parts of the powdered normal salt with eight parts of sulphuric acid. It forms rhombic pyramids, which melt at 197°. It dissolves in three parts of water of 0° C. The solution behaves as if its two congeners, K_2SO_4 and H_2SO_4, were present side by side uncombined. An excess of alcohol, in fact, precipitates normal sulphate (with little bisulphate) and free acid remains in solution. Similar is the behaviour of the fused dry salt at a dull red heat; it acts on silicates, titanates, etc., as if it were sulphuric acid raised beyond its natural boiling point. Hence its frequent application in analysis as a disintegrating agent. The sulphate is also used in alum manufacture; fertilizer and medicine. For the salts of other sulphur acids, *see* SULPHUR.

Potassamide, NH_2K, discovered in 1811, is obtained as an olive green or brown mass by gently heating the metal in ammonia gas, or as a white, waxy, crystalline mass when the metal is heated in a silver boat. It decomposes in moist air, or with water, giving caustic potash and ammonia, in the latter case with considerable evolution of heat. For the nitrite, *see* NITROGEN; for the nitrate, *see* NITRIC ACID AND NITRATES; and for the cyanide, *see* PRUSSIC ACID; for other salts *see* the articles wherein the corresponding acid receives treatment.

Analysis, etc.—All volatile potassium compounds impart a violet coloration to the Bunsen flame, which is masked, however, if sodium be present. The emission spectrum shows two lines, $K\alpha$, a double line towards the infra-red, and $K\beta$ in the violet. The chief insoluble salts are the perchlorate, hydrogen tartrate and chloroplatinate (platinichloride); and the difference in solubility between the potassium and ammonium salts of "eikonogen" enables a separation to be effected, most other salts of these two radicals being similarly soluble. The atomic weight was determined by Stas, Richards and Stähler.

MEDICINE

Pharmacology.—Numerous salts and preparations of potassium are used in medicine; viz., *Potassii Carbonis* (salt of tartar), dose 5 to 20 gr., from which are made (*a*) *Potassii Bicarbonas*, dose 5 to 30 gr.; (*b*) *Potassa Caustica*, a powerful caustic not used internally. From caustic potash are made: (1) *Potassii Permanganas*, dose 1 to 3 gr., used in preparing *Liquor Potassii Permanganatis*, a 1% solution, dose 2 to 4 dr., (2) *Potassii Iodidum*, dose 5 to 20 gr., from which are made the *Linamentum Potassii Iodidi cum Sapone*, strength 1 in 10, and the *Unguentum Potassii Iodidi*, strength 1 in 10. (3) *Potassii Bromidum*, dose 5 to 30 gr. (4) *Liquor Potassae*, strength 27 gr. of caustic potash to the oz. *Potassii Citras*, dose 10 to 40 gr. *Potassii Acetas*, dose 10 to 60 gr. *Potassii Chloras*, dose 5 to 15 gr., from which is made a lozenge, *Trochiscus Potassii Chloratis*, each containing 3 gr. *Potassii Tartras Acidus* (cream of tartar), dose 20 to 60 gr., which has a subpreparation *Potassii Tartras*, dose 30 to 60 gr. *Potassii Nitras* (saltpetre), dose 5 to 20 gr. *Potassii Sulphas*, dose 10 to 40 gr. *Potassii Bichromas*, dose $\frac{1}{10}$ to $\frac{1}{5}$ gr.

Toxicology.—Poisoning by caustic potash may take place or poisoning by pearl ash containing caustic potash. A caustic taste in the mouth is quickly followed by burning abdominal pain, vomiting and diarrhoea, with a feeble pulse and a cold clammy skin. The treatment is washing out the stomach or giving emetics followed by vinegar or lemon juice and later oil and white of egg.

Therapeutics.—Externally: Caustic potash is a most powerful irritant and caustic; it is used with lime in making Vienna paste, which is occasionally used to destroy morbid growths. *Liquor potassae* is also used in certain skin diseases. The permanganate of potash is an irritant if used pure. Its principal action is as an antiseptic and disinfectant. If wet it oxidizes the products of decomposition. It is used in the dressing of foul ulcers. The 1% solution is an antidote for snake-bite.

Internally: Dilute solutions of potash, like other alkalis, are used to neutralize the poisonous effects of strong acids. In the stomach potassium salts neutralize the gastric acid, and hence small doses are useful in hyperchlorhydria. Potassium salts are strongly diuretic, acting directly on the renal epithelium. They are quickly excreted in the urine, rendering it alkaline and thus more able to hold uric acid in solution. They also hinder the formation of uric acid calculi. The acetate and the citrate are valuable mild diuretics in Bright's disease and in feverish conditions, and by increasing the amount of urine diminish the pathological fluids in pleuritic effusion, ascites, etc. In tubal nephritis they aid the excretion of fatty casts. The tartrate and acid tartrate are also diuretic in their action and, as well as the sulphate, are valuable hydragogue saline purgatives. Potassium nitrate is chiefly used to make nitre paper, which on burning emits fumes useful in the treatment of the asthmatic paroxysm. Lozenges of potassium chlorate are used in stomatitis, tonsilitis and pharyngitis; it can also be used in a gargle, 10 gr. to 1 fl.oz. of water. Its therapeutic action is said to be due to nascent oxygen given off; so it is local in its action. In large doses it is a dangerous poison, converting the oxyhaemoglobin of the blood into methaemoglobin. Internally the permanganate is a valuable antidote in opium poisoning. The action of potassium bromide and potassium iodide has been treated under bromine and iodine (*qq.v.*). All potassium salts if taken in large doses are cardiac depressants; they also depress the nervous system, especially the brain and spinal cord. Like all alkalis if given in quantities they increase metabolism.

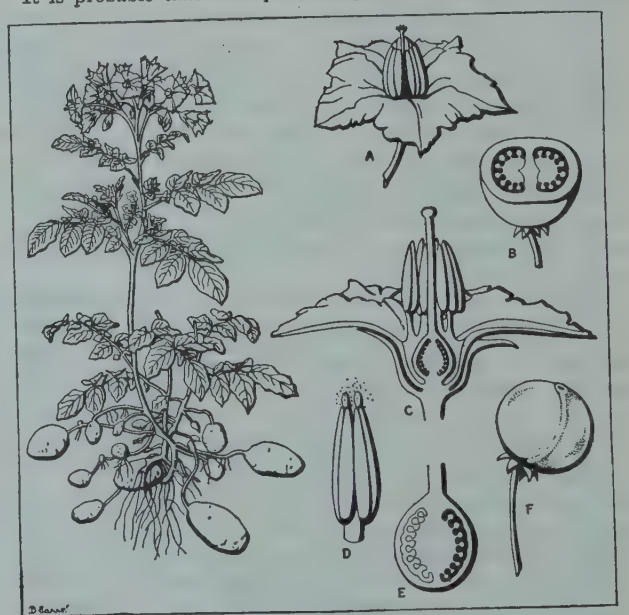
POTATO. The potato belongs botanically to the section *Tuberarium* of the genus *Solanum*, the members of which are, with few exceptions, tuber bearing. This section comprises not only the cultivated forms but many wild species, the number of which probably exceeds 100.

Formerly the species *Solanum tuberosum* was understood to comprise all cultivated varieties of the potato, but these were later assigned to 14 species. *S. tuberosum* is the most important of the group since it includes the Chilean cultivated forms as well as the commercial varieties of North America and Europe. Most of the common cultivated varieties of the Andes region belong to the species, *S. andigenum*. The 12 remaining species are grown in small local areas in the Andean countries and more or less resemble wild species in their general appearance.

Origin.—The origin of the potato is lost in antiquity, but it is known that when the Spaniards invaded South America in 1524 they found a large number of varieties and species under cultivation, the tubers of which were used as a common article of food by the natives. Where these varieties and species originated is more or less conjecture, but they seem to be native to the American continents since their relatives are still found growing wild in the elevated regions extending from the southwestern part of the United States to the southern part of South America, particularly in the higher altitudes of Bolivia and Peru and the coastal regions and nearby islands of Chile. All the species seem to require a cool climate; they are found growing in regions near the equator at high altitudes and none is known to occur under tropical conditions. If the origin of the potato is uncertain, information concerning its introduction into other countries is also shrouded in mystery. The exact history of such introductions has been lost, and the few historical stories that remain prove to have little solid foundation. Sir Walter Raleigh, for instance, is said to have brought back the potato from Virginia in 1585, yet on investigation it appears that the true potato did not reach Virginia until more than 100 years after this date. Nor could Raleigh have obtained the potato from Peru, for his ships apparently never visited that country.

Sir John Hawkins is also credited with having introduced the potato in 1565. Investigation shows that the potatoes brought back by Hawkins were the "sweet potato," *Ipomoea batatas* and not the ordinary potato, *S. tuberosum*. Claims are also made for Drake in this connection. Certainly his ships passed through the Straits of Magellan in 1578 and turned northwards looting the coast towns of Chile and Peru after which he returned to England across the Pacific and Indian oceans thereby completing his renowned trip around the world. There is, however, no record that potatoes were brought on his ship "Pelican," and indeed it was not until 1586 that he is alleged to have introduced the potato. The Germans are exponents of the Drake story, for there stands in Offenburg, Baden a monument inscribed: "Sir Francis Drake introducer of the Potato into Europe in the year of our Lord 1580."

It is probable that the Spaniards gave the potato to Europe.



FROM BAILLON, "HISTOIRE DES PLANTES" (BONNAIRE)

POTATO (SOLANUM TUBEROSUM), SHOWING WHOLE PLANT WITH UNDERGROUND STEMS AND TUBERS (POTATOES)

A. Single flower. B. Fruit cut across to show placenta and ripening ovules. C. Longitudinal section through flower. D. Two ripe stamens opening and shedding pollen. E. Longitudinal section through ovary. F. Fruit

In the *Cronica de Peru* of Pedro Creça (Seville, 1553) the potato is mentioned under the name "battata" or "papa." Hieronymus Cardan, a monk, is supposed to have been the first to introduce it from Peru into Spain, from which country it passed into Italy, from there early in the 17th century to Austria, then to Germany, from Germany to Switzerland and finally to France.

The earliest representation of the plant is to be found in Gerard's *Herball*, published in 1597. The plant is mentioned under the name *Papus orbiculatus* in the 1st edition of the *Catalogus* of the same author published in 1596 and again in the 2nd edition which was dedicated to Sir Walter Raleigh (1599). It is, however, in the *Herball* that we find the first description of the potato accompanied by a woodcut sufficiently correct as to leave no doubt whatever as to the identity of the plant. In this work (p. 781) it is called "Battata virginiana sive Virginianorum et Pappus, Potatoes of Virginia."

In 1629, Parkinson, the friend and associate of Johnson, published his *Paradisus*, in which (p. 517) he gives an indifferent

figure of the potato under the name of "Papas seu Battatas Virginianorum."

Little is known of the introduction of the potato into North America. It is generally believed that the English colonists of Virginia and Carolina obtained the potato from Spaniards or from other travellers. The most authentic report shows that potatoes were first grown in the United States at Londonderry, N.H., in 1719 from stock brought from Ireland. It was for this reason, no doubt, that the potato has been called the "Irish" potato. The name is still used, especially in the southern states, where it serves to distinguish the potato from the sweet potato.

Plant Characteristics.—The potato plant is a herbaceous annual, propagated by true seeds or by the tubers. The aerial stems may be erect or procumbent and have several axillary branches. Stems are round or angular, pubescent or glabrous, green or more or less purple. The first leaf on the stem is usually simple, and the later ones pinnate with three or four pairs of large, entire, petiolated leaflets and smaller ones between. The leaves are arranged on the stem in a spiral. Fibrous roots arise in groups of three just above the nodes on the underground part of the stem. They may extend to a depth of 3 or 4 ft. and nearly as far horizontally. As most of the roots are comparatively near the surface the potato does not seem adapted to culture without irrigation or frequent rainfall.

The cymose inflorescences occur in the axil of about every sixth node. The flowers of an inflorescence open progressively over a period of several days. They produce no nectar and are seldom visited by insects. The rotate corolla is five-lobed and white, yellow, purple, blue or striped, according to the variety. The five stamens are borne on the corolla tube and converge around the pistil. The large erect anthers dehisce by a terminal pore. There are two carpels forming the two-loculed ovary with a single style. The fruit, or seed ball, is a green round berry about ½-¾ in. in diameter and generally contains numerous seeds. The seeds are very small, kidney-shaped and smooth and are embedded in the pulp of the fruit.

The leaves on the underground part of the vertical stem are small and scalelike; in their axils lateral stems called stolons arise. These are of variable length, more or less fleshy and of typical stem structure. The tubers are swellings arising at the end of these stolons. The tuber is a shortened, thickened, underground stem, with scalelike leaves or leaf scars subtending the eyes. The eye in its entity is a leaf scar with its subtended axil which contains a lateral branch and the latter's axillary buds and undeveloped internodes. Because of short internodes, the nodes are brought close together and the buds lie in nearly the same plane. Since there are several buds on each of these shortened branches, it is possible to get several shoots from an eye. The central bud in an eye is the terminal bud of the branch and develops first upon renewal of growth. There is also a correlation between the development of different eyes on the tuber. Sprouts usually develop first from eyes at the apical or distal end of the tuber; this development is known as "apical dominance." When the vascular connection between the different eyes is severed by cutting the tuber into pieces or by notching around the eyes, apical dominance disappears and all eyes develop at about the same rate. Apical dominance within the tuber and within the individual eyes disappears when the first sprouts are destroyed or are checked in their growth.

The epidermis of the tuber sloughs off in the early stages of development and is replaced with a periderm six to ten cells thick. The periderm consists of small flat cells which become suberized during the ripening of the tuber or upon exposure to dry air. Thus a tough skin is formed which protects the tuber against

TABLE I.—*Potato Area and Output, 1937*

Country	Area in Acres	Production in Short Tons	Yield per Acre in Short Tons
	1000 Acres	1000 Short Tons	
Northern Hemisphere			
North America			
Canada	531	2,128	4.0
United States	3,174	11,827	3.7
Total	3,705	13,955	3.8
Europe			
United Kingdom	714	5,477	7.7
Ireland	326	3,032	9.3
Norway	128	949	7.4
Sweden	333	1,991	6.0
Denmark	200	1,460	7.3
Netherlands	341	2,923	8.6
Belgium	390	3,408	8.7
France	3,554	17,544	4.9
Spain	1,030(1)	5,184(1)	5.0
Italy	1,042	3,541	3.4
Switzerland	121	968	8.0
Germany	7,136	60,985	8.5
Austria	538	3,550	6.6
Czechoslovakia	1,914	13,631	7.1
Hungary	729	2,822	3.9
Yugoslavia	657	1,786	2.7
Rumania	583	2,323	4.0
Poland	7,366	44,348	6.0
Lithuania	457	2,767	6.1
Latvia	314	1,965	6.3
Estonia	188	1,087	5.8
Finland	215	1,530	7.1
Union of Soviet Socialist Republics	18,303(1)	52,755(1)	2.9
Estimated European Total	46,579	236,026	
Southern Hemisphere			
Chile	126	482	3.8
Argentina	314	1,050	3.3
Bolivia	652(2)	341(2)	0.5(2)
Australia	141(1)	394(1)	
Estimated World Total	51,517	252,248	

(1) Five year average 1930–34 inclusive.
(2) Crop year 1926.

TABLE II.—*International Trade in Potatoes, 1937*

Country	Exports Short Tons	Imports Short Tons
	1000 Short Tons	1000 Short Tons
Exports Exceeding Imports		
Canada	98	8
United States	55	32
Netherlands	511	6
Italy	172	85
Poland	61	0.3
Czechoslovakia	9	8
Hungary	87	0.1
Spain	113(1)	23(1)
Portugal	19	15
Algeria	87	37
Ireland	55	0.1
Estonia	26	0
Japan	45	0
Malta	16	6
Cyprus	20	1
Netherlands Indies	1	0.6
China	5	0.2
Denmark	65	0
Norway	1	0
Yugoslavia	0.6	0.4
Imports Exceeding Exports		
Germany	23	157
United Kingdom	62	249
France	61	177
Belgium	95	99
Cuba	0.8	33
Austria	6	29
Switzerland	0	58
Uruguay	0	37
Brazil	0.9	1
Egypt	3	24
Finland	0	1
Sweden	0.1	7
Tunisia	1	12
Philippine Islands	0	12
Argentina	4	267
Venezuela	0	6

(1) 5 year average, 1930–34 inclusive.

bruising. It is fairly impermeable to gases. Lenticels take the place of stomata. Below the periderm is a rather dense layer of cortex which is variable in width and consists of small parenchyma cells densely filled with starch grains. The vascular bundles approach the surface of the tuber at the eyes. The pith enclosed by the vascular ring constitutes the greater portion of the tuber. It may be divided into the more dense portion, the outer medulla, and the less dense portion, the inner medulla. The medullary regions consist of large parenchyma cells less densely filled with starch and other contents than is the cortex.

World Production.—Most of the accounts of the introduction of the potato into Europe and North America are without doubt legendary, but the spectacular increase of the potato as a food crop is not legendary. It is one of the miracles of agriculture and is grown in almost every important agricultural country in the world. Though it succeeds best in the cooler regions, it has made rapid development as a food crop in many other places and exceeds, in point of total production, that of any other table plant grown.

It will be noted in Table I that the countries which may be classed as cool produced the highest average yields. The average for the United States as a whole is comparatively low, although it had increased to approximately 4 tons per acre in 1942. The yields in Maine and Idaho, with cool summer climates, and in California, where the potato crop is grown for the most part in late winter and early spring, compare favourably with the highest yielding countries of Europe. A plentiful supply of irrigation water in California and Idaho also accounts to some extent for the large yields produced there. The international trade in potatoes is quite important, as indicated by Table II.

Europe as a whole exports more potatoes than it imports, as do also Canada and the United States. On the other hand, Central America, South America, Africa and Asia are deficit zones.

The demand in England and Wales is not satisfied by the home crop, and supplies are sent from both Scotland and Ireland, where production is always in excess of home needs. In most seasons the British Isles as a whole are almost self-supporting in potatoes. Imports of early kinds, however, are brought in from the Canary Isles, Spain, France and the Channel Islands in the early months when people have tired of eating "old" tubers. Commercial production of the main crop is centred in Lincolnshire, Yorkshire, Lancashire and Durham in England; Forfar, Fife and Perth in Scotland and in Counties Down and Antrim in Northern Ireland.

Potatoes are grown throughout France, though in some of the departments the soils are not well suited to culture and acreages are small. In other departments, Vienne, Rhin, Saône-et-Loire, Loire, Haute-Loire, Loire Inférieure, Maine-et-Loire and Morbihan, considerable areas are planted for commercial production. In certain specially favourable places such as St. Malo, Brittany and also in the Rhône valley, quick-growing varieties are planted to give an early supply to the markets not only of France but in normal times to England also.

Potato production in Germany is of two kinds. The crop of the west is grown mainly for table purposes, that of the east mainly for industrial purposes—though naturally much variation occurs at times. In eastern Germany there exist vast tracts of light sandy soil of little use for grass or cereal production, but by continuous and judicious manuring with fertilizers they have been rendered fertile for potatoes which are grown in large quantities and largely used for making farina or alcohol.

The late or main crop of potatoes in the United States is grown mostly in the states bordering Canada, where climate and soil are most favourable. The states leading in production are Maine, Idaho, Minnesota, New York, Michigan, Wisconsin, Pennsylvania, North Dakota, Colorado and California. Every state produces potatoes at some season, but the surplus commercial crop is grown mostly in the above named states. Colorado, California, Florida, Alabama, Louisiana, North Carolina, South Carolina, Virginia, Maryland and New Jersey ship to distant markets when the potatoes from the north are scarce. The southern states grow the crop in the winter and spring, when the temperatures are comparatively cool.

Varieties.—Many hundreds of varieties of potatoes are grown in the different countries of the world. In England and America they are divided into first earlies, second earlies, mid-season or early main crop and main crop or late varieties. In England the heaviest croppers among the first earlies are Epicure, Duke of York, Sharpe's Express and Immune Ashleaf. The principal second early and main crop varieties are Ally, King George, Great Scott, King Edward, Arran Chief, Majestic and Kerr's Pink.

For many years the varieties grown commercially in the United States were mainly those which were originated by pioneer potato breeders in the 19th century. Some of these were products of hybridization, some were discovered as mutations or "sports," others originated as chance seedlings. A number of these continue to be standard varieties in certain sections of the country. Among them are the early varieties, Irish Cobbler, Triumph and Early Ohio, and the late varieties, Green Mountain, Rural New Yorker No. 2, Russet Rural, White Rose, Burbank and Russet Burbank. The National Potato Breeding program, organized cooperatively by the U. S. department of agriculture and state experiment stations, distributed to growers 16 new varieties. Among these are 4 first earlies: Earlaine, Mesaba, Warba and Red Warba; 3 second earlies; Chippewa, Pawnee and Kasota and 8 late varieties: Katahdin, Houma, Golden, Pontiac, Sebago, Sequoia, Erie and Mohawk.

Dr. William Stuart of the department of agriculture classified the American varieties into 12 groups, largely on the basis of tuber characters, season of maturity and blossom colour. Each group was named for the leading variety in it and contains all of the commercially important varieties of the respective type which it represents. The 12 groups are: Cobbler, Triumph, Early Michigan, Rose, Early Ohio, Hebron, Burbank, Green Mountain, Rural, Pearl, Peachblow and Up to Date.

Potato Soils.—The potato can be grown on almost any soil, but deep, rich sandy loams or well drained alluvial silts are most suitable. The Lancashire and a part of the Lincolnshire and Irish crop are produced in black peat. These soils produce good yields, but the tubers are dull and dark in appearance and sell at lower prices than bright skinned tubers produced in the red sandstone silts and limestone soils. One of the most ideal soils for potatoes in the United States is the Caribou loam in Aroostook county, Maine. This is a chocolate brown coloured soil abundantly supplied with small decomposing fragments of shale rock with which it is underlaid.

It has been found highly profitable to grow potatoes on the muck or peat soils that are so extensive in a number of states. The potatoes grown on such soils usually have good shape, but like those grown on the Irish peat they have a dark appearance. This difficulty is overcome by the practice of many growers of brushing or washing the tubers before they are packed for market. When this is done the potatoes often bring a premium.

Rotations.—The importance of an abundant supply of organic matter in the soil cannot be over-emphasized. A large amount of humus keeps the land in a friable condition and provides a continuous supply of available plant food. There is no general and well-defined system of crop rotation adhered to in any of the large potato growing centres. The desirability of rotating crops is well understood, but the temptation to grow a money crop as often as possible is very great so that the benefits from the practice of rotation are often sacrificed to the prospect of immediate gain. In England the position of the potato crop in the rotation varies very much in different localities, but potatoes do particularly well after old grass or a short fallow. In the United States the potato is usually grown in a rotation series of two or more crops; the one preceding is preferably a legume. Type and length of rotation depend on the kind of agriculture practised. In the Aroostook section of Maine, where the potato is the major crop, a three-year rotation of potatoes, oats and clover is standard, the clover being usually plowed under as green manure.

Sweet clover commonly precedes potatoes in the rotation in the central states and alfalfa in the western states. In most New England and middle Atlantic states timothy sod containing clover residue is plowed before potato planting. Frequently the

sod residue is too scanty to be of much benefit to the potato crop.

Along the eastern seaboard potatoes are commonly grown year after year on the same soil. If little or no stable manure is available, the growers depend on rye as a winter green manure crop to maintain the soil humus supply. In the south, velvet beans, soybeans and cowpeas are used for the same purpose. Rotation is necessary in many sections where the soil reaction is nearly or quite alkaline to avoid infection of the tubers with the common scab disease. In these sections growers avoid the use of lime, and an effort is made to use commercial fertilizers that increase soil acidity. It is usually advisable to decrease the acidity of potato soils only when and to the extent necessary to promote the growth of legumes in the rotation.

Fertilization and Preparation of Land.—Stable manure is always beneficial to the potato crop, and within reason the greater the dressing the larger the crop. In practice in England not more than 20 tons per acre should be applied. Often the amount has to be cut to 10 or 12 tons; and where this is done, the deficiency should be made good by using some other material. Seaweed, for instance, is an excellent substitute and is much used by the potato growers of Scotland, Ireland, Cornwall and the Maritime Provinces of Canada. Irish growers have to use artificial fertilizers as a supplement. Most experimenters are agreed that a fertilizer containing nitrogen, phosphates and potash is desirable, but the exact proportion in which they should be mixed depends in large measure on specific soil requirements.

The following mixture per acre may be generally depended upon to produce good crops:

2 cwt. sulphate of ammonia
6 cwt. super phosphate
2 cwt. sulphate or muriate of potash

In the trials conducted at the Rothamsted experimental station in England, the nitrogen fertilizers proved over a period of years the most consistent in their action, giving every year with rare exceptions an increase of about 20 cwt. of potatoes per cwt. of sulphate of ammonia used, whatever the season and whether or not farmyard manure was used. At Rothamsted there was little variation from season to season in the maximum yield of potatoes obtainable by good manuring. Their maximum was 11-13 tons per acre and usually 4 cwt. of sulphate of ammonia and 4 cwt. of sulphate of potash per acre were necessary to secure this. Economy of either ammonia or potash reduced the yield. The action on other soil would no doubt be somewhat different.

In the eastern and southern sections of the United States, chemical fertilizers make up nearly ½ of the total cost of production. In Maine and along parts of the Atlantic seaboard 1-1½ tons to the acre of a complete fertilizer is commonly applied. Westward and on heavier soils a smaller quantity of fertilizer containing less nitrogen and potash is used. In the first mentioned regions 5-8-7 or 4-8-7 analyses are recommended while on the newer and heavier soil types 4-12-4 and 5-10-5 are often used. Double-strength fertilizer in correspondingly decreased acre applications is also used. When stable manure is applied liberally, as in the dairy regions, commercial nitrogen may not be needed.

Modern planters are equipped to distribute commercial fertilizer in bands on each side of the seed piece and well mixed with the soil to avoid possible burning of the sprouts. Stable manure when used may be spread on the land by hand or with a manure spreader, either before or after the land is plowed. Some growers prefer to plow the manure under while others favour its application to the plowed land. Regardless of how or when it is applied, the best results are obtained when it is thoroughly incorporated with the soil and well decomposed before planting time.

Where potatoes follow the cereal crop, which frequently happens in England, preparation of the land should begin with an autumn cleaning followed by deep winter plowing and spring cultivation to give moderately fine tilth. In April, the ridging plow is used to throw the soil into ridges between which lie the furrows (distance between the furrows being about 27 in.) into which the potato-sets will go; before these are planted it is customary to scatter the barnyard manure and artificial fertilizers in the furrows so that they lie close to the sets.

In the United States it is generally desirable to plow the land for the potato crop in the fall, except where soil is liable to wash badly during the winter. Fall-plowed land should be disked and harrowed as early as possible in the spring and then kept friable until the crop is planted. Spring-plowed land should be disked as plowed and kept mellow. The deeper it is prepared and the more finely it is pulverized, the more suitable it is for producing large yields. It is much easier to do this before than after planting. The old adage that "a stitch in time saves nine" is quite applicable to the proper preparation of the land.

Seed.—The importance of using good seed cannot be overemphasized, but the term "good seed" needs careful definition. A potato tuber of any size when planted is capable of giving a crop, but in practice in Great Britain and parts of the U.S. it is found most economical to select seed tubers weighing approximately 2-3 oz. These can be planted whole. If large tubers are used they may be cut into seed pieces or sets. The latter is the common practice in the larger growing areas of the United States.

Good seed cannot be judged by appearance alone. It should be true to name and free from diseases, and the variety should be well adapted to the region in which it is to be grown. It is impossible even for experts to recognize varieties by examination of the tubers alone, so a record of the purity of the crop from which the seed stock was selected is the most reliable guide. Unfortunately tubers infected with virus diseases such as mosaics, leaf roll, crinkle or curly dwarf cannot be distinguished from healthy potatoes. The disease readings of the crop from which the seed was harvested is the only sure guide. If the parent crop was all of one variety, free from mosaics, leaf roll, crinkle, spindle tuber and curly dwarf, the seed selected from it has a good history and a good potential yielding capacity; if the parent crop was mixed or had much virus infection, the seed from it will be distinctly inferior, regardless of the appearance of the seed tubers.

The virus diseases are not peculiar to any country or region, but in some places and in some seasons they spread more rapidly than in others. They are spread mostly by insect vectors such as aphids or plant lice; conditions that favour insect infestations also favour the spread of these diseases. Potato crops grown in the colder districts are known usually to be freer of viruses than those of the warmer regions, and in consequence the former districts are the better areas in which to grow potatoes for seed. Consequently, growers in the southern districts of the United States buy nearly all of their seed from producers in the north and the Maritime Provinces of Canada. This is necessary because southern-grown potatoes are often seriously devitalized by heat and virus diseases.

To combat these diseases and raise the standards of potato cultivation, many countries—including the United States, Canada, the Netherlands, England, Scotland, Northern Ireland and the Irish Free State—have established systems of seed-potato-certification under which fields of potatoes are examined by inspectors and certificates given for those crops that reach certain specified standards of purity to type and freedom from diseases. The increase in the production of such seed in the United States was tremendous. In 1919 about 475,000 bu. of potatoes were certified, and in 1941 more than 17,000,000 bu. met the certification standards.

Storage is an important factor in the maintenance of good seed. At harvest time potatoes are in a dormant condition and cannot be made to sprout at once. This rest period lasts from about 6 weeks to 3 months depending on the variety and the conditions under which the tubers are stored. Tests have shown that dormancy can be maintained in some varieties for 6 to 8 months at temperatures ranging from 36° to 40° F. When kept at high temperatures the tubers sprout after a few weeks and soon become shrunken and lose vitality; each successive generation of sprouts is weaker than the preceding one. In fact, seed vigour in stored tubers can be measured to a degree by noting the character of the sprouts; if slender and originating from many eyes the seed may be adjudged weak. Long storage sprouts should not be allowed to develop. In preparing the seed for planting it is common practice to disinfect uncut seed potatoes against such tuber-borne diseases as common scab, rhizoctonia (black scurf) and

blackleg. This is done at any time up to the planting date, preferably when the tubers are in a clean, dormant condition Various disinfectants and methods are used. Corrosive sublimate (mercuric chloride) and formaldehyde have been used most. Treatment of uncut rather than cut tubers is advised.

In the mercuric chloride (corrosive sublimate) treatment the standard solution is made by dissolving 1 part of mercuric chloride in 1,000 parts of water, or, 4 oz. in 30 gal. of water. Potato tubers are immersed for 30 min. to 2 hr. in this solution. Mercuric chloride goes into solution very slowly in cold water and it should therefore be dissolved in a small volume of hot water. The solution should be prepared and used in wooden, enamel or concrete containers. The solution decreases in strength with use. To correct this, ½ oz. of the chemical should be added for every 4 bu. of potatoes treated for 2 hr. If a shorter treatment is used, the amount of chemical added should be reduced proportionately. Enough water should be added each time to bring the solution up to its original volume. Make up a fresh solution after 4 treatments. Wetting the tubers for 20-24 hr. before treatment makes the disinfection more effective.

Cold formaldehyde is not effective in controlling rhizoctonia but may be used for the control of scab. The solution is prepared by adding 1 pt. of formalin (40% commercial formaldehyde solution) to 30 gal. of water. The tubers are immersed in this solution for 2 hr.

Hot formaldehyde is not so effective as mercuric chloride but is widely used in some places. Previous to being treated it is desirable to keep the potatoes wet for 24 hr. The solution is made up by dissolving 2 pt. of formalin in 30 gal. of water heated to a temperature of 124° to 126° F. and held within these limits by steam or by means of a fire maintained beneath the tank. The tubers are then dipped for 4 min. A false bottom to the tank is necessary to keep the tubers at the bottom from becoming overheated. The solution should not be warmer than 126° F. because above this temperature injury to the sprouting of the potatoes results. Nor should it be cooler than 124° as it would then not control the disease if the tubers are dipped for only the 4-min. period. To allow for condensation water when live steam is used for heating, 0.9 pt. of formalin should be added after every 50 bu. of tubers are treated. The solution does not lose its strength on standing if it is well covered and may safely be kept thus for a few days or weeks. Covering the tubers with a canvas or burlap for an hour after treatment adds to the efficiency of this method.

It is considered by a number of experts in the United States that such seed treatments are very inefficient in the control of disease and in most cases not worthwhile. If the seed tubers are clean there is no need for treatment. If they are badly infected they should be sold for table stock. If diseased tubers must be used some of the organisms will be killed by the mercuric treatments, but very few by formaldehyde and if the treated tubers are planted in soil infested with disease organisms, the resulting crop of tubers will be diseased.

Green sprouting seed potatoes before planting in order to hasten the development of marketable tubers is a common practice in Great Britain and on the continent but is employed to a very limited extent by U.S. growers. This is essentially a germination test which results in more perfect stands of plants, less disease, increased earliness and possibly higher yields.

The questions of size of the seed piece and of planting whole rather than cut seed are still not fully answered. The superiority of whole over cut or of cut seed over whole has been demonstrated for both, and the conclusion can be drawn that no general rule can be given, but that much depends on the variety and the environmental conditions in which the crop is grown. Seed pieces should be cut large enough to ensure at least one vigorous healthy sprout. They should be blocky and as uniform in size and shape as possible especially where they are planted with a self-feeder planter. Pieces weighing less than an ounce are subject to drying out when planted in hot dry soil and may result in weak plants or missing hills. Experiments have shown that the eyes from the basal and the seed end of the tuber of most varieties are of equal value for seed.

As a rule potatoes are planted as soon after cutting as possible. This is a satisfactory method in the large producing areas of the United States if the soil at planting time is not too wet or too dry and the weather too cold. In regions where seed piece rot is a problem, whole tubers or suberized seed should be used. Suberization or corking over is best accomplished by storing the cut tubers in an atmosphere of relatively high humidity and a temperature range of from 60° to 70° F. Under these conditions a protective layer of cork cells will develop over the cut surface forming an effective barrier against disease organisms in the soil. The use of such materials as hydrated lime, gypsum and sulphur to cause rapid drying is no longer recommended.

Planting and Cultivation.—Potatoes are planted in the United States every month of the year although the bulk of the crop is planted from March 15 to June 30. The date depends on the regional climate, latitude or altitude, but it is desirable to plant at such date as will allow the period of blossoming and tuber-setting to come in relatively cool weather. In some regions subject to late blight infection, the early planted crop is most likely to escape while at the same time it may be more subject to injury by leafhoppers and flea beetles.

In England the soil is thrown into ridges with a ridging plow. The seed pieces are planted by hand in the furrows between these ridges. The distance between the furrows is about 27 in. and between the plants in the row, 10 in.–1 ft. The seed pieces are covered by splitting the ridges with the ridging plow so that the soil falls into the furrows on either side. There are potato planting machines which open the furrows, place the fertilizers and sets in position and cover them as they proceed across the field. Hand planting is practised on many of the small acreages in the United States, but probably more than ¾ of the commercial acreages are planted with machines. Many of these machines plant one row at a time, but two row planters are quite common and some plant 4 rows in one operation. These planters are of two types, an automatic picker type requiring only one man to operate or an assisted feed type requiring an additional man to regulate the flow of the seed. Modern planters are equipped to distribute fertilizer in bands on each side of the seed piece and mix it with the soil to avoid possible burning of the potato sprouts. These machines can be adjusted to various distances between rows and to drop the sets at various distances apart in the row. Four inches is the depth of planting recommended, with shallower depth for heavy soils and deeper for sandy soils. The average amount of seed used is approximately 15 bu. to the acre, the range being from 8 to 30.

Cultivation for weed control is very important, as the potato plant is very sensitive to weed competition. On the other hand the plant may be seriously checked in growth and yields reduced when harsh, deep, late season cultivation results in cutting off the extensive, lateral, fibrous root system and disturbing the developing tubers between the rows. Thorough seed bed preparation and early season cultivation rather than late are therefore recommended. If late cultivation is practised it should be very shallow and just deep enough to cut off the weeds. Moisture conservation is not, as was formerly thought, a prime factor in cultivation. Shallow cultivation of heavy soils to break the crust that forms after heavy rains is desirable to provide soil aeration and permit absorption of later rains. Ridging of rows especially on heavy soils has several advantages. It affords an effective means of weed control, run-off of excess surface water, protection of the tubers from sunburn and to a degree from late blight spores and allows easier digging of the crop. Tractor or horse drawn cultivators for early cultivation and hillers or hoe ridgers are used for ridging the rows.

POTATO DISEASES AND INSECTS

Potato diseases are very numerous. They can be classed as virus, fungus, bacterial and physiological.

Virus Diseases.—The virus diseases are not due, as far as is known, to any living organism or to nutritional disturbances. They were formerly believed to be the result of degeneration brought about by continuous vegetative propagation of a variety. They

were spoken of as "degeneration" diseases. The fallacy of this belief has been clearly demonstrated. The most troublesome virus diseases are mild mosaic, latent mosaic, rugose mosaic, leaf roll, spindle tuber and yellow dwarf.

Mild Mosaic.—The usual symptom of mild mosaic is the mottling of the leaves. The leaflets, instead of being uniformly green, show different shades of green or a slight yellowness; the leaves may also show some crinkling. In many cases the name "mild" is a misnomer, since the disease can be very severe. In such cases the plants may be dwarfed and the yield markedly reduced. Under hot, dry conditions the mosaic symptoms may not be so marked or may disappear altogether, but the yield of diseased plants is nevertheless diminished.

Latent Mosaic.—This disease is true to name in varieties like the Green Mountain and Irish Cobbler, in which it is present in 100% of the plants. No disease symptoms develop in these varieties and it is not known if the yields are reduced since no tubers can be found free from the virus and as a consequence no comparative yield tests between diseased and healthy plants can be made. In other varieties and seedlings it can hardly be considered latent since various reactions are discernible. Some varieties show mottling, others a top necrosis and in some of them the yields are severely reduced even if no symptoms are observed.

Rugose Mosaic.—This disease is considered by some to be more serious than mild mosaic and is entirely distinct from it. The mottled areas are smaller and more numerous and typically are distributed closer to the main veins. The mottling is readily masked under high-temperature conditions but the crinkling of the leaves makes identification rather certain. The veins on the underside of the lower leaves often show necrotic areas as black, pencil-like lines. Affected plants are usually stunted and die much earlier than the healthy ones. Rugose mosaic is spread readily by aphids. If infection takes place early in the season, current-season symptoms are likely to develop before the plant dies. If infection occurs late, symptoms may not appear the same season but tubers from such plants will carry the disease. Current season symptoms are characterized by a burning and discolouration of the leaf veins and leaf blades, brittleness, leaf dropping and premature death.

Leaf Roll.—This virus disease is very common in Britain, Canada, the United States and in potato growing countries generally. It is characterized by the upward rolling of the leaflets so that the midrib remains at the middle of the trough thus formed. The lower leaves usually show the symptoms first. Other symptoms are dwarfing, rigidity, leathery texture, chlorosis and reddish or purplish discolouration of the affected leaves. Net necrosis appearing in newly infected tubers is a symptom of leaf roll of certain varieties. It is a network of small brown strands of discoloured tissue extending throughout the interior of the potato tuber, the discolouration usually beginning at the stem end. As in the case of the mosaics described above, the leaf roll virus can be transmitted by aphids and possibly by other insects. Infection can also be produced by grafting together of healthy and diseased tubers or other portions of the plant. Hot dry weather often causes a curling of the leaves which can easily be mistaken for the virus leaf roll.

Spindle Tuber.—This disease is so named because of the spindle-shaped tubers produced by infected plants. Such plants are often slender, upright and smaller than healthy ones and the foliage is sometimes darker green. In Triumph, infected tubers are lighter red than the healthy tubers and have a tendency to be blocky and cylindrical in shape. Experiments have shown that this disease can be transmitted by various insects, including grasshoppers, flea beetles, tarnished plant bugs and Colorado potato beetles. To some extent the disease may be spread by contact with cut seed pieces, by the seed-cutting knife and by picker-planters.

Yellow Dwarf.—The foliage of plants with yellow dwarf takes on a yellowish-green colour, whereas the upper surface of the leaves becomes slightly rugose. Dying from the tip downward is characteristic. High temperatures and low humidity tend to hasten the death of infected plants. Brown spots in the pith of the stem are common. In warm soil, seed pieces from infected tubers often fail to germinate; others produce shoots that die before they reach the surface. Infected plants often produce small, misshapen tubers which in cross-section show small necrotic areas scattered throughout the flesh.

Experiments conducted in New York state showed that this disease is transmitted by the clover leafhopper. This insect retains the virus during the winter and infects healthy potato plants in the spring.

Fungus Diseases.—*Late Blight.* This is the most serious of the many diseases to which the potato is heir. It is found in all the potato growing countries and as a whole causes more damage to the potato than all the other diseases combined. It is caused by a parasitic fungus *Phytophthora infestans,* which seems to have been noticed in Europe about 1840 and by 1845 had become widespread. It was the cause of the Irish famine in 1846, when the potato crop was almost completely destroyed. It is always present in Britain but is much more severe some seasons than others.

In the United States it is most destructive in the New England and north central states. At times it is responsible for considerable loss in nearly all the eastern seaboard states even as far south as Florida and along the Pacific coast. It is seldom of any importance in the other southern and central states. Wet seasons are particularly favourable to the disease and much of the crop may be lost unless preventive measures are taken; in dry summers it may do little damage. The disease generally shows itself as purplish brown or blackish patches on the leaves, often appearing first on the leaves near the top or margin. In damp weather the undersides of the patches may show delicate white threads, the hyphae of the fungus. Under such conditions also the dark coloured patches spread rapidly, and the whole foliage may be transformed into a moist black mass. Leaves badly attacked give off an offensive odour, detectable at a considerable distance.

The minute white threads which make up the body of the fungus branch and produce large numbers of pear-shaped structures, the spores of the fungus. These spores are detached and are carried by the movement of the air to other plants, where they germinate. The resulting threads pass through the stomatal pores of the leaf and each starts a new infected area. Under suitable conditions a new crop of spores may be produced a few hours after infection so the fungus can spread rapidly. Under favourable warm and moist weather conditions all the plants in the field may be killed in a few days. The organism also attacks the tubers, which become infected either in the soil through spores washed from the diseased tops or in harvesting through contact with blighted foliage. When late blight tuber rot first develops in the soil, it is usually brown and spreads irregularly from the surface through the flesh. The affected part may become soft partly because of an abundance of moisture but mainly because other organisms, particularly bacteria, invade the diseased areas. Under storage conditions the disease is typically a dry rot forming irregular sunken patches, which under favourable conditions may involve the whole tuber. Secondary organisms may invade the tubers in storage and cause soft rots. The disease lives over in the tubers.

Early Blight.—Early blight, also known as leaf spot and caused by *Alternaria solani,* under some conditions occurs earlier in the season than late blight but under other conditions it may occur later. The fungus attacks the potato leaves causing the development of brown spots which, as they enlarge, develop concentric rings or markings. When the spots are numerous the leaves are killed and the yield of potatoes is consequently reduced. Small, shallow, more or less circular decayed lesions are sometimes formed on the tubers. These lesions rarely cause serious harm but they do afford entrance for soft rot organisms that complete the decay of the tubers.

Potato Scab.—This disease, often known as common scab of potato, is caused by *Actinomyces scabies.* It is particularly troublesome in sandy and gravelly soils, especially neutral or alkaline soils. It is known to exist in every potato growing section of the United States. It attacks the tubers and, when very

severe, renders them unfit for market. The scab lesions are small and brownish at first but later enlarge into hard, circular, or irregular corky areas on the surface of the tubers. They may separate or run together, sometimes covering the whole potato. They vary in type from shallow to deep.

Fusaria.—A number of species of *Fusarium* are known to attack the potato, causing wilt and other injury to the plants and tubers. Among these are *F. oxysporum, F. eumartii, F. avenaceum, F. coeruleum* and *F. trichotheciodies*. Plants attacked with *F. oxysporum* may wilt rather suddenly and die in a comparatively short time, or they may show the effects slowly and succumb gradually. The first symptoms are a yellowing and drooping of the lower leaves. There may be also some curling and rolling of the leaflets and tip burning. On hot days the yellowing is preceded by a wilting of the leaves and even of the stalks. The stems of affected plants are invariably discoloured in the interior. The woody tissues of the interior of the stem are yellow to brown, often extending from the base well into the top. The tubers of wilt infected plants often show a browning of the water vessels near the stem end. *F. eumartii* produces at first a burning and bronzing or slight yellowing of the upper leaflets. In late stages the plants wilt and die. Stems of the affected plants show a brownish flecking when cut longitudinally. Tubers of such plants show a browning of the stem end and vascular discolouration. The wilt organisms are carried over from one crop to the next in the tubers or in the soil. *F. avenaceum* has been reported from Wisconsin as behaving very much like *F. oxysporum*. Dry rots caused by *F. coeruleum* and *F. trichotheciodies* are generally referred to as storage dry rots. *F. coeruleum,* apparently the most common, can penetrate through an unbroken skin, but it usually enters through wounds and produces large sunken pockets or a wrinkled decay. Numerous bluish or whitish protuberances are formed on the surface of the decayed parts. The powdery dry rot caused by *F. trichotheciodies* is limited to situations having warm dry summers. Affected tubers shrink considerably and often develop in the interior large hollow pockets partly filled with a brick-coloured powdery mass of fungus growth.

Rhizoctonia Canker (Black Scurf).—The fungus that causes rhizoctonia or black scurf on the tubers, *Corticium solani,* ordinarily shows as small brown-black bodies closely adhering to the skin. These sclerotia, as they are called, may be as small as a pinhead or half as large as a pea. They are composed of mycelial threads and represent the resting stage of the fungus. Lesions or dead areas may develop on the underground stems and on the stolons and may so interfere with the proper functioning of the plant that the leaves roll, small tubers form in the axils of the leaves or the nodes of the stems become considerably enlarged and knobby because the starch cannot be properly transported downward. Many small potatoes and a few large knotty ones may be developed underground. This result often gives rise to the term "little potato disease."

Wart.—This disease is due to a fungus, *Synchytrium endobioticum.* It was discovered in 1896 in upper Hungary and was thought to be a new form of scab. The earliest definite record of it in England was in 1898 and in North America in 1912. It has caused serious damage in Europe, especially in certain districts of England and Ireland, but has been confined in the United States to a few small areas in limited districts of Pennsylvania, Maryland and West Virginia. The disease generally shows itself as warty outgrowths on the tubers and stolons and occasionally the stems and even the leaves. In severe cases the tuber may become a warty mass. The warty tissue of the tuber shows thick-walled sporangia which, reaching the soil, liberate free-swimming cells, zoospores. These penetrate some part of the young potato plant, usually one eye of the tuber and develop there, causing the abnormal warty tissue. In the affected tissue thinner-walled sporangia, the summer sporangia, are produced. These discharge to the exterior and liberate fresh zoospores which cause new infections, and so the process is repeated. The zoospores may unite in pairs and then after infection produce the thick-walled resting sporangia which, when they escape into the soil, are the source of infection for new crops. The fungus may live for many years even when the soil is kept in sod. The disease is easily spread by infected soil and tubers; the winter sporangia pass through the alimentary canal of animals unharmed.

Bacterial Diseases.—*Blackleg.*—Blackleg is caused by *Erwinia phytophthora.* It causes heavy losses in some potato growing sections under conditions favourable for its development. It may cause seed piece decay or destroy the sprout before it appears above ground. It causes also serious rotting of tubers in storage. The first symptoms are the rolling of the upper leaves of one or more shoots, compactness of the foliage and the gradual yellowing of the leaves. The plant dies as the base of the stem is rotted away by bacteria. The plant tissue in this region usually turns black, giving rise to the name blackleg. In seasons of abnormal rainfall the disease develops rapidly and involves a greater part of the stem than in dry seasons. When the disease progresses slowly aerial tubers may be formed on the stems, as in rhizoctonia canker. Tubers not severely affected if harvested and planted will very likely carry the disease over to the resulting crop. Unless conditions for the development of blackleg are favourable, however, the disease will not develop even if infected tubers are planted. It has been demonstrated in Minnesota and Maine that the seed-corn maggot is active in spreading the disease. If the fly has access to seed potatoes, eggs may be deposited. The maggots hatched from these eggs may be contaminated with the bacteria and may infect the seed pieces.

Brown Rot (Bacterial Wilt).—Brown rot is a bacterial disease resulting from infection with *Phytomonas solanacearum.* It is often called southern bacterial wilt. Climatic conditions limit this disease to the warmer potato growing sections of the United States. It is found in the south Atlantic and gulf coast states from Maryland to Texas and sometimes in Ohio, Illinois, West Virginia and Kentucky. The first symptom of brown rot is a slight wilting of the terminal leaves during the hottest part of the day. The plants may recover at first during the night but each successive wilting becomes more severe until finally the plants die. The vascular bundles in the stems, roots and stolons turn brown when they become stopped up with bacteria, causing the wilting and death by cutting off the plant's water supply. The brown colour is finally evident on the stem one or more inches above the soil line. When the vascular bundles are cut or broken, bacteria ooze from them as a white slimy mass. The bacteria sometimes ooze from the eyes of affected tubers, and become mixed with dirt which upon drying sticks to the surface. Tubers left in the ground continue to decay. Other rot organisms may invade the injured tissue and assist in making it a slimy mass with a very offensive odour. Plants with their tops killed by brown rot may bear healthy as well as diseased tubers. Other plants showing no signs of disease in their tops may sometimes produce diseased tubers.

Ring Rot (Bacterial Ring Rot) results from infection with *Phytomonas sepedonica.* It has been known in Europe for a relatively long time but has not been prominent in the United States until recently. It is an infectious bacterial wilt and ring rot disease. It differs from brown rot in that it is not so limited by climatic conditions and has been known to occur in nearly all the potato growing states. The symptoms of this disease generally do not become evident until late in the season. Some varieties become infected without showing symptoms in the leaves. When affected tubers are present there are usually found all gradations, from sound to completely decayed tubers. Decay begins in the region near the vascular ring of the tuber; hence the name ring rot. The decayed tissue is yellowish white and of a crumbly nature and may ooze from the infected parts under pressure. Infected tubers are often invaded by other soft rot organisms causing more rapid decay. The bacteria live over winter on slightly affected tubers. In many of these tubers the disease cannot be detected, but they may contain enough bacteria to contaminate the cutting knife, the receptacle that the seed is carried in or the planter; and the disease is spread to healthy seed by contact with such infested equipment.

Physiological Diseases.—These diseases are due to unfavourable environmental conditions and are not known to be caused by

any virus; fungus or bacteria. A number of physiological diseases are due to a deficiency in the soil of the elements necessary for growth. Those most often deficient are nitrogen, phosphorus, potassium and magnesium. Other abnormalities in potatoes may be due to a number of causes.

Heat and drought necrosis occurs in tubers that are allowed to lie in the hot soil after the vines begin to die. The water vessels of the affected tubers take on a golden yellow to brown discolouration. Freezing necrosis is caused by limited ice formation within the tuber. Upon thawing several kinds of internal discolouration may appear. In the ring type discolouration is limited to the vascular ring and adjacent tissue; in the net type there is more or less blackening of the vascular tissue and the fine strands that extend from the vascular tissue into the interior pith and outer tissues; in the blotchy type discolouration is characterized by irregular patches ranging from an opaque gray or blue to sooty black and may occur anywhere in the tuber.

Sunburn or greening results from exposure to light. In case of long exposure the outer tissues turn deep green and those underlying a greenish yellow or deep yellow. Greened tissue is unpalatable for most people and may be poisonous for a few.

Sunscald is caused by the development of extremely high temperatures in the tuber when exposed to sunlight. Often the tissues are killed to a considerable depth. Tubers may become watery and turn brown throughout or at least to a considerable depth, or they may have a blistered appearance externally and a metallic colour. Such areas may dry out and appear chalky and granular or hard and leathery. Most frequently, however, they are attacked by bacteria and fungi that cause a rapid decay.

Blackheart is a result of the asphyxiation of the tissue of the potato tuber. It occurs either when the temperature is too high or when the ventilation is so poor that the supply of oxygen is inadequate. The external symptoms of blackheart are moist areas on the surface which may be purplish at first but turn brown or black within a short time. The internal symptoms are a dark-grayish to purplish or inky black discolouration. Tissues cut soon after injury are of normal colour; shortly after access to air, however, they turn pink, then gray or purple and finally jet black. Generally the discolouration is restricted to the interior but may radiate to the exterior. With slight drying, affected tissues are firm and leathery; with prolonged drying, cavities result.

Insect Pests.—The common insect enemies of the potato are the Colorado potato beetle, flea beetle, leafhopper, aphid, psyllid, seed-corn maggot and wireworm.

The *Colorado Potato Beetle, Leptinotarsa decemlineata,* was unknown to the potato growers of North America prior to 1855. About that time the potato growing industry had spread west, and when it reached the section where these beetles were native they left the wild solanums on which they customarily fed and began to infest the plants. They soon spread in all directions until they were found in nearly all the potato growing regions of the United States and Canada. The adult potato beetle is about three-eighths of an inch long and yellow in colour with five black stripes running lengthwise on each wing cover and a series of black spots on the thorax. The eggs, 500–1,000 of which may be laid by one female, are yellow and are usually deposited in clusters on the under side of the potato leaflets. They hatch out in about a week. The full grown larva is a stout fleshy grub with a black head and black spots over the body. It consumes a large amount of foliage; and if many larvae are allowed to remain on the plant, they soon strip it of all its leaves. They mature in about three weeks, after which they enter the ground to pupate. Two or three generations may be produced in a season. The last generation winters underground, emerging as mature beetles early in the spring.

Flea Beetle.—The potato flea beetle, *Epitrix cucumeris,* is a small black jumping beetle, slightly over one-sixteenth of an inch in length and about one twenty-fourth of an inch in width. The antennae and legs are yellowish but the body parts including the head, wing covers and thorax are jet black. These beetles eat small holes in the leaves and when they are present in large numbers cause serious injury and reduced yields. The eggs are laid under rubbish on the ground, and the larvae attack the underground parts of the plant. In some sections, particularly in the south, the tubers at times are so seriously injured that they are inferior in market quality, if not unsalable. One or two broods are produced each season depending on the locality.

Leafhopper.—The potato leafhopper, *Empoasca fabae,* is a sucking insect. It causes a very destructive disease-like condition called hopperburn. This condition begins with a yellowing of the leaf around the margin and tip followed by a curling upward and rolling inward. The leaf changes from yellow to brown and becomes dry and brittle. When the hopperburn is very severe, the plant may die prematurely. The adult leafhopper is a pale green insect about one-eighth of an inch in length with wings that fold over the back. The nymphs are wingless and usually feed on the underside of the leaves from which they suck the juices. Leafhoppers pass the winter in the adult stage hidden beneath weeds or other rubbish and appear in the spring, when they deposit their eggs. In some sections of the United States this insect is very destructive, causing as much as 50% reduction in yield.

Aphids.—Several species of aphids or plant lice attack potatoes. Among these are *Macrosiphum solanifolii* and *Myzus persicae.* The first of these is often called the pink and green louse; the second is known as the green peach or spinach aphid. Both live on the juice which they suck from the host plant, thus depriving it of its vigour and reducing the yields. They are the common vectors that spread most of the virus diseases and these diseases are more of a problem to the growers than the aphids themselves.

Potato psyllid.—This pest causes a diseased condition commonly called psyllid yellows. It has also been referred to as "blight" or "purple top." The adult psyllid is very active in hot weather and has been called the jumping plant louse. The average female lays about 700 eggs. The adults appear incapable of producing psyllid yellows. As many as 1,000 have been observed on a plant with no deleterious effects. The nymphs are very destructive; as few as from three to five on a plant have been known to cause yellows. They feed for about 16 days. Psyllid injury has been reported from all states west of the Missouri river, but it is most severe in the plateau section. It has been stated that in Colorado psyllid yellows spreads more rapidly and uniformly and causes greater losses than any other disease or pest.

The first symptom of the disease consists of an upward rolling or cupping of the basal portion of the leaflets at the top of the plant. This rolling is usually accompanied by a marginal yellowing. In some varieties such as the Triumph and Irish Cobbler the upper parts may assume a distinct reddish or purplish colour. The symptoms spread from the top downward, often involving the entire plant. In some cases the nodes of the plants enlarge and the axillary buds are stimulated into growth, producing either an aerial tuber or a stocky shoot capped with a rosette of leaves. The plants often set a large number of tubers, as many as 50 being sometimes found. These tubers seldom attain marketable size and often sprout in the ground before digging time. Results of planting such tubers have not been consistent. Some lots have produced normal crops, others have resulted in weak spindly plants and still others have remained dormant. Attempts at transmitting the malady except by the feeding of the nymphs have resulted in failure.

Prevention and Control of Diseases and Insects.—Since many diseases of the potato are tuber-borne, the most important preventive measure is to secure seed stock that is as free as possible from viruses or disease producing organisms. Virus diseases in susceptible varieties are especially difficult to control. They are spread for the most part by insect vectors, and theoretically it ought to be possible to control them by eradicating the insects; but this method has not proved very satisfactory. Tubers from infected plants carry the virus but generally do not show disease symptoms; consequently they cannot be separated from healthy tubers in the storage house. On the other hand inspection of potato fields early in the growing season makes it possible to de-

tect the diseased plants by the definite symptoms they show. If these plants are rogued out promptly and destroyed before heavy infestations of insect vectors are present, further spread of the viruses is prevented and the crop is greatly improved for seed purposes. Since the heaviest infestations usually take place late in the growing season, early harvesting is often recommended to avoid consequent heavy spread of viruses.

The knowledge of potato diseases and especially of the virus diseases grew rapidly until the production of certified seed potatoes became a specialized industry. Standards for seed certification differ slightly in various countries and among the various states of the U.S.A., but they are all sufficiently high to ensure a minimum of virus diseases and, as a result, increased yields.

In the control of late blight, prevention is perhaps as important as protection. Partly rotted tubers taken out of storage and piled or scattered on the ground may sprout early in the spring; the blight fungus carried over in these decayed tubers develops on the new sprouts and is quickly carried by the wind to the growing crops in the field. These early infections often result in heavy epiphytotics. All waste potatoes should be prevented from growing by feeding them to livestock or by burning them. Seed tubers infected with blight should be discarded; if planted they may cause a recurrence of the disease. Under wet weather conditions, however, the fungus quickly comes in from outside sources so the vines have to be protected with copper sprays or dusts. The spray or dust must be applied before the blight makes its appearance and must adhere to the plant to prevent the fungus from penetrating into the tissues. In practice Bordeaux mixture (copper sulphate combined with lime) or Burgundy mixture (copper sulphate combined with washing soda) are used as sprays. There is some experimental evidence to show that both are equally effective. Bordeaux mixture is the standard spray in most potato growing sections. The formula commonly used is 8-8-100 (8 lb. of copper sulphate, 8 lb. of hydrated lime, 100 gal. of water).

For small areas the spray can be applied by means of a knapsack machine which must be provided with a nozzle that throws a fine misty spray. The Irish growers use these knapsacks. For the first spraying 120 gal. per acre or ¾ gal. per sq.rd. is sufficient, though for subsequent spraying 160 gal. per acre or 1 gal. per sq.rd. will be needed to cover the larger amount of foliage. In England, Scotland, Germany, Canada and the United States it is customary to use horse or tractor drawn machines, each capable of spraying many rows of potatoes at one time. Power sprayers fitted with 3 nozzles per row and delivering about 120 gal. per acre at 300-400 lb. pressure are used in many commercial fields. Copper dusts, although perhaps not so effective as the Bordeaux spray, give good control if proper materials are applied correctly.

It is fortunate that early blight and hopperburn can also be controlled by copper sprays or dusts; and if arsenical poisons are added, Colorado potato beetles and flea beetles can also be held in check. Copper lime arsenate dust (20 lb. monohydrated copper sulphate plus 70 lb. fresh hydrated lime plus 10 lb. calcium arsenate) is a standard mixture for dusting potatoes. It is usually applied at the rate of 25-35 lb. per acre. Machines are used for applying the dust. It should be blown on the leaves as a very fine powder when they are somewhat moist with dew or fine rain. Arsenical compounds are highly poisonous to men and animals and must be carefully handled. A respirator should be worn by the operator while mixing such chemicals and applying them as dusts. Hands, face and clothing should be washed thoroughly after spraying and dusting operations.

For the control of the tuber-borne diseases such as common scab, rhizoctonia and blackleg see the section *Seed*, above.

As fusarial wilts are carried over from one crop to another in seed potatoes and in the soil, seed selection and crop rotation are the means by which these diseases can be avoided.

Potato wart is controlled most satisfactorily by the use of immune varieties, a number of which are available.

Losses due to brown rot can be greatly reduced by the use of resistant varieties such as Katahdin and Sebago. It can be controlled to some extent in sandy types of soil by an application of 800 lb. of sulphur to the acre applied in the summer, followed by 3000 lb. of limestone per acre in the fall. The treatment is not recommended on muck, peat, loam or clay types of soil.

Colorado potato beetles, leafhoppers and flea beetles, as mentioned above, can be controlled by copper sprays or dusts combined with arsenical poisons. Aphids are more difficult to control. One of the best ways to eliminate heavy infestations of these insects is by eradicating the weeds, especially the mustards upon which they multiply and from which they migrate to the potato plants. Good results are often obtained by spraying at the early stages of infestation with a mixture of 1½ pt. of nicotine sulphate in 100 gal. of Bordeaux mixture. Another spray for aphids on potatoes can be prepared by adding 3 lb. of either derris or cube root powder and 2 qt. of soybean oil to 100 gal. of Bordeaux mixture. If Bordeaux mixture is not needed for the control of diseases and other insects, a nicotine soap solution consisting of 1½ pt. of nicotine sulphate, 4-5 lb. of soap and 100 gal. of water may be used. Dust mixtures containing .75% of rotenone are also effective against aphids. The principal objection to spraying or dusting for aphid control is the high cost of the chemical compounds. Psyllids can be controlled to a certain degree by spraying with liquid lime-sulphur. One gallon of lime sulphur is mixed with 40 gal. of water. The sprayer used in applying this mixture should be capable of maintaining a pressure of 300 lb. and there should be three nozzles per row, the two lower ones turned upward at an angle to cover the under surface of the leaves. The success of this treatment depends upon its thoroughness and timeliness.

Control of heat and drought necrosis involves keeping the soil moist and cool and shaded, and if the soil is light and the weather hot, digging as soon as the vines begin to die.

To prevent freezing injuries, tubers should not be exposed to temperatures below 32° F. Greening of the tubers may be prevented by protecting the tubers from light.

Sunscald can be avoided by protecting the tubers from long exposure to the sun. If tubers are not exposed to temperatures of more than 95° F. and are given good ventilation they will not develop black heart.

POTATO BREEDING

The potatoes that were brought to Europe from Peru and Chile in the latter half of the 16th century had very irregularly shaped tubers, disfigured by outgrowths and extremely deep eyes. These features were characteristic of the early Peruvian varieties, and in England and on the continent these very rough deep-eyed varieties were the rule until the earlier part of the 19th century. In the hands of plant breeders the shape, colour and quality were much improved. Most of the improvements were made after 1845, when potato diseases focused attention on the crop. In that year potato blight reached Europe and became so destructive in Ireland as to cause a famine and much loss of life. This gave an impetus to the search for varieties resistant to disease. Perhaps the first and most important introduction in Great Britain was the variety Victoria, raised and introduced by William Paterson of Dundee. Victoria was a great and successful cropper and proved the parent of many other great potatoes later produced, including Champion, Up-to-Date, Great Scott and Ninetyfold. Simultaneously and for the same reasons there was great activity in the production of new varieties in the United States. Reverend C. E. Goodrich of Utica, New York, conceived the idea that the disastrous epidemics of late blight during the years 1843–47 were the result of a reduction in the vigour of the plants caused by long-continued propagation by vegetative means, and that this vigour could be restored by growing plants from true seed. While he did not succeed in the control of late blight by this means, he may be considered to have laid the foundation of potato breeding in the United States by furnishing material to be used by other breeders. The ancestry of 170 varieties can be traced back to Goodrich's Garnet Chili, a seedling of the imported Rough Purple Chili. They include several well known varieties of commerce such as Beauty of Hebron, Burbank, Early Ohio, Early Rose, Green Mountain, Prolific and Triumph. The Magnum

Bonum, a very popular potato of England and north European countries, was bred from Early Rose by J. Clark of Christchurch. Clark also grew Abundance, Epicure and Ninetyfold, varieties still of some importance.

The second wave of potato blight came in 1870 and caused much destruction of the existing varieties. Breeders concentrated on securing more resistant forms. Nicol of Arbroath then introduced the Champion, a high yielding resistant variety, which soon became largely grown throughout Scotland and Ireland and in time in most potato districts of the world.

Great credit should be given to Archibald Findlay of Scotland, however, for his success in developing many varieties, including Up-to-Date and British Queen. The Up-to-Date, especially, made both Scotland and Ireland famous for potatoes, and this variety was exported to all parts of the world. From 1907 to 1928 Donald McKelvie was active as a potato breeder; his Arran Chief, Arran Banner, Arran Comrade and Arran Consul became popular in many places. German breeders raised Richter's Imperator, the President and Paulsen's Juli, all of such merit as to justify wide cultivation. The work of C. G. Pringle of Charlotte, Vt., is worthy of mention in that it is said to represent the first systematic effort to obtain seed by controlled hybridization. His varietal contributions were the Alpha, Adirondack, Rubicund, Ruby and Snowflake.

Early in the 20th century another era in potato breeding began in Europe. The recognition and alarming spread of potato wart forced to the front the question of "immune varieties." Immunity from wart, like any other genetic character, is the end result of the interaction of genetic factors and environment. Several genetic factors are involved in the inheritance of this character. Some of them are dominant, causing immunity independent of all other immunity factors; others work together in a complementary manner and still others are cumulative in effect. With a number of dominant factors available, it was not a difficult task to produce many new varieties with immunity from wart combined with other characters of economic importance.

When potato breeding was actively taken over by the United States department of agriculture in 1910 under the direction of Dr. William Stuart, the only disease resistance sought was that against the late blight fungus. It was not until some years later that it became evident that the virus diseases were a greater menace to potato production than late blight because the viruses are transmitted from one crop to the next through tuber infection and they cannot be controlled by fungicidal application to the foliage or by seed treatment. It was soon realized that the widespread occurrence of potato virus diseases such as the various types of mosaic, leaf roll, spindle tuber, curly dwarf, yellow dwarf and streak could be controlled only by the breeding mode of attack. The first step in this direction was toward the development of varieties resistant to one of the commonest of these diseases, mild mosaic. Seedlings that showed some resistance to virus infection were selected by Dr. Charles F. Clark, who became associated with Dr. Stuart in this work. Dr. Clark crossed the resistant seedlings with one another and with other seedlings and varieties. As a result a number of new varieties with a high degree of resistance to mild mosaic, with desirable tuber characters, good habit of vine growth and relatively high yield were distributed to growers. Katahdin, Chippewa and Houma were the first of these. Katahdin has exceptionally wide adaptation. It has been grown successfully in nearly every potato growing section of the United States and in Canada, Uruguay, Argentina, south Africa and Australia.

While this work was being carried on by the department of agriculture a few of the state experiment stations, especially Minnesota and Cornell university, had undertaken potato breeding work. It was soon realized that problems and objectives in this field of endeavour cut across state lines and involved large regions of the entire country. It was therefore decided in 1928 to organize the work as a national project with all interested state experiment stations and the United States department of agriculture co-operating. Material was sent also to any foreign country requesting it. The expansion in the organization greatly increased the number of problems attacked. The so-called "economic" characters such as yield, time of maturity, depth of eye, shape of tuber and culinary quality were given primary consideration but intensive work was done also on resistance to various diseases and insect pests. Resistance was obtained to the virus diseases such as mild mosaic, latent mosaic, veinbanding, leaf roll and yellow dwarf. Immunity from late blight was found in many hybrid seedlings of the wild species, *Solanum demissum,* crossed with cultivated varieties of *S. tuberosum.* Resistance to this disease was found too in some of the cultivated varieties themselves and in a number of progenies obtained from Germany. The latter may be related to *S. demissum.* Seedling varieties, both late and early, highly resistant to common scab under a wide range of environmental conditions were produced. Varieties tolerant to Fusarium wilt also were produced. Many of the new productions were resistant, if not immune, to potato wart. Resistance to brown rot and ring rot are inherent in a number of varieties and progenies. Wide differences were found between varieties and seedlings in their reaction to injury by the insect pests, leafhoppers, flea beetles and psyllids.

Composition of the Potato.—The composition of the potato is to some extent inherent in the variety but is modified greatly by the conditions under which the plants are grown. Some of the factors that are known to result in variability even between tubers of the same variety are: the physical and chemical make-up of the soil, the kind and amount of fertilizer applied, climatic conditions, cultural methods such as depth of planting, state of maturity at harvest time and in irrigated districts the time and rate of application of water. Storage conditions, especially temperature, contribute to the variability.

Because of the wide variability all statistics on composition are subject to error. The average potato tuber contains 75%-80% water, 11%-20% starch (occasionally 23%-25%), 1.5%-2% of proteins and 2%-3% of fibre and mineral salts or ash. Its value, both as a food and in the manufacture of by-products, is due to its starch content. The normal potato contains only a small quantity of sugar (about 0.3%). If the tuber is analyzed in parts it is found that the dry matter usually decreases toward the centre. In one type analyzed the percentage of dry matter in the cortex, outer medulla and inner medulla respectively was 22.20, 19.41 and 14.92.

The desirable characteristic of a potato in England and America is a capacity to develop mealiness when boiled, and this depends largely on the percentage of starch in the tuber. In France, however, potatoes are rarely boiled but usually cooked in fat, hence there is a demand for a potato with a firm flesh becoming not mealy but "soapy" on boiling; such a potato is usually low in starch and high in nitrogen content. Since the culinary qualities of a potato are closely associated with its starch content the factors that cause variation in the latter will also cause variability in the former. As a result, the cooking quality of a variety may range from poor to excellent according to the conditions under which it was grown and harvested. Some varieties are more variable than others when grown under similar conditions.

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POTATO-LIFTER: *see* HARVESTING MACHINERY.

POTATO RACE, a contest, in which the winner is the first who collects in a basket or other receptacle a number of potatoes, usually eight, placed two yards apart along a straight line, and then crosses a line five or ten yards farther on.

POTATO SPIRIT. The replacement of grain by potatoes as the source of supply of alcohol for commercial use has, since the middle of the 19th century, developed into an important industry, particularly in Germany, where it is a prominent feature in the organization of the agriculture of the country. In great measure it is carried on by the mutual co-operation of the farmers who supply the potatoes to joint-owned distilleries for conversion into alcohol, receiving later the spent wash and residues which,

containing nitrogen, phosphorus and potash, are of considerable value as a cattle food. Extensive breeding of cattle is thus facilitated, resulting in a heavy production of manure useful in the cultivation of the potatoes.

The initial operations in the production of alcohol from potatoes are the mashing and the saccharification of the starch by means of malted barley or acids. The details of the process show considerable variation. In one method extensively adopted, the potatoes, after being cooked by steam heating and reduced to a homogeneous pulp in a mill, are mixed with malt and water. After the mass has been maintained at a temperature of about 60° C. for three to four hours, yeast is added and fermentation takes place. Distillation is accomplished by steam heating with mechanical agitation. In another method the potatoes after being reduced to a pulp in a rasping machine are partially drained of their natural water. Boiling water and malt are added, the mass being allowed to stand for three to four hours. The clear liquid and subsequent washings are fermented with yeast and the spirit distilled off in the usual manner; this method has considerable advantages over that first described, the distillation from the liquid being cleaner and the residual paste being excellent as a cattle food.

The spirit obtained by pot-still distillation is liable to act in a deleterious manner upon the animal economy. It has a strong flavour of fusel oil, since amyl and isobutyl alcohols are present in considerable proportions. These may be almost completely removed by distillation in a patent still.

It has been claimed that 28.6 gal. of absolute alcohol can be obtained from a ton of potatoes. (F. G. H. T.; R. Su.)

POTATO WAR, the name given by the Prussians to the War of the Bavarian Succession in 1778–79 (*Kartoffelkrieg*). The Prussians and a Saxon contingent, commanded by Frederick the Great and his brother Prince Henry, were opposed to two Austrian armies under Ernst von Loudon and Franz Moritz, Count Lacy. The operations consisted almost entirely of manoeuvres which had for their object the obtaining or the denial to the enemy of food supplies. The war thus acquired the name of *Kartoffelkrieg*. Its duration was from July 3, 1778, to the assembly of the congress of Teschen on March 10, 1779, and its total cost £4,350,000 and 20,000 men to all parties. The war may be studied from a military point as an extreme example of what Karl von Clausewitz calls "war with a restricted aim."

POTAWATOMI, a tribe of North American Indians of Algonkin stock. When first known, about 1670, they lived around Green Bay, Wis. They subsequently moved south and eventually settled in lower Michigan. They were allied with the French in their wars against the Iroquois and took part in the conspiracy of Pontiac (*q.v.*). In the American Revolutionary War they fought for England, and also in the War of 1812. In 1846 most of them were removed to a reservation in Kansas. Others are in Wisconsin and Oklahoma.

The name "Potawatomi" is properly *Potewatmik,* firemakers, in allusion to the tribe's secession from the Ojibway and their establishment of a separate council fire.

See O. Winger, *The Potawatomi Indians* (1939).

POTCHEFSTROOM, a town in Transvaal, Union of South Africa, at 26° 30′ S., 27° 40′ E., altitude 4,436 ft., 88 mi. by rail S.W. of Johannesburg. Pop. (1946) 27,205, of whom 13,750 were Europeans, 12,119 natives (Bantu), 373 Asiatic and 963 coloured. The town is built on the banks of the Mooi river, 15 mi. above its junction with the Vaal. Gold occurs in the neighbourhood.

Potchefstroom was founded in Nov. 1838 by Hendrik Potgieter, and is the oldest town in, and first capital of, the Transvaal. In 1862 it was the scene of civil war between rival Boer factions. In 1880–81 the garrison camped outside the town was besieged by Boers under Commandant P. A. Cronje. The British troops, 250 in number, were confined to a fort 25 yd. square and lost more than one-third of their strength in killed and wounded before they surrendered on March 21, the action having begun on Dec. 18, 1880. Charges of treachery were brought against Cronje for failing to notify the besieged that an armistice had been agreed to by the Boer leaders. Of this armistice Col. R. W. C. Winsloe, who was in command of the British, became aware before the surrender took place. On the suggestion of Commandant Gen. P. J. Joubert the capitulation was considered as cancelled, and a detachment of British troops reoccupied the town until the conclusion of peace.

In the Anglo-Boer War of 1899–1902 Potchefstroom was occupied by the British without opposition.

Potchefstroom was developed as an educational centre. It has several high schools, a training college, a university college, a constituent of the University of South Africa, and an agricultural school. The latter is situated on the government experimental farm.

POTEEN, called also potheen, potsheen and potyeen, the term usually applied in Ireland to any potable spirit illicitly distilled in a pot still—poit'in, pota or pot. Illicit distillation was extensively practised in the 19th century, particularly in the inaccessible districts of the island, but it has in great measure been suppressed. The character of the substances used in preparing the wash, which is fermented preparatory to distillation (*see* Rum; Whisky; etc.), varies greatly. While malt and barley chiefly are used, the spirit is often obtained by the fermentation of molasses or other saccharine matter. The method of fermentation, the type of still employed, the rate of distillation and the proportion of distillate to wash, depending as they do upon the circumstances and wish of the distiller, are also lacking in uniformity. This absence of standardization in materials and methods results in great variation in the composition of the resultant spirits. Generally they may be stated to fall into two classes, approximating to whisky when malt and barley are used, and to rum when the wash is of a more saccharine nature. The proportion of secondary ingredients almost invariably is high, however, even when compared with pot still spirits made by reputable firms. Allen, in a series of analyses presented to the Select Committee on British and Foreign Spirits, recorded 128.8 gr. of amyl alcohol in poteen as compared with an average of 56 gr. in eight samples of Irish whisky.

(F. G. H. T.)

POTEMKIN, GRIGORY ALEKSANDROVICH, Prince (1739–1791), Russian statesman, was born at Chizheva, near Smolensk. He was educated at the Moscow university and in 1755 entered the "Reiter" of the horse guards. His participation in the coup d'état of July 8, 1762, attracted the attention of the new empress, Catherine II, who made him a *Kammerjunker* and gave him a small estate. In 1768 he quitted the guards and was attached to the court as a *Kammerherr,* but in 1769 he volunteered for the Turkish war and distinguished himself at Khotin, Focshani and Larga, beside routing the Turks at Olta.

It was not until 1771 that he became Catherine's prime favourite. In that year he was made an adjutant general, lieutenant colonel of the Preobrazhensky guards, a member of the council of state, and, in the words of a foreign contemporary diplomatist, "the most influential personage in Russia." Later he was created a count and appointed commander in chief and governor general of "New Russia," as the conquered provinces in the Ukraine were then called. In 1776, at Catherine's request, Emperor Joseph II raised Potemkin to the rank of a prince of the Holy Roman empire. In 1775 he was superseded in the empress's graces by Zavadovsky; but the relations between Catherine and her former lover continued to be most friendly, and his influence with her was never seriously disturbed by any of her subsequent favourites.

Potemkin's correspondence with the empress was uninterrupted. He was deeply interested in the question of the southern boundaries of Russia and consequently in the fate of the Turkish empire. In 1776 he sketched the plan for the conquest of the Crimea which was subsequently realized; and he was busy with the so-called "Greek project," which aimed at restoring the Byzantine empire under one of Catherine's grandsons. In many of the Balkan states he had well-informed agents. After he became field marshal, in 1784, he introduced many reforms into the army and built a fleet in the Black sea, which, though constructed of very bad materials, did excellent service in Catherine's second Turkish war (1787–92). His colonizing system was exposed to very severe criticism, yet it is impossible not to admire the results of his stupendous activity. The arsenal of Kherson, begun in

1778, the harbour of Sevastopol and the new fleet of fifteen liners and twenty-five smaller vessels, were monuments of his genius. But there was exaggeration in all he attempted. He spared neither men, money nor himself in attempting to carry out his gigantic scheme for the colonization of the south Russian steppes; but he never calculated the cost, and more than three-quarters of the design had to be abandoned when but half finished.

Catherine's famous expedition to the south in 1787 was a triumph for Potemkin, for he concealed all the weak points of his administration. On this occasion he received the title of prince of Tauris. The same year the second Turkish War began, and the founder of New Russia acted as commander-in-chief.

But the army was ill-equipped and unprepared; and Potemkin, in an hysterical fit of depression, would have resigned but for the steady encouragement of the empress. Only after Suvarov had valiantly defended Kinburn did he take heart again, and besiege and capture Ochakov and Bender. In 1790 he conducted the military operations on the Dniester and held his court at Jassy with more than Asiatic pomp. In 1791 he returned to St. Petersburg where, along with his friend Bezborodko (*q.v.*), he made vain efforts to overthrow the new favourite, Zubov. The empress grew impatient and compelled him (1791) to return to Jassy to conduct the peace negotiations as chief Russian plenipotentiary. On Oct. 5, while on his way to Nikolayev, he died in the open steppe, 40 mi. from Jassy.

Potemkin was indubitably the most extraordinary of all the Catherinian favourites. He was an able administrator, licentious, extravagant, but loyal, generous and magnanimous. Nearly all the anecdotes related of him by Helbig, in the biography contributed by him to the journal *Minerva* (1797–1800), and freely utilized by later biographers, are absolutely worthless.

See V. A. Bilbasov, *Geschichte Katharinas II.* (Berlin, 1891–1893); C. de Larivière, *Catherine la Grande d'après sa correspondance* (Paris, 1895); Anonymous, *La Cour de Catherine II. Ses collaborateurs* (St. Petersburg, 1899); A. V. Lopukhin, *Sketch of the Congress of Jassy, 1791* (Rus.; St. Petersburg, 1893); *The Papers of Prince Potemkin, 1744–1793* (Rus.; St. Petersburg, 1893–1895). (R. N. B.)

POTENTILLA, a large genus of plants of the rose family (Rosaceae, *q.v.*), comprising more than 200 species, mostly herbs, widespread in north temperate and Arctic regions, many of which are cultivated as border and rock-garden plants. Various species bear brilliantly coloured flowers and graceful foliage.

A soil of a good loamy staple, enriched with rotten dung is the most suitable. Potentillas may be increased, though not very freely, by parting them into as many pieces as there are crowns, the side growths being those which can usually be thus separated. This may be done in autumn or spring, and the plants will generally bloom the following season. The species and some of the varieties reproduce true from seed, and are readily increased by that means. Nine wild species occur in the British Isles and more than 50 in North America, many of which are called cinquefoil or five-finger.

POTENTIOMETER, an instrument, due to J. C. Poggendorff, for the measurement of electromotive force and also of the difference of electric potential between two points. The term potentiometer is usually applied to an instrument for the measurement of steady or continuous potential difference between two points in terms of the potential difference of the terminals of a standard voltaic cell of some kind, such as a Clark or Weston cell but alternating current potentiometers are in use. (*See* INSTRUMENTS, ELECTRICAL.)

POTENZA (anc. *Potentia*), a town and episcopal see of Lucania, Italy, capital of the province of Potenza, 103 mi. by rail E. by S. of Naples. Pop. (1936), 18,872 (town); 25,103 (commune). Situated 2,700 ft. above sea level on an isolated hill above the Basento (anc. *Casuentus*), it is much exposed to winds and has a far more northerly climate than its position (40° 40′ N.) implies, and is one of the coldest towns in Italy.

The ancient Potentia lay some 470 ft. lower, by the river, at the intersection of the road leading west to the Via Popillia and northeast to the Via Appia, with the Via Herculia.

Potentia must be distinguished from Potentia in Picenum, on the Adriatic coast. In 1694 there was a severe earthquake; and the more terrible earthquake which on Dec. 16 and 17, 1857 passed through southern Italy, and in Basilicata (Lucania) alone killed 32,475 persons, laid the greater part of Potenza in ruins. It was also damaged by the earthquake of 1910. In 1860 it was the first town to rise against the Neapolitan government.

POTGIETER, EVERHARDES JOHANNES (1808–1875), Dutch prose writer and poet, was born at Zwolle, in Overyssel, on June 17, 1808. He started life in a merchant's office at Antwerp. In 1831 he made a journey to Sweden and then settled in Amsterdam. With Heije, the popular poet of Holland in those days, and Bakhuizen van den Brink, the historian, Potgieter founded *De Muzen* ("The Muses," 1834–1836), a literary review, which was, however, soon superseded by *De Gids* ("The Guide"), a monthly, which became the leading magazine of Holland. In it he wrote, mostly under the initials of "W.D ——g," a great number of articles and poems. The first collected edition of his poems (1832–1868) appeared in 2 vols. (Haarlem, 1868–1875), preceded by some of his contributions to *De Gids*, in 2 vols. also (Haarlem, 1864), and followed by 3 vols. of his *Studien en Schetsen* ("Studies and Sketches," Haarlem, 1879). Potgieter's favourite master among the Dutch classics was Hooft, whose peculiarities in style and language he admired and imitated. In Holland Potgieter's influence has been very marked and beneficial; but his own style, that of ultra-purist, was at times somewhat forced, stilted and not always easily understood.

The best edition of Potgieter's works is that by his friend and executor J. C. Zimmermann (19 vols., 1885–90).

POTHIER, DOM JOSEPH (1835–1923), French musical scholar, was born at Bouzemont, near Saint Dié, Dec. 7, 1835. He became a Benedictine in 1859 and after holding various positions of authority in two French abbeys, was named abbot of a third, St. Wandrille, in 1898. In 1901, when members of religious orders were compelled by law to leave France, the monastery was temporarily located in Belgium. Shortly after he entered the Benedictine order at Solesmes, Dom Pothier was encouraged by Dom Guéranger, who had started a movement to revive the ancient plainsong, to study early church music. In 1880 Dom Pothier published *Les Mélodies grégoriennes,* which became the standard work on Gregorian chants. During the next 25 years he wrote 7 other treatises on various phases of ancient religious music and was responsible for beginning a collection of musical manuscripts at Solesmes.

Pope Pius X made him chairman (1904) of a commission which re-edited and published the musical parts of the Roman Catholic Mass. He died at Conques, Belgium, Dec. 8, 1923.

POTHIER, ROBERT JOSEPH (1699–1772), French jurist, was born at Orléans on Jan. 9, 1699. He studied law for the purpose of qualifying for the magistracy, and was appointed in 1720 judge of the presidial court of Orléans. This post he held for 52 years. He paid particular attention to the text of the *Pandects,* his *Pandectae Justinianae in novum ordinem digestae* (Paris and Chartres, 1748–1752) being a classic in the study of Roman law. In 1749 he was made professor of law in the university of Orléans. He wrote many learned monographs on French law, and much of his work was incorporated almost textually in the French Code Civil. He died March 2, 1772.

Of his numerous treatises the following may be especially mentioned: *Traité des obligations* (1761); *Du Contrat de vente* (1762); *Du Contrat de bail* (1764); *Du Contrat de société* (1765); *Des Contrats de prêt de consomption* (1766); *Du Contrat de dépôt et de mandat* (1766); *Du Contrat de nantissement* (1767), etc. His works have several times been published in collected form (edited by Giffrein, 1820–24; by Dupin, 1823–25, and by Bugnet, 2nd ed. 11 vols. 1861–62). *See* Dupin, *Dissertation sur la vie et les ouvrages de Pothier* (Paris, 1825), and Frémont, *Vie de R. J. Pothier* (Orléans, 1850).

POTHOOK, a metal hook, frequently S-shaped, for suspending a pot over a fire. While one extremity is hooked to the handle of the pot, the other is caught upon an iron crane moving on a pivot over the fire. Modern cooking-ranges have obviated the necessity for this arrangement, but it is still to be seen in great numbers of country cottages and farmhouse kitchens all over England, and in small artisans' houses in the west midlands and

the north. In the elementary teaching of writing, the "pothook" is a script of similar shape.

POTI, a seaport of Russia, in the Georgian S.S.R., in 42° 10′ N., 41° 38′ E., on the Rion river, on the Black sea coast, in a marshy and malarial district. Population (1933) 16,200.

During west and southwest gales the harbour is very difficult to approach.

There are berths for eight or ten large steamers and an elevator for loading manganese, the chief export from the Kvirili valley. The town is linked by rail with Baku, and there is a line northward along the coast.

The town has a saw-milling industry. The ancient Phasis, a commercial colony of the Greek city of Miletus, stood on this site.

In 1578 Sultan Murad III, of Turkey, built a fortress there, which was destroyed during a war with Persia. In 1640 the Imeretians attacked the town. Poti was a great slave market. It was captured by the Russians in 1812 and in 1829 recaptured and annexed.

POTIOREK, OSKAR (1853–1933), Austro-Hungarian general of artillery, was born at Blieburg, Carinthia, in 1853. His career was chiefly spent on the general staff, where he held the post of chief of the section of operations, and later that of deputy to the chief of the general staff, Count Beck. After Beck's retirement he was in command of the III corps, in 1911 army inspector and governor (*Landeschef*) in Bosnia and Hercegovina. As such, he was officially responsible for countenancing the fateful visit of the heir to the throne to Serajevo, out of which World War I ensued.

In the offensive taken by Austria against Serbia in the winter of 1914, which eventually broke down after great initial success, his judgment was also found wanting. He was then relieved of his command.

POTLATCH, an Indian term, denotes the lavish feasts especially characteristic of the Tlingit, Kwakiutl and other tribes of the northwest coast of America. The potlatch is given by one chief or clan to another, and is marked by great profusion of food and gifts, often accompanied by destruction of some of the property of the hosts, as in the breaking of highly prized copper plaques, an act which adds greatly to their fame. The keynote of such excesses is the exaggerated respect which these Indians show for wealth in use—an attitude shared by many other savage peoples and not without its cultural value. It is a matter of honour to accept any invitation to a potlatch, and to give a grander feast in return. Refusal involves loss of prestige and rank.

Rivalry in feast-giving may become so intense that a man will beggar himself and relatives in the effort to win renown. But the potlatch is not a mere wasteful orgy; it maintains differences of chieftainship and rank, binds together kinship groups and offers a medium for repayment of debts, thus serving as an institution of real importance in social and economic life.

See F. Boas, *Ethnology of the Kwakiutl,* Part I, 35th Ann. Rept. Bureau Amer. Ethnology (1914); Swanton, *Social Conditions, etc., of Tlingit Indians,* 26th Ann. Rept. *ibid.* (1905); Marcel Mauss, "Essai sur le Don," *L'Année sociologique,* n.s. I (1924).

POT-METAL. The glass employed in "stained-glass" windows is coloured in the making by tinting the glass in the melting-pot with various metallic oxides. This self-coloured glass, which afterward may or may not be painted or decorated, is called pot-metal.

(*See* STAINED GLASS.)

POTOCKÍ, STANISLAW FELIX (1752–1805), Polish politician, son of Franciszek Salezy Potocki, palatine of Kiev, was born in 1752. Through family influence, he became grand standard-bearer of the crown at the age of 22. In 1782 he was made palatine of Russia, in 1784 a lieutenant-general and in 1789 purchased the rank of a general of artillery. Liberal, enlightened, a generous master and a professed patriot, he had awakened great hopes; but he identified the public welfare with the welfare of the individual magnates, and when elected to the Four Years' diet, schemed to divide Poland into an oligarchy of autonomous grandees exercising the supreme power in rotation (in fact a perpetual interregnum).

The election of Stanislaw Malachowski (*q.v.*) and Kazimierz Sapieha as marshals of the diet still further alienated him from the Liberals; and he retired to Vienna where he continued to carry on an active propaganda against the new ideas. He protested against the constitution of May 3, 1791, and after attempting fruitlessly to induce the Emperor Leopold to intervene, proceeded with his friends in March 1792, to St. Petersburg, and subsequently with the connivance of the Empress Catherine formed the confederation of Targowica (May 14, 1792), of which he was the marshal, or rather the dictator, directing its operations from his castle at Tulczyn.

When the May constitution was overthrown, Potocki (March 1793) went on a diplomatic mission to St. Petersburg; but, finding himself duped, he settled down at Tulczyn. He wrote *On the Polish Succession* (Pol.) (Amsterdam, 1789); *Protest against the Succession to the Throne* (Pol.) (*ibid,* 1790); and other political works.

POTOMAC, a river in the east central part of the United States, having its source in the Allegheny mountains and flowing southeast into Chesapeake bay. It is formed by the union of its north and south branches, about 15 mi. S.E. of Cumberland, Md.

The united stream has a length of 287 mi. and is navigable for large vessels for 113 mi. above its mouth. From the junction of its two branches until it reaches Harper's Ferry the Potomac river separates Maryland from West Virginia. At Harper's Ferry it receives the waters of the Shenandoah river and cuts through the Blue Ridge mountains in a gorge noted for its beauty.

From this point to its mouth it forms the boundary between Virginia and Maryland. The stream crosses the Blue Ridge mountains at an elevation of about 245 ft., and at Georgetown (Washington, D.C.), 62 mi. distant, it meets tidewater. Of this descent about 90 ft. occurs about 15 mi. above Washington at the Great Falls, a series of rapids about a mile long and including a cataract about 35 ft. high.

Three and a half miles above Washington are the Little Falls, which mark the head of navigation.

At Washington there are two channels, with respective depths at mean low water of 18 and 21 ft.

Large sums have been spent since 1870 on improving these channels.

A few miles below the city the river broadens into a deep tidal estuary from 2½ to 7 mi. wide; and channels 24 ft. deep and 200 ft. wide through all the shoals were secured by the project of 1899.

The Anacostia river, or "East Branch," which flows into the Potomac just south of Washington, is navigable for large vessels for about 2 mi. and for small scows and lighters as far as Bladensburg, Md., 8¾ mi. above its mouth. Improvements (begun in 1902) have produced a channel 21 ft. deep at mean low water and 380 ft. wide.

The Chesapeake and Ohio canal, from Georgetown to Cumberland, Md., follows the Potomac closely on the Maryland side.

POTOROO: *see* RAT KANGAROO.

POTOSÍ, a department of Bolivia occupying the southwestern angle of that republic, bounded north by Oruro, Cochabamba and Chuquisaca, east by the two last departments and Tarija, south by Argentina and west by Chile and Oruro. Pop. (1947 est.) 768,800, the larger part Indians; area 41,297 sq.mi. The eastern part of the department is traversed north to south by the eastern branch of the Andes, locally known as the Cordillera de los Frailes and the Cordillera de Chichas. Spurs and broken ranges project eastward from these, between which are the headstreams of the Pilcomayo and Grande, the first flowing southeast to the Plata and the second northeast to the Madeira and Amazon. The Pilcomayo itself rises in the department of Oruro, but several of its larger tributaries belong to Potosí—the San Juan, Cotagaita and Tumusla in the south, and Cachimayo in the north. The western part of the department belongs to the great Bolivian *altiplanicie,* or southern extension of the Titicaca basin. It is

a barren, saline waste, almost uninhabitable. In the north, bordering on the transverse ridge of which the Cerro de Tahua (17,457 ft.) forms a part, is the depression known as the Salar de Uyuni, 12,080 ft. above sea level. Near the southern frontier is another transverse ridge, in part formed by the Sierra de Lipez and in part by apparently detached groups of high peaks; it is a waterless desert like the Puna de Atacama.

Potosí is essentially a mining department, though agriculture and grazing occupy some attention in the eastern valleys. The plateau there is rich in minerals, especially silver and copper. The Huanchaca-Pulacayo group of mines, situated on the slopes of the eastern Cordillera, about 13,600 ft. above sea level overlooking the Salar de Uyuni, has the largest output of silver in Bolivia. Between 1873 and 1901 it yielded 4,520 tons of silver, of an estimated value of £23,200,000. Farther south are the Portugalete mines, once very productive, and near the Argentine border are the Lipez mines. East of the Cordilleras are the famous "silver mountain" of Potosí, once the richest silver mine in the world; the snow-capped peak of Chorolque (18,452 ft.), which is claimed to have the highest mine in the world, 18,000 ft. above sea level; Porco, a few miles southwest of Potosí; Guadalupe, Colquechaca and Aullagas. Besides silver most of these mines yield tin, copper, zinc, bismuth, tungsten, antimony and wolfram and are now being worked chiefly for their tin, of which Bolivia produced 34,115 long tons in 1949. The production of minerals in these famous centres was eclipsed by the enormously rich deposits of tin at Uncia and Llallagua in the same department. The department is traversed by the Antofagasta & Bolivia railway and by a line from Uyuni to the Argentine frontier at La Quiaca. A branch line of the former also runs to Sucre via Potosí.

Besides Potosí, the capital of the department (1946 pop. 40,000), the principal towns are Huanchaca, Pulacayo, Uyuni (9 mi. from Huanchaca, 12,100 ft. above sea level, a small town but an important railway junction and commercial centre on the waterless plain, the shipping point and supply station for an extensive mining region) and Tupiza (pop. about 8,000), a prettily situated town near the Argentine frontier, on a small branch of the San Juan river, 9,800 ft. above sea level.

POTOSÍ, a city of Bolivia, capital of the department of Potosí, 47 mi. S.W. of Sucre, or 106 mi. by the post road. Pop. (1946 est.) 40,000. Potosí stands on a barren terrace on the northern slope of the Cerro Gordo de Potosí, 13,189 ft. above sea level, and is one of the highest towns in the world. The famous *cerro* from which its name is taken rises above the town to a height of 15,380 ft., a barren, white-capped cone, honeycombed with mining shafts.

The foundation of the city dates from 1547, two years after the first discovery of silver on the *cerro* by an Indian herder. Charles V conferred upon it the title of "villa imperial." From 1545 to 1800 the crown tax of one-fifth upon the mineral product amounted to £32,600,000, showing an acknowledged output of £163,000,000. The total output to 1864 has been estimated at more than £400,000,000, but the annual output at the beginning of the 20th century barely exceeded 400,000 oz. The town is regularly laid out with streets crossing each other at right angles. The age-begrimed buildings, many of which are unoccupied and in ruins, are commonly of adobe. A large plaza forms the conventional centre, around which are grouped various religious edifices, the government house, town hall, national college, the old "royal mint," dating from 1572, and the treasury. The city has a massive, plain cathedral, which in part dates from early colonial times and in part from the closing years of Spanish rule. The water supply is derived from reservoirs constructed during the years of the city's greatest prosperity. Potosí was long accessible from the outside world only by rough mountain roads, until rail connections were made with Río Mulatos on the Antofagasta-Bolivia line and with Sucre. In 1611 the population of Potosí was reported to be 160,000, which probably included the whole mining district. A part of the diminution since then is explained by the fact that the great majority of the mines on the *cerro* were abandoned. Subsequently valuable deposits of tin were found and many of the mines re-opened.

POTOTAN, a municipality (with administrative centre and 64 *barrios* or districts) of the province of Iloilo, island of Panay, Philippines, on the Jaluar river, and located along the railway, about 17 mi. N.E. of Iloilo, the provincial capital. Pop. (1939) 33,020; 15,871 were males and 7 were whites. The chief agricultural products are sugar, maize (corn), palay (rice), tobacco and abacá (Manila hemp). Cattle, carabao and horses are bred for local use and for export. Panay-Bisayan is the vernacular. Of the inhabitants aged 6 to 19 inclusive, 41.7% in 1939 attended school, while 51.8% 10 years old and over was literate.

POTSDAM, a town in Germany, the administrative capital of the Prussian province of Brandenburg and formerly one of the residences of the German emperor, on the river Havel, 16 mi. S.W. of Berlin, on the main line of railway to Magdeburg. Pop. (1939) 136,167. It is connected with the capital by two local lines and by a steamboat service through the chain of lakes formed by the river. Potsdam, originally Poztupimi, a Slavonic fishing village, is first mentioned in 993. A town in the 14th century, it was unimportant until the great elector built a palace there between 1660 and 1682, and even at the close of his reign it contained only 3,000 inhabitants. The elector Frederick William I greatly enlarged Potsdam, and his stiff military tastes are reflected in the monotonous uniformity of the streets. Frederick the Great continued his father's work, and was the real creator of the splendour of the town.

The palace, a large quadrangular building of the 17th century, is chiefly interesting for the numerous relics it contains of Frederick the Great. It also contains reminiscences of Voltaire, who resided there for several years. The principal churches are the Nikolaikirche; the Church of the Holy Ghost, built in 1728; and the Friedenskirche, or Church of Peace, erected in 1845–50, to which is attached a mausoleum. Among other conspicuous buildings are the military establishments, the town hall and the Brandenburg gate. Potsdam has manufactures of chemicals, furniture, chocolate, soap, tobacco and surgical and musical instruments. Market gardening affords occupation to many of the inhabitants, and the cultivation of winter violets is a specialty. The Havel is well stocked with fish. To the south of the town lies the observatory.

POTSDAM, a village of St. Lawrence county, N.Y., U.S., on the Raquette river, federal highway 11 and the New York Central railroad, 30 mi. E. of Ogdensburg. Pop. (1950), 7,491; (1940) 4,821. It is the seat of the Clarkson College of Technology (1895) and a state teachers' college (1866) with which is incorporated the former Crane Normal Institute of Music, and is the centre of a large dairy industry and of several electric power developments. Settlement there began in 1803 and the village was incorporated in 1831. It gives its name to deposits of a reddish sandstone studied there first by E. Emmons in 1838–42.

POTT, PERCIVALL (1714–1788), English surgeon, was born in London on Jan. 6, 1714. He became assistant surgeon at St. Bartholomew's in 1744 and was full surgeon from 1749 till 1787. He died in London on Dec. 22, 1788. The first surgeon of his day in England, excelling even his pupil, John Hunter, he introduced various important innovations in procedure, doing much to abolish the extensive use of escharotics and the actual cautery that was prevalent when he began his career.

A particular form of fracture of the ankle which he sustained through a fall from his horse in 1756 is still described as Pott's fracture, and his book, *Some Few Remarks upon Fractures and Dislocations,* had a far-reaching influence in Great Britain and France.

"Pott's disease" is a spinal affection of which he gave an excellent clinical description in his *Remarks on that kind of Palsy of the Lower Limbs which is frequently Found to Accompany a Curvature of the Spine* (1779).

See Fielding Hudson Garrison, *Introduction to the History of Medicine,* p. 344 (1929).

POTTER, ALONZO (1800–1865), American bishop of the Protestant Episcopal Church, was born at Beekman (now La Grange), N.Y., on July 6, 1800. He graduated in 1818 at Union

college, where he became tutor and then professor of mathematics after a brief period spent in studying theology at Philadelphia. He was rector of St. Paul's, Boston, from 1826 to 1831, when he returned to Union as professor of philosophy and political economy, becoming vice president of the college in 1838. He was consecrated bishop of Pennsylvania on Sept. 23, 1845, and died on board ship in San Francisco harbour on July 4, 1865. By his publication with G. B. Emerson of *The School and the Schoolmaster* (1842) and by lectures Potter did much to extend and better public school education. He was particularly interested in work for young men and in temperance reform. As a legislator in the church he was wise and progressive. He established the Philadelphia Divinity school (1861), and laboured for the "Hospital of the Protestant Episcopal Church in Philadelphia."

See M. A. De Wolfe Howe, *Memoirs of the Life and Services of the Rt. Rev. Alonzo Potter, D.D.* (1870).

His brother, HORATIO POTTER (1802–1887), was born in Beekman, N.Y., Feb. 9, 1802. He graduated at Union college in 1826 and was successively rector in Maine, professor of mathematics and natural philosophy at Washington (now Trinity) college at Hartford, Conn., rector in Albany and after 1854 provincial bishop of New York. Failing health put an end to his active service in 1883, when his nephew, H. C. Potter (*q.v.*), became his assistant. He died in New York city Jan. 2, 1887.

POTTER, HENRY CODMAN (1834–1908), American Protestant Episcopal bishop, the son of Bishop Alonzo Potter, was born in Schenectady, N.Y., on May 25, 1834. In October 1883 he was consecrated assistant to his uncle, Horatio Potter, bishop of New York, whom he succeeded in 1887. He died in Cooperstown, N.Y., on July 21, 1908. During his administration the corner-stone of the cathedral of St. John the Divine was laid (Dec. 27, 1892). As rector of Grace church he worked to make it an "institutional church" with clubs for working men and girls, day nurseries and kindergartens. He won fame on the centennial of Washington's inauguration by his address on the dangers and corruptions of the spoils system.

See Harriette A. Keyser, *Bishop Potter, the People's Friend* (1910), and the official biography by George Hodges (1915).

POTTER, PAUL (1625–1654), Dutch animal painter, was born at Enkhuizen, Holland. He was instructed in art by his father, Peter Potter, a landscape and figure painter of some merit, and by Nicolas Moeyaert, of Amsterdam. Other masters and influences are mentioned by various writers, but more than any other of his contemporaries he learnt through direct study from nature. In 1646 he went to Delft, where he became a member of the gild of St. Luke. At the age of twenty he settled at the Hague, and there married in 1650. He was patronized by Maurice, prince of Orange, for whom he painted the life-size picture of the "Young Bull," now one of the most celebrated works in the gallery of the Hague. In 1652 he was induced by Burgomaster Tulp of Amsterdam to remove to that city. He died Jan. 15, 1654.

His paintings are generally small; early in life, however, he attempted, but with ill success, to work on a monumental scale, as in the "Bear Hunt" at the Rijks Museum and the "Boar Hunt" of the Carstanjen collection, Berlin. Even the famous "Equestrian Portrait of Tulp" formerly in the Six collection, Amsterdam, is awkward and stiff and hard in handling. His animals are accurately designed, and the landscape backgrounds are introduced with spirit and appropriateness. His colour is clear and transparent, his execution firm and finished without being laboured. His view of nature is purely objective and unemotional; he painted with the greatest directness and simplicity the things he saw before him, and his paintings of horses and cattle are so individualized that they become faithful portraits of the animals. The best among his small portraits of horses are in the Louvre and in the Schwerin Gallery; and certain of his studies are the most brilliant of all.

The earliest dated picture of importance is "Abraham Entering Into Canaan" (1642), at the Germanic Museum in Nuremberg, in which he makes the Scriptural subject an excuse for painting the patriarch's herds, just as in his "Orpheus" of 1650 (Rijks Museum, Amsterdam) he makes similar use of the Greek myth. Among his finest works on a small scale are a cattle piece (1653) in the Duc d'Arenberg's collection, and a similar, though earlier, picture in the Munich Pinakothek. Hofstede de Groot enumerates 177 works by Potter. He worked with feverish application, as though he were aware of the short span of life that was granted him. He executed a series of some twenty etchings, mainly of animals, which are simple and direct in method and handling.

Potter's works have been engraved by Bartolozzi, Danckerts, Visscher, Le Bas and others. There are two of his paintings at the National Gallery, three in Buckingham Palace and a few in the duke of Westminster's collection. On the continent of Europe the most numerous and representative examples are to be found at the Rijks Museum in Amsterdam, the Hermitage in Leningrad and the Dresden Gallery. (P. G. K.)

See *Paulus Potter, sa vie et ses oeuvres,* by T. van Westrheene (the Hague, 1867); *Eaux-fortes de Paul Potter,* by Georges Gratet Duplessis; and an old but interesting volume, *Paul Potter, peintre de l'école hollandaise,* by C. L. F. Lecarpentier (Rouen, 1818); Hofstede de Groot, *Catalogue of Dutch Painters* (1912).

POTTERIES, THE, a name applied to a district of north Staffordshire, the principal seat of the china and earthenware industry in England. It lies in the upper part of the Trent basin. For a distance of 9 m. from south-east to north-west, and about 3 m. from north-east to south-west, the district resembles one great town, but the chief centres are Burslem, Hanley, Longton, Stoke-on-Trent, Fenton and Tunstall. These towns were amalgamated in 1910 as one municipal borough under the name of Stoke-on-Trent, which was raised to the dignity of a city in 1925. Newcastle-under-Lyme, though not sharing in the staple industry, may also be reckoned in the district. In 1769 Josiah Wedgwood founded pottery works at Etruria, now in the parliamentary division of Hanley. The Wedgwoods and the Mintons are the two most famous family names connected with the china industry of the district. Coal and coarse clay are the only local natural products used in the industry, the finer clay and other ingredients being brought from Cornwall and elsewhere. Ironstone is raised, and many new industries have been established in the district.

POTTERY AND PORCELAIN. The word "pottery" (Fr. *poterie*) in its widest sense includes all objects fashioned from clay and then hardened by fire; the word "porcelain" should only be applied to certain well marked varieties of pottery. Pottery is dependent on two important natural properties of that great and wide-spread group of rocky or earthy substances known as clays, viz., the property of plasticity and the property of being converted when fired into one of the most indestructible of ordinary things.

"Ceramics" or "Keramics" (Gr. κεραμος, earthenware) is a general term for the study of the art of pottery. It is adopted for this purpose both in French (*ceramique*) and in German (*Keramik*).

INTRODUCTION

The primitive races took such clay as they found on the surface of the ground, or by some river-bed, and, spreading it out on a stone slab, picking out the rocky fragments, then beating it with the hands, with stones or boards, or even treading it with their feet, proceeded to fashion it into such shapes as need or fancy dictated. Fired in an open fire, such pottery may be buff, drab, brown or red—and those from imperfect firing become smoked, gray or black. For ages tools and methods remained of the simplest—the fingers for shaping or building up vessels, a piece of mat or basket-work for giving initial support to a larger vase—until some original genius of the tribe found that by starting to build up his pot on the flattened side of a boulder he could turn his support so as to bring every part in succession under his hand, and thus the potter's wheel was invented.

At first this simple hand-made pottery was hardened by drying in the sun, but the increasing use of fire soon brought out the fact that a baked clay vessel became as hard as stone. Different districts produced different colours of clay, and thus colour decoration arose. On this substructure all the pottery of the last 4,000 years has been built, for behind all Egyptian, Greek or

Chinese pottery we find the same primitive foundations.

In subsequent articles on this subject we find that the Egyptians evolved schemes of glowing colour—brilliant glazes fired on objects, shaped in sand held together with a little clay, or actually carved from rocks or stone; the Greeks produced their marvels of plastic form, and then turned the plastic clay into imitations of metal forms; the Romans spread some knowledge of the craft over all the empire, but with its fall pottery was forgotten along with its greater achievement. Egypt and the Near East continued the splendours of their glorious past, and glazed and painted pottery was still made by traditional methods. Many interesting kinds of decorated pottery were made at Old Cairo, Alexandria, Damascus, in Syria, Anatolia and elsewhere (on which the later Moslem potters founded their glorious works).

Meantime, in the farther East, the Chinese—the greatest race of potters the world has ever seen—were quietly gathering strength, until from their glazed, hard-fired pottery there emerged the marvellous, white translucent porcelain, one of the wonders of the mediaeval world.

With the dawn of the 15th century, the state of affairs was practically this: In European countries proper, we find rudely fashioned and decorated wares in which we can trace the slow development of a native craft from the superposition of Roman methods on the primitive work of the peoples. The vessels were mostly intended for use and not for show; were clumsily fashioned of any local clay, and if glazed at all then only with coarse lead-glazes, coloured yellow or green; in no case above the level of workmanship of the travelling brick- or tile-maker. The finest expression of this native style is to be found in the Gothic tile pavements of France, Germany and England.

As early as the 12th century the superior artistic pottery of the Moslem nations had already attracted the notice of Europeans as an article of luxury for the wealthy; and we may well believe the traditional accounts that Saracen potters were brought into Italy, France and Burgundy to introduce the practice of their art, while Italian potters certainly penetrated into the workshops of eastern Spain and elsewhere and gathered new ideas.

During the 15th and 16th centuries, Chinese porcelain also began to find its way into Europe, and by the whiteness of its substance and its marvellous translucence excited the attention of the Italian majolists and alchemists. The first European imitation of this famous oriental porcelain of which we have indubitable record was made at Florence (1575–85) by alchemists or potters working under the patronage, and, it is said, with the active collaboration of Francesco de' Medici. This Florentine porcelain was the first of those distinctively European wares, made in avowed imitation of the Chinese, which form a connecting link between pottery and glass, for they may be considered either as pottery rendered translucent or as glass rendered opaque by shaping and firing a mixture containing a large percentage of glass with a very little clay.

During the 18th century not only was there a very large trade in imported Chinese and Japanese porcelain, but there was a great development of porcelain manufacture in Europe.

The 19th century witnessed a great and steady growth in the output of porcelain and pottery of all kinds in Europe and the United States. Mechanical methods were largely called in to supplement or replace what had hitherto remained almost pure handicraft. The English methods of preparing and mixing the materials of the body and glaze, and the English device of replacing painted decoration by machine printing, to a large extent carried the day, with a great gain to the mechanical aspects of the work and in many cases with an entire extinction of its artistic spirit.

The 20th century opened with a wider outlook among the potters of Europe and America. In every country men were striving once again to bring back to their world-old craft something of artistic taste and skill.

TECHNIQUE

All pottery, whether of ancient or modern times, is made by the simplest method. The clay, dug from the earth's surface, is prepared by beating and kneading with the hands, feet or simple mallets of stone or wood. Care is taken that all stones and hard particles are picked out. In ancient pottery, the clay, well tempered with water, was almost invariably used without any additional material. From this pure clay, vessels were shaped by scooping out or cutting a solid lump or ball, by building up piece by piece or by squeezing cakes of clay on to some natural object or prepared mould or form. The potter's wheel, though very ancient, was a comparatively late invention, arrived at independently by many races of men. In its simplest form it was a heavy disk pivoted in a central point to be set going by the hand, as the workman squatted on the ground. About the Christian era, and in Egypt apparently, a much larger disk, which the potter could rotate with his foot, was introduced; this gave the potter an opportunity to use both hands in the manipulation of the clay. In the 17th century the wheel was spun by means of a cord working over a pulley, and in the 19th century the steam driven wheel was introduced.

The rotating process completed, the piece is removed from the wheel and set aside to dry. When it is about leather-hard, it may be recentred carefully on the wheel (the old practice), or placed in a horizontal lathe (16th century) and turned down to the exact shape and polished to an even, smooth surface. Many Greek vases have obviously been "thrown" in separate sections. So too with the Chinese; many of their forms have been made in two or three portions, subsequently joined together and finished on the outside as one piece. (*See* TERRA-COTTA.)

Firing.—The type of kiln used by the potters of ancient Egypt or Greece have not entirely vanished from present day use; it is only in the civilized countries of the modern world that they have been replaced by improved and perfected devices. The potters of certain sections of the Near East and of Japan remain content with the crudest and most primitive types of kilns. With the organization of the pottery as a factory industry in the 18th century, improved kilns were introduced, and the type of kiln now used in civilized countries is a verticle furnace from 10 to 22 ft. in diameter and of similar height, capable, therefore, of containing at one firing a quantity of pottery that would have formed the output of a mediaeval potter for a year. Gas-fired kilns and ovens are now being used or experimented with in every country, and their perfection, which cannot be far distant, will improve the most vital of the potters' processes both in certainty and economy.

Glazes.—We can only consider as glazes those definite superficial layers of molten material which have been fired on the clay substance. Glazes are as varied as the various kinds of pottery, and it must never be forgotten that each kind of pottery is at its best with its appropriate glaze. The most important types of glaze are (1) alkaline glazes, *e.g.*, Egyptian, Syrian, Persian, etc., the oldest and most uncertain; (2) lead glazes, the most widespread in its use and the best for all ordinary purposes; (3) felspathic glazes, the glazes of hard-fired porcelains, generally unsuited to any other material; (4) salt-glaze, produced by vapours of common salt, the special glaze of stone-wares.

Colours.—The primitive potters of ancient and modern times have all striven to decorate their wares with colour. The simplest, and therefore the earliest, colour decoration was carried out in natural earths and clays. The clays are so varied in composition that they fire to every shade of colour from white to grey, cream, buff, red, brown or even to a bronze which is almost black. One clay daubed or painted upon another formed the primitive palette of the potter, especially before the invention of glaze. When glaze was used these natural clays were changed in tint, and native earths, other than clays, containing iron, manganese and cobalt, were gradually discovered and used. It is also surprising to note that some of the very earliest glazes were coloured glasses containing copper or iron (the green, turquoise and yellow glazes of the ancient Egyptians and Assyrians). Marvellous work was wrought in these few materials, but the era of the finest pottery-colour dawns with the Persian, Syrian and Egyptian work that preceded the Crusades. By this time the art of glazing pottery with a clear soda-lime glaze had been thoroughly learnt. Vases,

tiles, etc., shaped in good plastic clay, were covered with a white, highly siliceous coating fit to receive glazes of this type, and giving the best possible ground for the painted colours then known. The colours already spoken of were either clay colours or what are known as "under glaze" colours, because they were painted on the pottery before the glaze was fired.

The earliest glazes of the Egyptians appear not to have been white, but were coloured throughout their substance, and this use of coloured glazes as apart from painted colour was developed along with the painted decoration by the later Egyptian, Syrian and Persian potters. Green, yellow and brown glazes were almost the only artistic productions of the mediaeval European potters' kilns, and their use everywhere preceded the introduction of painted pottery.

With the exceedingly refractory felspathic glazes of Chinese porcelain very few underglaze colours could be used; and the prevalence of blue and white among the early specimens of Chinese porcelains is due to the fact that cobalt was almost the only substance known to the potters of the Ming dynasty which would endure the high temperature needed to melt their glazes. Consequently the Chinese were driven to invent the method of painting in coloured fusible glasses on the already fired glaze. They adopted for this purpose the coloured enamels used on metal; hence the common term "enamel decoration," which is so generally applied to painting in those colours which are attached to the already fired glaze by refiring at a lower temperature. With the introduction of this many-coloured Chinese porcelain into Europe the same practice was eagerly followed by our European potters, and a new palette of colours and fresh styles of decoration soon arose amongst us.

It must be pointed out that the colour possibilities in any method of pottery decoration are largely dependent on the temperature at which the colour needs to be fired. The clay colours are naturally more limited in range than the under-glaze colours, and these in their turn than the on-glaze colours.

Metals.—The noble metals, such as gold, platinum and silver, have been largely used since the early years of the 18th century as adjuncts to pottery decoration, especially on the fine white earthenwares and porcelains of the last two centuries. At first the gold was applied with a kind of japanner's size and was not fired to the glaze, but for the last 150 years or so the metals have generally been fired to the surface of the glaze like enamel colours, by mixing the metal with a small proportion of flux or fusible ground glass. There can scarcely be a doubt that the ancient lustres of Persia, Syria and Spain were believed to be a form of gilding, though their decorative effect was much more beautiful than gilding has ever been. The early Chinese and Japanese gilding appears, like the European, to have been "sized" or water-gilt, not fired; and it seems probable that the use of "fired" gold was taught to the Oriental by the European in the 18th century. To-day "liquid" gold is exported to China and Japan from Europe for the use of the potter. (For Egyptian pottery, *see* EGYPT: *Archaeology and Art*, section *Ceramics;* for primitive far eastern and near eastern pottery, *see* section *Near and Far East* of this article. *See* also BABYLONIA AND ASSYRIA: *Archaeology*, and POTTERY, PRIMITIVE.) (X.)

GREEK POTTERY

The pottery of ancient Greece, prehistoric and historical, is distinguished from all other fictile wares of the same ages by its free development of naturalistic painted decoration. The ceramic painter's art was so far separated from the potter's in the classical period, that each could put his signature to his own portion of the work, and there can be little doubt that the best Minoan pottery was equally the joint product of the two craftsmen. This uniformity in Prehellenic and Hellenic ceramics can hardly be fortuitous. Though Late Minoan (Mycenaean) vase-painting contains no visible element of design that was adopted by the Geometric artists, the technique of potter and painter passed intact across the apparent gap in culture that separates the Aegean ages of Bronze and Iron, and the subsequent revival of naturalistic ornament in the Archaic Greek period shows that something more than mere mechanical skill had been inherited.

Prehistoric Origins.—The technique in which the masterpieces of classical vase-painting were executed was first perfected in Minoan Crete, but its invention was not Cretan. Painted pottery was made in prehistoric Mesopotamia and Egypt long before its appearance in Aegean lands. Pre-Sumerian ware bears decoration fired on pale clay in a dark medium of ferruginous earth fused with an alkaline flux, and one variety of Egyptian predynastic pottery has dull white pigment similarly fired on a dark ferruginous wash. Both processes were applied in Early Minoan pottery; the latter was brilliantly exploited in the polychrome Middle Minoan style (Kamares ware), but the former finally prevailed, because of its greater freedom, in the Late Minoan age. (*See* CRETE: *Archaeology*.) At the close of the M.M. period, when Cretan arts were transplanted to the Greek mainland, the colonial (Mycenaean) fabric of Minoan pottery displaced the inferior and largely handmade native wares, Helladic, Cycladic and Thessalian, which formerly marked the various cultural regions. (*See* GREEK ARCHAEOLOGY.) By the end of the Mycenaean age the pottery of the whole Aegean area was uniform, except on its northern and eastern borders, where Danubian and Anatolian influences were preponderant. This latest Mycenaean ware preserves the forms and fabric of the best Minoan models, but its ornament is atrophied. Shells, octopods and seaweed have degenerated into rows of wavy lines, lily and papyrus flowers appear as groups of parallel curves or chevrons, and the rich designs of linked and running spirals give way to bands of single coils. But the clay is finely worked, the pots accurately turned, the firing hard and even, the glaze dense and lustrous. Two Mycenaean fabrics can certainly be distinguished. The more numerous class has a warm yellow clay surface and its black glaze fires red. The smaller group is made of exceedingly smooth pale greenish clay, and painted with brown-fired glaze, which tends to flake away from the close texture of the surface. The latter belongs to the Argolid, and was made from the same white clay that produced the later Protocorinthian and Corinthian wares.

The Geometric Style.—The next historical phase in Greece was the transition from bronze to iron, about 1000 B.C., a cultural change that involved the violent downfall of the Mycenaean polity. Arts were generally submerged, but the pottery can be identified. It is called Submycenaean or Protogeometric, as its elements appear to attach themselves to the old Minoan or the new Hellenic system. The technique is still Minoan and is often brilliant, but many of the pot-shapes are modified and the decorative patterns assume a new character. The surviving Mycenaean motives are resolved into their simplest linear elements, and these tend to combine again in rigid geometric schemes. Another tendency was to abandon painted patterns and cover the whole pot with black glaze. In this potent fallow the new principles of Hellenic art were laid, and the so-called Geometric style sprang rapid and luxuriant. In its mature phase a Geometric vase is covered with narrow horizontal bands of minute and crowded ornament, rows of repeated figures, triangles, lozenges, circles, continuous or panelled bands of zig-zags, chequers and, chiefly characteristic, the maeander. This last motive, always drawn in double outline filled with hatching, is probably the key to the origin of the style. It appears at the same period in Italy, in the pottery and bronze work of the Villanova culture, and since there is no evidence of intercourse between the two countries at this date, must have been introduced into both from a common northern source. Its first occurrence in Greece is in isolated bands or panels reserved on necks or bodies of black-glazed pots, a rudimentary form of decoration which was as universal as the former Mycenaean style. Subsequent developments were local, and many styles have been identified in mainland Greece, the Aegean islands and the coast of Asia Minor. The most elaborate is that of Athens, called Dipylon ware after the cemetery at the city-gate, where the largest vases have been found. These are huge sepulchral jars which sometimes bear among the geometric patterns broader bands or longer panels filled with pictures of funerals, a corpse surrounded by mourners, and processions of chariots, human and animal figures being drawn

schematically in black silhouette. These subjects are the first expression of Hellenic delight in representation, which quickly dominated decorative art and ultimately destroyed it. The live subject, human and animal, was also utilized in the Geometric style as a decorative unit, in bands of soldiers carrying shields and spears, of grazing horses, deer and goats, running dogs and birds. The birds belong, like the maeander, to primary sources of the style, but the grazing and running quadrupeds are a later feature, and are probably the first signs of oriental influence.

Oriental Influences.—The political changes that destroyed the Mycenaean power had also interrupted Aegean relations with Asia and Egypt, but when contact was restored, about the 10th century, the new Greek world became doubly linked with the ancient foreign civilizations, by its colonies on the coast of Asia Minor as well as by its own and Phoenician commerce. The effects of oriental contact are visible in all Greek arts after the 9th century. The actual commodities that served Greek vase-painters for models have not been identified, and if, as is possible, they were textiles, cannot have survived. They seem to have been brightly coloured, for touches of red and white paint enliven the black figures in all the orientalizing styles. But accurate drawing and incised contours suggest metal prototypes, and some bronze and silver bowls and cups engraved in the same manner have been found in Greece and Italy. (*See* BRONZE.) Oriental motives in the late Geometric style, besides the bands of animals, are cable-pattern (*guilloche*), palmettes in bands or panels, and base-rays. The latter are derived from the petals of a flower-calix; originally Egyptian, they are a common feature of Asiatic pottery, and particularly of late Hittite vases. These novelties broke up the conventional Geometric art, and the succeeding local wares bear very little resemblance to one another.

Protocorinthian, etc.—The principal early orientalizing styles are Protocorinthian, Protoattic, Island (Melian), and Ionian (Rhodian). They belong broadly to the 7th century. The true Protocorinthian fabric was located in the Argolid, where a very precise and simple geometric style had been established. Precision is the distinguishing feature of Protocorinthian ware, and is accentuated by the miniature forms of nearly all existing vases. They are made of the smooth pale yellow clay which distinguishes the local Mycenaean fabric, and which invites fine craftsmanship by its plasticity. Conical cups (*skyphoi*) and pointed oval scent-bottles (*lekythoi*) are typical forms. Their earliest subgeometric ornament of simple linear patterns was soon displaced by bands of animals, particularly running dogs, palmettes and lotus, cables and rays, all of which were in turn subordinated to a main frieze containing human or monstrous figures, sphinxes, chimaeras, centaurs and the like. The background in the figure-friezes is filled with detached ornaments, in this style typically the dot-rosette, a device which belongs properly to metal reliefs, where it is simply executed with a round-nosed punch. The influence of metal-work is also visible in the sharpness of this style and in its use of engraving to define outlines and inner markings of the silhouettes. The colour is enriched with patches of dull red and white, as if inlaid on the black-glaze figures, for details such as manes, throats and bellies of animals, armour, clothes and hair of men. Masterpieces of the Protocorinthian style are the Chigi vase in the Villa Gierlia at Rome, a large jug with an amazingly elaborate battle-piece and hunting-scenes in three friezes, and two small scent-bottles, with fancifully modelled tops and hardly less elaborate hunts and battles on their bodies, in Berlin and London (the Macmillan *lekythos*). A purely decorative Protocorinthian scheme consists of scales or tongues closely incised on a black-glazed surface and painted alternately white and red, together with thin bands and dot-rosettes in the same bright colours. Large and small vases are entirely or partially covered with these ornaments. This fabric was largely exported, particularly to Italy, where it was more or less successfully imitated by Greek and Etruscan potters. Another Protocorinthian group consists of little vases moulded in natural forms, squatting men, busts and heads, animals, birds and shells. They were largely copied from Egyptian faience figures, and in their turn influenced the Egyptian vase-shapes. Large quantities of these Egyptian blue-glazed wares were exported from the Greek settlement of Naucratis, and some were evidently made there, or in some Greek colony in Asia, for the style of many pieces is more Greek than Egyptian, and one found in Rhodes bears a Greek inscription. The same shapes, particularly heads in helmets, were made in ordinary Greek pottery in Rhodes, and other plastically decorated fabrics from the same island are made of black ware like the Etruscan *bucchero nero*. Large storage-jars, with plastic patterns worked in relief or impressed in friezes with engraved cylinders, are also represented on Ionian sites. Protoattic pottery exhibits the same developments as Protocorinthian, but in a very different style. Vases and their painted decoration are large and vigorous, their fabric rather coarse, in red clay. Various stages of development are called by names of places where typical examples have been found, Phaleron and Vourva. They illustrate the intrusion and refinement of the Oriental repertory, from the animal-frieze with its close array of filling-ornaments to the isolation of human subjects in a clear field. The Island style is as bold as the Attic; it affects heavy spiral ornaments, gay colours, and ambitious narrative-subjects. Crete was a main channel of the new influence, but its pottery is not yet adequately represented. A typical Island form is a large high-necked bowl with a tall conical foot. Some examples, usually attributed to Melos, are painted over a white slip.

Ionian.—In this technical peculiarity they resemble the fabrics of Ionia, where the white slip was universal. This is a pipe-clay wash laid on the rough body of the vase to make a ground for painting. It is rare in Geometric fabrics, and seems to have come in with Oriental decoration; it was probably an ancient Anatolian invention, for it occurs in Hittite, Syrian, and Cypriote wares, and its immediate source may have been Lydia. The many fabrics of early Ionian style are generally represented by Rhodian vases. These are mostly jugs with rays or lotus-wreaths on foot and shoulder, and animal-friezes on the body, done on the white ground in large black-glaze figures with dull red patches. Among the filling-ornaments are looped semicircles (roundels) attached to the borders of the frieze. Human subjects are rare, the most prominent animal-figures are sphinxes, and the characteristic motive is a band of grazing goats. Large plates are a frequent shape, painted with lotus designs, or with concentric panel-friezes containing heads of goats and birds. A very similar fabric, mostly found in the Ionian city of Naucratis in Egypt, has been called Milesian, but may have been made locally. Clazomenae is chiefly represented by large painted sarcophagi. The red and white ornament on black, which was used in Protocorinthian ware, appears also on Rhodian vases, though not quite in the same forms. Red and white bands stand alone, or separate the floral and animal friezes, and the same colours are used for drawing lotus wreaths, or for filling tongues or lotus and palmette-petals, or even animals outlined by incision on the black ground. A fabric resembling the Ionian, but apparently belonging to mainland Greece, is the so-called Cyrenaic, which, since the discovery of a complete stylistic series in Spartan temple-deposits, has been known rather as Laconian. The excavation of Cyrene should decide the question of its origin. It is a white-slipped ware with bold decorative painting, large black and white chequers and step-patterns and solid rays in its subgeometric form, pomegranates and lotus-buds formally disposed between animal-friezes in its orientalizing phase. Its early shapes are somewhat fantastic; a typical drinking-cup (*lakaina*) has a low convex body, from which two long loop-handles spring, and a tall concave lip or neck. A mature work is the famous *kylix* in the Bibliothèque Nationale of Paris, with a picture of King Arcesilas of Cyrene supervising in oriental state the lading of a ship. It is this scene that caused the fabric first to be attributed to Cyrene.

The Black-figure Style.—Towards the end of the 7th century the local fabrics, which had diverged so widely in their orientalizing phases, tended to come together again, perhaps under Athenian influence, in the Black-figure style. The expansive interest in human form and human life enlarged the fields in which these subjects were accommodated; animal and floral friezes were reduced in width and relegated to the less conspicuous positions

on the pots. In the mature style of the 6th century ornamental animals hardly occur at all, and floral patterns are only used for borders or bands and panels in which narrative-pictures are displayed. But the new pictorial style retained the technique of the old ornament. The figures are drawn in black silhouette on the clay ground, and inner details are indicated by incision and by colour. The same dull red and white pigments were laid on the black glaze or on the clay in place of it. Both were decoratively applied without consideration of reality to produce a colour-pattern, but white was specially used for faces and limbs of women. White slip disappears as a mark of locality, but occurs on special occasions in several fabrics. The normal surface has the same colour as the body of the clay, light yellow in Corinthian, light red in Attic and most other wares. The natural colour of Attic clay was enriched with red ochre (*miltos*) and this substance had such industrial importance that its supply was strictly controlled by the Athenian Government. Corinthian ware in its latest development tried to imitate the Attic colour with a red wash. The history of Greek pottery in the 6th century is the continuous progress of the Athenian fabric towards its ultimate monopoly. At the beginning of the century there were numerous other black-figure wares, Protocorinthian and Corinthian, Laconian (or Cyrenaic), Boeotian, Chalcidian, and Ionian, but hardly any of these survived beyond its elementary stages. The passing of Protocorinthian into Corinthian was accompanied by such a fundamental change of content that the process is obscured, and it is sometimes supposed that the Corinthian potteries displaced those of some neighbouring city, perhaps Sicyon, which had produced the Protocorinthian ware. But though the output was increased and the style changed, the fabric remained constant, and most of the old forms continue to appear with the new decoration. The change took place at the end of the 7th century, and was evidently due to new Oriental models, perhaps textiles instead of metal work. Globular and baggy oval bottles (*aryballoi* and *alabastra*) came into fashion, with large figures, often monstrous or grotesque, painted in a loose style which is the antithesis of Protocorinthian precision. Backgrounds that had been sparsely studded with neat dot-rosettes are now filled up with irregular patches. This is the common ware that was distributed east and west by Corinthian trade. Besides it is a pictorial style which omits the filling-ornament. There is a splendid series of large Corinthian bowls (*krateres*) bearing scenes from life and legend, with single subsidiary bands of animals or horsemen. In their free use of colour, their technique of outline-drawing, and their deep designs of overlapping figures, these vase-pictures probably give a better idea of monumental painting than any other surviving documents. Chalcidian pottery stands very close to metal work in its angular vase-shapes and sharp figures. The evidence by which the various fabrics are assigned to their localities lies in the forms of the letters in which the names of gods and heroes are inscribed beside their figures. Ionian black-figure designs are lively in colour and in action; the Clazomenian fabric, like the Laconian, retains its subgeometric subsidiary bands. Ionian wares were largely imitated in Etruria, and some of them may have been made there by immigrant craftsmen. Such are the Caeretan *Hydriai*, a brilliantly decorated series of water-jars found at Cervetri (Caere). Their free floral patterns connect them with the Fikellura vases (so-called after a Rhodian site), an odd old-fashioned group that keeps the white slip technique and is shy of narrative-pictures. One of the last Ionian inventions, the *eye-kylix* (a cup mainly decorated with two large pairs of eyes), was adopted by Attic potters. A related Attic series (*Kleinmeister kylikes*) has miniature figures, often single, in an upper band, and below these, or sometimes alone, a line of minute writing, a drinking posy, a love-name or an artist's signature.

Signatures.—The practice of signing vases began in the 7th century; a Protocorinthian *lekythos* and a (perhaps Argive) *krater* with the names of their potters, Pyrrhos and Aristonothos, are the earliest examples. Timonidas, Chares and Milonidas are the only known Corinthian painters; there are four or five Boeotians, and the rest are Attic. Names are always accompanied by the words *made* (ἐποίησε) or *painted* (ἔγραψε), sometimes by both. The former is taken to be the potter's signature, but the term is not explicit, and may apply to the owner of the factory, to the manipulator of the clay, or to the maker and decorator. But double signatures indicate that the functions of potter and painter were generally separate: "Ergotimos made me, Klitias painted me" on the François vase; and one man occasionally claims both honours: "Exekias painted and made me." More than 100 Attic masters are known by name. Many were manifestly foreign, and some were slaves from the unpromising regions of Thrace and Scythia. One of the great black-figure potters bears an Egyptian name, Amasis; his work reveals Ionian affinities and shows that the Athenian monopoly was partly achieved by attracting foreign craftsmen to the city. Mature Attic pottery incorporates the best qualities of the fabrics which it superseded, technical excellence accomplished draughtsmanship and a large repertory of pot-shapes and decorative schemes.

Vase Shapes.—In archaeological usage the numerous shapes are denoted by ancient names which do not always rest on ancient authority, but they are accepted as a convenient means of classification. Important forms are two-handled storage-jars (*amphora, pelike, stamnos*), mixing-bowls (*krater*, in variety), water-pots (*hydria, kalpis*), jugs (*oinochoe, olpe, prochoos*), drinking-cups (*kylix, kantharos, kotyle, phiale, skyphos*), and oil-bottles (*alabastron, aryballos, askos, lekythos*). All were copied from metal models. Greek pottery was never a free art; its forms and decoration were inspired, controlled, and finally destroyed by progress in the arts of painting and metallurgy. After the middle of the 6th century, when technical perfection had been achieved, Attic decorators set themselves to perfect their draughtsmanship and power of expression, and the interest of painted pottery after that time is largely as a document in the history of drawing. The finest early black-figure work is the François vase in Florence, a monumental *krater* signed by Klitias and Ergotimos. It is covered with bands of lively narrative, the Calydonian boar-hunt, the funeral games of Patroclos, the marriage of Peleus and Thetis, the death of Troilos, and the battle of Pygmies and cranes. Among many later masterpieces is an *amphora* in the Vatican made and painted by Exekias, with a single panel-picture on each side. One picture shows Achilles and Aias playing draughts. The group is a stock subject reproduced by several painters, an excerpt, doubtless, from a monumental picture of the siege of Troy. The intentness of the poses and the elaboration of incised detail represent the last possible achievement of this style.

The Red-figure Style.—The innovation was made before the end of the 6th century, about 520 B.C. Some masters, notably Andocides and Pamphaios, produced vases in both styles, and even combined the two on one vase. In the new process the background was blacked and the figures reserved on the red clay; inner markings, details of limbs and features were drawn in thin lines of black glaze, hair and clothing were occasionally done with a diluted brown or yellow wash of the same medium. The glaze has not been successfully reproduced by modern experiment, but analysis shows that it was composed of ferruginous earth with an alkaline flux. It was applied to the pot after the clay was dried, and before firing. The design was lightly sketched with a point, then drawn in outline and detail, apparently with a pen. The background was blacked in, and certain contours of the figures accentuated with relief lines of thick glaze. Touches of colour, red and gold, were very rarely added, and pot and glaze were fired together in a single operation. The new drawing had unlimited freedom and made rapid progress in truth and expression, but its decorative qualities were slight. The formality of archaic art and the restraint of early classical drawing preserved the decorative value of the figures to some extent, but after the middle of the 5th century, when the problems of representation had been solved, this character was lost, and facile drawing admitted weak design.

Attic Masters; Love-names.—Epiktetos, Euphronios, Euthymides, Brygos, Hieron, Douris, are a few names of the great archaic-masters; Sotades, Polygnotos, Meidias, of the free style. Some of these signed as potters, some as painters, and there are anonymous painters, no less capable and far more numerous,

whose style can be recognized in their work. Recent research has gone far towards identifying all the hands in Attic red-figure drawing. Where the artist is not known by name, he is called after the potter for whom he worked (the Brygos painter, Meidias painter), after one of his vases or the collection in which it is preserved (the Villa Giulia painter, the painter of the Bowdoin Box) or a notable subject (the Pan painter), or after other persons named on his vases (the Panaitios painter). These, the so-called love-names, refer to popular idols of their day. When known to history they are youths of noble family, and the form of inscription *Panaitios is handsome* (Παναίτιος καλός) indicates that their fame rested on their good looks. The duration of this popularity was therefore not very long, and the use of historical names, Glaukon, Leagros, Miltiades, is valuable evidence for the dates of the vases. The character of red-figure subjects changes with the style. Archaic artists favoured heroic deeds and genial life, exploits of Herakles and Theseus, battles with Amazons and Centaurs, athletic contests and drinking-bouts. The early free style suited contemplative subjects, boys leaving home for the wars, religious and musical ceremonies. In the late free or florid style the scene is largely filled with idle women clad in voluptuous robes and trifling with winged love-gods.

Late Attic and Italian Fabrics.—In the early 4th century an attempt was made to revive this dull field again with colours, white generally for flesh of one or two figures in a group, blue, green, red and gold for drapery and jewels. Gold was often laid on details modelled in relief. These vases have been largely found in North Africa and South Russia, and take their name from the Crimean town of Kertch. They represent the last phase of pictorial painted pottery in Greece. The art survived, however, and even flourished for at least another hundred years in South Italy, where it was first established at the end of the 5th century. Another Attic fabric, the white-slipped ware which was regularly used for funeral *lekythoi* and occasionally for *kylikes* and other shapes in black-figure and outline-drawing, also came to a natural end in the 4th century, but was not involved in the same artistic decadence, since its decoration had proceeded on the broader lines of painting. These little vases, oil-bottles made for offerings to the dead, generally bear pictures of the tomb with boys and maidens bringing gifts. Clothes and mourning-sashes are painted in bright colours, and free brush-work dominates the designs. But painted patterns did not entirely disappear with pictorial subjects.

Hellenistic Relief-wares.—There was always a large class of black-glazed vases which had no other painting, but were sometimes fluted or impressed with slight ornaments in close imitation of metal. These were further adorned in the 4th and 3rd centuries with wreaths and necklaces drawn or engraved, or modelled and painted white or gilt, and occasionally with moulded figures like bronze plaques in relief. This style seems to have been universal in Hellenistic Greece, and was also produced extensively in Apulia and Campania (Gnathia and Capua wares). Another Hellenistic fabric, usually black-glazed, has purely plastic decoration, being exactly copied or even cast from contemporary bronze and silver vessels ornamented with reliefs. One group of bowls is called, for no good reason, Megarian or Homeric; it may be the Samian ware mentioned by Pliny, and is certainly the prototype of the Roman pottery wrongly called by that name. Bowls have decorative foliate patterns, or bear mythological and heroic scenes, often accompanied by written descriptions or verses quoted from the plays or poems which they illustrate. Another type, called Calene *phiale*, and mostly made in Italy, is a shallow bowl with a central medallion or interior border-frieze in relief. Two examples in the British Museum, with a frieze of chariots, are replicas of a silver bowl in the same collection. (*See* SILVERSMITHS' AND GOLDSMITHS' WORK.) Some Hellenistic wares preserved the old tradition of black painted ornament on a light clay ground or slip. Their designs are mostly wreaths and garlands, and their fabrics seem to be located in the East, particularly at Alexandria in Egypt (Hadra vases). Alexandria and Tarsus were the first centres of manufacture of Greek pottery glazed in modern fashion. Blue and green faience was the speciality of Egyptian potteries. It had been imitated by the archaic Greeks and appears with Greek designs again in the Hellenistic age. But the new glaze is quite different, and was probably an Asiatic invention. It is a thick vitreous substance made with a metallic flux, in colours ranging from brown through yellow and green to blue, and was usually laid over lamps and similar small vessels moulded in relief or entirely modelled in natural forms. But at this point Greek plastic pottery finally merges with Italian. The art of the Mediterranean world in the 2nd century B.C. was Hellenistic, industry was cosmopolitan, and it is not always possible to know in which country the fabrics were located.

ANCIENT ITALIAN POTTERY

North and south Italy were separate cultural provinces in prehistoric times. The south, with Sicily, produced some elaborately painted pottery, which may be related to the Neolithic wares of mainland Greece, and some incised with rectilinear patterns like those on the earliest fabrics of Troy and Crete. But there is no evidence of contact between the Aegean and Italian areas before the Late Mycenaean age (*c.* 1300 B.C.), and the mutual resemblances in the pottery are equally referable to the universal similarity of primitive abstract decoration. In any case this south Italian art lived and died in isolation. Contemporary pottery of the north and central regions was of much coarser type, seldom decorated at all and never painted. But the Bronze age (*Terremare*) fabrics, though inferior in quality, had a plastic character that influenced the southern shapes and developed through the Villanova style into classical Etruscan ware. It was probably not fortuitous that the Hellenistic relief styles were largely established in Italy, and that the pottery of the Roman empire bore plastic decoration.

Prehistoric Origins.—The decorative elements in Terremare pottery are knobs and ribs on the bodies and fantastic modelling of handles, which often end in horns and crescents. The same elements, which had Danubian affinities, persisted in early Iron age (*Villanova*) fabrics, and the Geometric style in which the other Villanova ornament was designed also reflects the influence of central European art. The similarity of this Villanova Geometric to the contemporary Dipylon Geometric style of Greece has sometimes been referred to Greek influence in Italy, but there is no other trace of contact at this time (*c.* 900 B.C.), and it is probable that the same style penetrated both peninsulas from the north. In each case the new designs found an effective medium ready for their expression. Greek Geometric pottery was painted in the old Minoan technique, the Italian patterns were engraved or stamped or modelled in soft clay. The characteristic maeander, which the Greeks painted in a hatched band, appears in Italy in a band of parallel incisions. The Italian style, like the technique, is far more primitive than the Hellenic. Villanova pottery is not wheel-made; its clay is coarse, red or brown in body with a darker surface which at its best is polished black. This type of pottery is known in Italian archaeology as *impasto*. The surface colouring was probably done by fumigation. The fabric is thick and clumsy and the shapes are composed of the simple globular and conical forms that belong to elementary metalwork. A typical cinerary urn has a tall biconical body with a single horizontal handle on its wide middle. Its mouth is often covered with a shallow one-handled bowl. The natural development of such pottery was towards closer imitation of metal in refinement of fabric and accuracy of form, but the process was disturbed by the intrusion of foreign influences from Greece and Asia. This contact, which began in the 8th century, coincided with the first settlements of Greeks in Italy and with the rise of Etruscan civilization.

Etruscan Bucchero.—The native Etruscan pottery is called in Italian *bucchero nero*, or simply *bucchero*. The clay is fine and coloured black throughout its substance, probably by chemical reduction in the kiln or by previous staining. The fabric is generally heavy, since most of the vases were made in moulds and the wheel was rarely used. There are, however, some very fine, thin pieces. Besides the simple developments from Villanova forms, among which the arched band-handle is conspicuous, are

copies of Greek and oriental models, *oinochoai, kantharoi, kylikes,* enriched with various kinds of moulded ornament, engraved, impressed or modelled. The three processes were often applied to one pot. Linear designs were drawn freehand with a graver or a wheel; they consist of animal and human subjects, floral ornaments, palmette and lotus and simple geometric figures, zig-zags, hatched triangles, linked arcs and spiral coils. Common patterns are fan-shaped groups of dots or dashes impressed with toothed wheels. Small decorative units like rosettes and stars were applied with separate stamps, and continuous patterns such as cables (*guilloche*) were done with engraved wheels. Elaborate friezes in relief were similarly executed with cylinders like Babylonian seal-stones engraved with real and monstrous animals and scenes of hunts, races, banquets and funerals. They were applied to all kinds of vases, but are particularly common on the body of the characteristic Etruscan *kylix* or *calix,* a cylindrical cup on a heavy stem which was a Phoenician form, and perhaps originally Hittite. Some ivory examples carved with similar reliefs were among the foreign articles in the Barberini tomb at Praeneste. Many of these cups are supported by three or four modelled struts, in addition to or instead of the central stem, set between the edges of base and body. They are in the form of human figures or flat strips decorated in relief or openwork. Plastic ornament was also applied to these and other vessels in large reliefs, usually of single animal figures on the bodies, rows of masks on rims, and heads standing free on handles. Bodies were also ribbed and fluted and moulded with gadroons, tongues and petals.

Greek Influences.—Though the foreign influence in this modification of Etruscan pottery may have been Asiatic and derived through Phoenician channels, Greek models introduced the innovation of painted patterns in ferruginous glaze. Greek artistic influence was doubly strong in Italy because the workmen were imported together with their works, either as colonists in the Greek settlements of the south or as adventurers in Etruscan cities. There was, for instance, a considerable manufacture of Protocorinthian ware at Cumae (Naples), founded from Chalcis about 750 B.C., and the local Greek fabric can only be distinguished from imported originals by a slight difference in the clay. But some other pieces found at Cumae reveal their provincial origin in coarser forms and decoration, and still more debased versions found on Etruscan sites are evidently the work of Italian potters. The Greeks rediscovered Italy at the end of their Geometric period and the first Etruscan ware painted in the Greek method bears simple rectilinear patterns, not often closely copied from Greek designs, in dull black glaze on light clay. At the same time, and perhaps earlier, there was painted decoration in Etruscan and Latin pottery done in dull white on the dark *impasto* and *bucchero* surfaces. A fabric of red *bucchero* connected with Falerii frequently bears white linear patterns. Greek and oriental subjects, bands of animals and lotus, were also painted in the same medium, and black *bucchero* was perhaps more often finished with polychrome ornament than the present condition of the vases indicates, for these colours were badly fixed and are very fugitive. Protocorinthian and Corinthian pottery were more skilfully copied and to such an extent that the Italian versions of these styles are now as plentiful as Greek originals, particularly jugs with subgeometric patterns, *lekythoi* and *alabastra* with polychrome imbricated decoration and those with bands of running dogs. In the black-figure period (6th century) Greek influence was so intense that it is not possible to decide whether some groups, Caeretan *hydriai* and Pontic *amphorae* were made in Italy, Ionia or Greece. But ordinary Italian products are easily detected by their inferior style and fabric. As Greek art progressed, Etruscan fell behind, and there can be no confusion between the two fabrics in the red-figure style, though most of the existing Attic vases have been found in Etruria. For this reason they were thought on first discovery to be Etruscan, and the false name still lingers in popular usage. It has also been supposed that Attic vases were made chiefly for the Etruscan market, but the fact is that their better preservation in Italy is due to the Etruscan practice of burying them as funeral furniture in chamber tombs.

South Italian Red-figure.—Between the later Attic originals and their Etruscan imitations stand the great series of red-figure vases made in the Greek cities of south Italy, which are derivative rather than imitative, and contain many Italian elements. They had a vigorous life for a hundred years after the disappearance of the true Greek industry. Painted pottery had been made by the natives of south Italy since the 8th or 7th century, at first without any traces of Hellenic influence, in fantastic shapes, large *askoi* and strongly curved and carinated cups with horned handles, elaborately ornamented with geometric patterns (Peucetian ware), and in the 5th century with Greek floral motives in place of the rectilinear designs (Messapian). Some of their peculiar shapes were ultimately incorporated in the red-figure fabrics, but the new style at first was wholly Greek, and its earliest examples are not easily distinguished from Attic vases; they may, indeed, be the work of Athenian artists living in Italy. But in the 4th century definite local styles were formed, differing from Attic in certain vase-shapes, colours of clay and paint, types of subjects and styles of drawing. The recognized south Italian fabrics are Lucanian, Campanian and Apulian, with a special group attributed to Paestum. They differ from one another in some technical and stylistic details, but all are marked by dull brownish clays, extravagant shapes and florid ornament. The simplest style is Lucanian, which probably represents an early phase of the industry. Mature Campanian and Apulian are gaily and profusely ornamented, but the effort is generally limited to one face of the pot, the reverse side being filled with dull conventional figures. Some large vases bear mythological scenes, but ordinary pieces have commonplace subjects of youths and maidens lounging in exaggerated elegance and a close atmosphere of ribbons, flowers, pet animals and domestic furniture. The filling of the backgrounds approaches that of the Greek orientalizing styles. Border patterns, palmettes, waves and foliate wreaths are bold and large. Subsidiary colours, white, yellow, red, were freely applied in dots, lines and washes. Men's costume often reflects Italian fashions, particularly on Campanian vases, a very short tunic with broad belt, and feathered helmets and triangular breastplates for soldiers, presumably the Samnite armour. Dress, pose and gesture of the figures have a histrionic extravagance which seems actually to have been taken from the stage. An important class of subjects consists of theatrical scenes, particularly from the tragedies of Euripides. Burlesques of tragic and heroic legends are also depicted. These were the local *phlyakes,* the kind of farce that the Tarentines were attending in the theatre when they saw the Roman fleet entering their harbour, in 302 B.C. The stage and scenery are often illustrated in these pictures. Only three artists are known in the Italian schools, and two of them, Assteas and Python, belong to the Paestum group. Both painted theatrical scenes. A *krater* by Python shows Alcmena on the funeral pyre, Antenor and Amphitryon setting light to it, and in the upper background, by a characteristic and perhaps theatrical convention of perspective, half-figures of rain-nymphs pouring water out of pitchers on the fire at the behest of Zeus. The most imposing Apulian vases are great sepulchral *amphorae, hydriai* and *krateres.* They bear pictures of elaborate funeral monuments, done in white paint, gabled tombstones or shrines with reliefs or statues of the dead, to whom mourners (in red-figure) bring gifts. Another florid south Italian class of pottery has free plastic ornament; large globular *askoi,* a native shape, have gorgon-masks and fronts of horses on their bodies, large statuettes of women, cupids and winged goddesses standing on rims and handles, all brightly painted in blue and red.

Hellenistic Relief-wares.—These Graeco-Italian fabrics were succeeded, in the 3rd century, by Hellenistic pottery imitating metal, black glazed ware painted with white, yellow and red necklaces and garlands or moulded in relief. The first class takes the name from Gnathia (Egnazia) in Apulia, where much of it has been found. There was certainly an Italian fabric in this style, for several pieces bear Latin legends, mostly dedications to deities such as *Aecetiai pocolom* (*Aequitiae poculum,* the cup of Justice) painted with the foliate decoration. Some of the contemporary relief wares were also made in Italy. Moulded signa-

tures on several bowls fix their place of origin at Cales in Campania and their maker's nationality as Roman: *L. Canoleios L. F. fecit Calenos.* A similar fabric assigned to Bolsena in Etruria is unglazed, and may have been gilt or silvered.

Roman Pottery.—It was also in Etruria, at Arezzo (Arretium), that the first Italian fabric was established of the fine red pottery, variously called Arretine or Samian or *terra sigillata,* which became the standard ware throughout the Roman world for several centuries. *Terra sigillata* is the modern archaeological name for the whole class. Samian is a misnomer; it may perhaps be applied to some Greek fabrics, but means nothing definite. Pliny says that the reputation formerly held by Samian table pottery had passed in his day to Arretium and other places in Italy, Spain and Asia Minor. There is no trace of a Spanish fabric in the existing material, but examples of Asiatic origin have been found at Laodicea, Pergamon, Myrina and elsewhere. It is a purely Hellenistic type of pottery, whether made in Italy or Greece.

Arretine.—Arretine is the name of the Italian fabric, which was not made solely at Arezzo. Provincial Roman varieties, mostly Gaulish, are named from their places of manufacture, La Graufesenque, Lezoux, etc. All this pottery is made of bright red clay and, when ornamented, moulded with reliefs (*sigilla*). Some early (2nd century B.C.) products of Arezzo are black glazed, but they hardly enter into the series. The vases are generally small, for table use, and very rarely have handles; they are mostly bowls, cups and saucers of shallow cylindrical and globular forms. Their lustre was produced with a thin alkaline glaze, which gives an extraordinary depth and richness to the colour of the clay. The earliest decoration was copied from the embossed silverware which was originally a speciality of Alexandria and Antioch. (*See* SILVERSMITHS' AND GOLDSMITHS' WORK.) The bodies are completely covered with floral and foliate designs, masks and decorative furniture, human and animal figures, allegorical and mythological scenes, processions, sacrifices, battles, hunts, dances, feasts and similar episodes of social life The vases, or their decorated bodies, were cast complete in clay moulds, which were prepared mechanically by means of separate stamps, for the component elements of the design. The final artistic effect was therefore dependent on the potters' manipulative skill. The potters' signatures were stamped into the moulds, sometimes appearing in relief on small tablets among the ornamental figures, sometimes in sunk spaces, rectangular, round or fancifully shaped as footprints, wreaths or stars on rims or bases, inside or outside the vessels. Plain wares are ordinarily stamped inside the base. The names of Arretine potters begin about 100 B.C. They represent owners of factories, whose names are sometimes given in the formal Roman manner, sometimes greatly abbreviated and in monogram, and the actual potters, slaves, who often have foreign names. The master potter Marcus Perennius signed *M. Perenni, M. Peren, M. Pere, M. Per,* and *M. Pe.* Seventeen slave names occur on his vases, sometimes in conjunction with the master's, sometimes alone. Bargates and Tigranes are the best known; the latter signed *Tigran, Tigra and Tigr.* Aulus Titius signed *A. Titi. Figvl(ina) Arret(ina).* The factory of Rasinius was directed by Lucius of that family in the Augustan period and by Gaius Rasinius Pisanus in the Flavian, by which time the Arretine potteries were turning out replicas of Gaulish work. The large numbers of names and the many varieties of vase shapes and types of ornament that were produced during the long life of this pottery, have been very accurately recorded, and the pottery has become a valuable archaeological index for determining the dates of other Roman objects, buildings and sites, with which it is found in excavation.

Gaulish Terra Sigillata.—The Italian fabric came to an end about A.D. 100, being displaced in Italy and the provinces by *terra sigillata* made in France. Italy still produced its own coarse pottery for ordinary domestic use, unglazed and undecorated vessels, which formed the bulk of ancient pottery at all periods. The new Gaulish ware was precisely the same as Arretine in fabric, and at least as good in technical quality; its colour is even superior, a darker and brighter red, and its paste is usually harder than the Arretine. But the decoration is inferior, the ornament is in very low relief, and designs and figures are generally small and mean. It is found all over the Roman world, but most abundantly in central France. Finds of moulds and kilns have fixed the localities of the two principal fabrics at La Graufesenque (Aveyron) and Lezoux (Puy-de-Dôme), in the ancient Rutenian and Arvernian territories. The Gaulish fabrics began before the middle of the 1st century A.D. and ended about the middle of the 3rd, but ornamented vases were probably not cast from moulds after the middle of the 2nd century. The names are often Gaulish, and even Roman names are spelt in Gaulish fashion, *Tornos* for *Turnus.* It is a strange fact that native elements do not appear in the designs. The forms were at first identical with Arretine or derivative, and there was the same distinction of shapes for ornamented and plain wares. The commonest type of ornamented vase was a carinated bowl with a band of design on each plane (*Form 29*). It was succeeded in popularity about A.D. 150 by a bowl cylindrical in form, which in its turn gave place to a type of hemispherical shape (*Form 37*). The commonest plain red vessels are very wide and shallow cylindrical and conical bowls or flat saucers. The earliest ornament consists of purely decorative motives, wreaths and scrolls, with a few animals incorporated in the foliate designs. These bands are continuous, but the figure-subjects, which began about A.D. 75, are broken up in panels, medallions and arcades, and a free style of figure composition was not reached until the 2nd century. It is characteristic of Lezoux bowls. The figures are minute and were generally taken from well-known Hellenistic sculptural types. There are a few mythological groups. A purely Roman subject, the gladiatorial duel, is very frequent. In the free style hunters chasing animals are popular subjects.

Barbotine and Lead-glaze.—A technical innovation of the 2nd century was relief applied in *barbotine,* slip clay laid on by piping. It seems to have been a German invention, since it appears first on native Rhenish pottery of the 1st century. Its early use in *terra sigillata* was for small foliate patterns on the rims of flat bowls and dishes, but in the 3rd century it began to replace moulded work on bowls of the standard Roman shape. Another Teutonic element in the Roman fabrics of this date is a globular jar with narrow neck (*olla*), which could not be cast entire. Its ornament was therefore made in separate plaques or medallions and affixed to the pot; scrolls in *barbotine* form a setting for these reliefs, which are largely topical in subject, portraits of emperors, gladiatorial contests and theatrical scenes, often accompanied by explanatory inscriptions. These were made in Provence and also at Lezoux, where they were the last products of the Roman industry. The Gaulish output was not large in Roman times and its forms were trifling, small vases and lamps and toys ornamented with reliefs or modelled in the shapes of animals and common objects. But in the Eastern empire the process was generally used for Byzantine pottery. It was adopted by the conquering nations after the fall of Rome, and became the medium of ceramic decoration in mediaeval Europe. (E. J. F.)

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EUROPEAN POTTERY

TO END OF 18TH CENTURY

Byzantine.—The Eastern Empire with its capital at Constantinople was the channel through which, after the downfall of Roman civilisation in the West, the art and culture of the East was communicated to Europe, and the artistic ancestry of later European pottery is to be sought, in part, in this quarter. Evidence is scanty, however, as to the nature of Byzantine pottery, owing to the cessation of the pre-Christian custom of burying earthenware and other vessels in the tombs of the dead. What little we know

is derived from finds of potsherds in excavations at Constantinople and a few sites in Greece, Cyprus, the Crimea and elsewhere. These are of two main types, both of red-bodied earthenware with a surface coating of transparent lead glaze. The decoration in one type is in relief, produced with impressions of a wooden stamp; in the other it is of the kind known as *sgraffito*, engraved with a pointed tool through a coating of white slip. The fragments are mostly those of bowls and deep dishes; the ornamental motives include human figures, animals and birds of symbolic import, simple leaf designs, interlacements, monograms and the Greek cross. The glaze is generally yellow; a bright copper-green is also found.

Hispano-Moresque Ware.—The chronology of the Byzantine wares discussed above is difficult to establish, but it is probable that they date from the two or three centuries immediately preceding the Turkish conquest of Constantinople in 1456. Pottery of artistic quality was known long before this date in Spain, fragments with painted decoration akin to that of the contemporary wares of Mesopotamia and Egypt having been found on the site of Medina az-Zahra, the palace of the Caliphs near Cordova, destroyed in the 11th century. References are found in writers of the 12th century and later to the "golden pottery" of Calatayud (in Aragon) and of the Kingdom of Granada; this phrase undoubtedly means the tin-enamelled earthenwares painted in metallic lustre colours, derived from silver and copper, which are the most famous of the Hispano-Moresque wares, although no surviving specimens are known which can be referred to a date earlier than the 14th century. To this period belong the celebrated vase in the Alhambra, with its decoration of confronted gazelles, arabesques and inscriptions, in golden lustre with touches of blue, and the similar vases scattered in various museums. A bowl of similar style, at Berlin, which is marked with the name of Malaga, suggests that that city rather than Granada was the place of origin of this Andalusian class of lustred pottery. In later times the manufacture passed to the kingdom of VALENCIA, whence in the 15th century such wares were shipped to places so far distant as Leeuwarden, London, the Crimea and Cairo. The chief Valencian pottery centre in the 14th century was Paterna, where quantities of enamelled ware have been found with human figures, animals and foliage designs of pronouncedly Gothic character painted in manganese-purple and green. In the neighbouring town of Manises, on the domain of the Buyl family, lustred pottery was made which the writings of Eximenes show to have been already famous for its beauty in 1383. In the earlier Manises wares we find designs of strongly Oriental character, comprising the Islamic "tree of life," palm-motives and Arabic inscriptions (generally the word *alafia*, "blessing," repeated in formalized characters). Early in the 15th century we find bold heraldic animals in blue against lustred spirals, and from about 1450, especially in wares made with heraldic designs for export to Italy, beautiful diapers of vine-leaves and small flowers. In the 16th century renaissance foliage makes its appearance, and in the decadent 17th century wares a crowded ornament of birds and leaves in a fiery copper lustre. Fine blue-and-white wares were made at Teruel (Aragon). At Seville and Toledo especially were produced polychrome-enamelled tiles, at first cut so as to form geometrical and other designs in enamel pigments, which are kept within the outlines, first by painting these in manganese mixed with a greasy medium (*de cuerda seca*), and afterwards (from about 1510) by moulding the outlines in slight relief (*de cuenca*). Earthenware dishes with bold animal designs executed by the *cuerda seca* technique were made at Toledo. Mention must be made also of the great amphora-shaped wine-jars, well-heads and fonts with stamped or incised ornament, sometimes covered with a green enamel, which were made at Triana (Seville) and elsewhere in southern Spain in the 14th and 15th centuries.

Italian Maiolica.—The Italian wares of the early Renaissance period represent the highest achievement of the potter's art in Europe. They are mostly of the type known as maiolica, that is, earthenware coated with an opaque tin glaze or enamel as a recipient for painted decoration. The name was first used in Italy in the 15th century of the lustred Valencian wares imported in Majorcan trading ships and mistakenly supposed to have been made in Majorca; it was afterwards extended to Italian limitations of them and finally to unlustred earthenware with a tin enamel. Such wares have been found at Orvieto, Faenza, Siena and elsewhere, dating from the 14th and 15th centuries, with designs of animals, birds, foliage and heraldry of Gothic style in manganese-purple and green, recalling those of the Spanish wares of Paterna.

BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM

DERUTA MAIOLICA DISH

By the end of the 15th century the palette was extended to five principal colours or more, but the designs retained their purely decorative character. After 1500 a change to pictorialism came about, with a further range of colouring, dishes and vases being at last treated merely as recipients for subject-paintings (*istoriati*); later in the century the arabesques of Raphael and his school based on ancient Roman wall-paintings began to influence maiolica design, and in the 17th century decoration of this type found a rival in monochrome blue painting in emulation of Chinese porcelain and the Dutch wares of the time, heralding the downfall of the art of maiolica in competition with English earthenware in the 18th century. A great part of the output of the maiolica-potters, in the form of large dishes, wall-panels and vases, was intended from the outset for decoration only; dishes with appropriate designs were a favourite form of gift as love-tokens or to celebrate betrothals and weddings. The "useful" wares include plates, jugs and large pitchers, and expecially drug-pots for the equipment of feudal or monastic pharmacies, either with a handle and short spout or of the waisted cylindrical shape known as *albarello*. Pavement-tiles were also an important part of the output of certain workshops. From about 1500 onwards the influence of contemporary graphic art becomes increasingly apparent in the decoration of maiolica. Woodcuts in devotional and other books and the engravings on copper of German as well as Italian masters provided the painters with motifs.

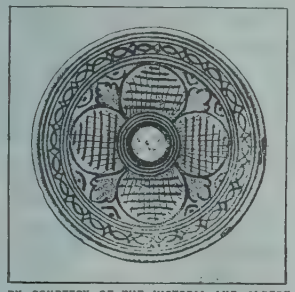
Early in the 15th century, under the lordship of the Manfredi, Faenza became an important centre of the craft; the city soon rose to such predominance that its name was adopted in French and other languages for enamelled earthenware in general. Floor-tiles, dated 1487, of great beauty, powerful design and colouring in the church of San Petronio, Bologna, are shown by inscriptions on them to have been made at Faenza in the workshop of the Betini family. The leading Faventine workshop from about 1500 was the Casa Pirota; the dishes and drug-vases there made display a great wealth and variety of ornament based on early Renaissance motives — cupids, masks, dolphins, cornucopias and the like, generally in reserve on a blue ground. One class of wares is painted in dark blue and white on an enamel stained lavender-blue. A great master of the craft, identified by the signature on the back of a dish painted with Christ amongst the Doctors as Ieronimo da Forli, is believed to have lived at Faenza; he adapted compositions of Dürer and others in paintings displaying all the resources of the art in unexcelled beauty of harmonious colour ("The Resurrection," Victoria and Albert Museum, London; "Martyrdom of St. Sebastian," Florence; "Death of the Virgin," British Museum).

BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM

CAFFAGGIOLO MAIOLICA JUG

It seems that maiolica was not made at Florence, but potteries

existed in its neighbourhood at Montelupo and Caffaggiolo. To the former perhaps belong the noble 15th century wares, especially two-handled nearly globular drug-pots, painted in a thick blackish blue and purple with animals, birds and human figures amongst foliage which from its type has won for these wares the appellation "oak-leaf jars"; in the 17th century this place produced dishes with crude figures of musketeers. A pottery attached to a castle of the Medici, Caffaggiolo, was the source of some of the most sumptuous maiolica ever made, great dishes, bowls and pitchers with the arms of the Medici and of the two popes of that family, triumphs in the manner of Mantegna, and subjects after Florentine artists. Hardly less splendid are the wares of Siena, particularly of one Maestro Benedetto; they excel in vigorous ornamental designs of early Renaissance character, in a palette dominated by a rich orange-yellow. Conspicuous among them are the drug-vases with an oval panel on one side formed by a ribboned wreath of fruit and foliage and traversed by a wide band bearing the name of the intended contents. The typical Sienese painting is seen also in the heraldic and grotesque designs of the pavement-tiles of the Petrucci Palace, Siena, now scattered in various museums. The Sienese wares were imitated at Deruta, near Perugia, which was, however, better known for its lustred wares (the earliest with a date, a relief of St. Sebastian in the Victoria and Albert Museum, is of 1501); these are painted in blue outline and shading, filled in with a pale lemon—or straw-yellow lustre. They take the form especially of two-handled vases and goblets and heavy wide-rimmed dishes, often painted with a lady's bust accompanied by a moralising adage or with figures influenced by Perugino.



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ANTWERP MAIOLICA DISH

A large share of the production of maiolica in the 16th century belongs to the duchy of Urbino. Castel Durante (now called Urbania) made wares predominantly decorated with fancifully-conceived arrangements of weapons, musical instruments and the like combined in trophies with grotesque masks, dolphins and cornucopias. One Zoua (*i.e.,* Giovanni) Maria employed such themes as borders to enclose figure-subjects of exquisite delicacy. Castel Durante was also the birth-place of Nicola Pellipario, the greatest of maiolica-painters, who migrated to Urbino and there adopted the name Fontana; he brought narrative (*istoriato*) painting to an unsurpassed pitch of perfection in several services of plates with mythological and other subjects, particularly one with the arms and devices of Isabella d'Este and another now in the Museo Civico, Venice. He freely adapted motives from engravings, including the woodcuts of an edition of Ovid's *Metamorphoses* published at Venice in 1497. Nicola's style was followed, in progressive deterioration, by his grandson, Orazio Fontana, and others of his family, and by Francesco Xanto and Alfonso Patanazzi, all of whom owned or painted at potteries at Urbino itself. In these, about 1550, a new and pleasing style of ornament was adopted, of airy and fanciful arabesques in the manner of Raphael scattered over a creamy white ground; about the same time also Urbino began to produce imposing snake-handled urns, fountains, wine-cisterns, salt-cellars and inkstands (the latter often in the form of a group of figures) in shapes largely borrowed from bronze or silver. Pictorial wares similar to those of Urbino were made about 1560 in the workshop of the Lanfranchi family at *Pesaro*. The maiolica of *Gubbio*, made by Maestro Giorgio Andreoli and his successors, is famous for its lustre painting, in golden yellow and especially in a rich ruby colour; at first this artist followed the style of the Deruta lustred wares, but about 1518 he began to produce designs of his own, including grotesques and trophies like those of Castel Durante, figures of *putti* within symmetrical border-ornament, and pictorial subjects based on engravings, chiefly after Raphael. Besides making pottery for his own decoration, he added lustre enrichments to already-painted wares sent from Urbino, Castel Durante and Faenza for the purpose.

There were several maiolica factories at Venice. In some of these pictorial wares were made like those of Urbino, but generally of indifferent quality. One Maestro Lodovico produced about 1530–50 a distinctive class of wares strongly influenced by the Near Eastern pottery and Chinese porcelain then beginning to be imported by Venetian traders; they are painted solely or chiefly in blue on an enamel stained to a pale greyish-blue. The 17th century Venetian maiolica displays a fondness for architectural subjects and occasionally ornament in high relief imitating contemporary *repoussé* silver.

The potteries of the Ligurian coast between Genoa and Savona came into prominence in the 17th century with their blue-and-white maiolica sometimes directly copied from Chinese porcelain; at the same time close imitations of Turkish earthenware were being made at Candiana near Padua. From about 1670 onwards the potteries of Castelli, in the Abruzzi, and its neighbourhood produced wares with polychrome painting in subdued colouring of figure-subjects and landscapes.

Italy is remarkable not only for its maiolica but also for a distinctive kind of lead-glazed earthenware with decoration incised through a coating of white slip (*sgraffito*). The glaze is generally of a deep buff tone, giving a dark brown colour to the red body where revealed by the engraving of the decoration, which is often heightened by touches of green and purple laid on with a brush before the application of the glaze. The technique, derived through the Byzantine dominions from the Islamic East, attained artistic importance in Italy towards the end of the 15th century. Recent investigations have shown that although it was practised at several other places north of the Apennines, the wares in which it is displayed at its best were made under the patronage of the Bentivoglio family at Bologna. Sgraffito ware was made at Bologna until the 17th century.

French Faience.—Pottery found in excavations at various places in Provence, and at Agen, and tiles from the church of Brioude, prove that tin-enamelled earthenware, with painting in manganese-purple and green, was made in Southern France as early as the late 14th century. Maiolica of a more developed type was made in the 16th century at Lyons by Italian potters from Florence and Faenza; to them are attributed certain wares with pictorial subjects in the Urbino style and French inscriptions, and tiles from the church of Brou. About 1540–60 Masseot Abaquesne was making maiolica and tiles painted with purely French renaissance designs at Rouen. Some rare examples with heraldic decoration are believed to be the work of Antoine Sigalon of Nîmes.

In 1578 a pottery for this kind of earthenware (called in French *faience*) was set up at Nevers by three brothers named Conrade, from Albissola near Genoa, and continued in the hands of their descendants. In the 17th century, under Chinese influences, polychrome gave way to blue-and-white painting, with manganese for the outlines, though classical themes continued for a time in favour. Soon after, subjects adapted from late Ming Chinese porcelain became the fashion.

A privilege for making faience at Rouen was accorded in 1644 to Nicolas Poirel, who was succeeded by Edme Poterat and his son, and in the reign of Louis XIV. the city became a thriving centre of the *faience* industry, noteworthy for the large dimensions of many of its wares—dishes, wall-cisterns, and life-size busts on pedestals. A distinctive style of decoration was introduced characterised by wide borders and radial arrangements of palmettes, scrolls and festoons somewhat resembling lace; in the motives of this graceful *lambrequin* decoration Chinese elements are blended with those of the classical baroque. The painting is carried out in blue, either alone or combined with red or ochre-yellow. About 1730, in the pottery of Guillibaud and others, a change came about in favour of a more varied polychrome palette; motives borrowed from the Far East assert themselves, together with the asymmetrical scrollwork, shells and cornucopias of the rococo, and towards the end of the century the enamel-painted flowers of contemporary porcelain were imitated. The faience industry at Rouen as elsewhere was killed by competition with imported English wares.

At Moustiers in Provence faience began to be made shortly before 1700 by members of the Clérissy family. Among their early productions are dishes of exceptionally large diameter with hunting-subjects after engravings by Tempesta and wares, especially oblong trays, with airy baroque designs in the manner of Bérain; these were at first in blue, afterwards polychrome. In 1738 Joseph Olerys, a Moustiers potter who had spent some years at Alcora in Spain, introduced a new floral style in colours with sprays resembling potato-blossoms, and grotesque figures borrowed from the engravings of Callot. About 1677 one of the Clérissys of Moustiers moved to Marseilles and there made faience, similar to that of his native town, in the suburb of St. Jean-du-Désert. Several factories were at work at Marseilles during the 18th century; chief among them were those of Veuve Perrin, Joseph Robert and Honré Savy.

In Lorraine flourishing faience-factories were carried on at Strasbourg and Niderviller, both conspicuous for the fine quality of their overglaze enamel painting. The Strasbourg pottery, in the hands of the Hannong family, came to an end in 1774 after some half century of existence. Its earliest wares were blue-and-white in the manner of Rouen. Its later table wares in good rococo shapes based on silversmith's work show quasi-naturalistic flower-painting skilfully rendered in fresh colours dominated by a strong crimson, which exercised a great influence on the work of other French faience factories. That founded by Baron Beyerlé in 1754 at Niderviller and transferred in 1774 to the Comte de Custine made similar enamel-painted faience, including admirable figures, mostly of children or peasants, from models by the sculptors Cyfflé and Lemire.

Faience of artistic quality was made at many other French towns in the 18th century. Sceaux near Paris produced both porcelain and enamel-painted faience hardly inferior to porcelain. Aprey is known for gaily-coloured wares of a more homely kind. In Paris, at Lille and Rennes the formal style of Rouen was followed. St. Omer and St. Amand-les-Eaux in French Flanders, and Montpellier in Languedoc also had faience-factories.

Faience of Northern Europe, Spain and Portugal.—Early in the 16th century an Italian potter from Castel Durante, Guido di Savino, was settled at Antwerp, and from this time may be dated the beginning of maiolica-production in the Netherlands. The Antwerp wares, which included pavement-tiles, show the influence of the Faenza potteries in simple floral and linear motives, but soon took on the distinctive characteristics of Netherlandish renaissance design. About 1560–70 maiolica-potters from Antwerp carried their art as Protestant refugees to Holland and England. Rotterdam and Haarlem became centres of production of earthenware and wall-tiles with animal, flower and fruit motives in strong colouring, and large tilework pictures with figure-subjects. Towards 1650 Delft came to the fore and for more than a century continued with its numerous potteries, known by their signs (the Peacock, the Star, etc.), as a thriving centre of industry exporting its wares all over the civilized world. Aelbrecht de Keizer is the earliest Delft potter whose productions are known, if the initials AK on certain blue-and-white pieces are rightly identified as his; the designs on these are borrowed from the contemporary Chinese porcelain then being imported in quantities by the Dutch East India Company. About 1600 we find plates and panels charmingly painted in blue with Dutch or Italian landscapes, by Frederick van Fritjtom. Samuel van Eenhoorn developed the Chinese fashion in a broad highly decorative manner of his own. To Adrianus Koek are owing the imposing blue-and-white hyacinth-vases made to the order of Queen Mary for the adornment of Hampton Court Palace; their ornament is borrowed from the French baroque designer, Daniel Marot. Other potters adopted Biblical subjects or scenes from Dutch life of the time (often in series continued through a set of plates or dishes) for the decoration of their wares. About 1700 close imitations of Chinese porcelain of the reign of K'ang Hsi, both blue-and-white and five-colour, were made, especially by Lambertus van Eenhoorn and Louwijs Fictoor, whose monograms are indistinguishable; notable amongst them are chimney-piece sets of large covered jars and vases, often reeded (so-called *cachemire* ornament). The wares produced became ever more varied, including statuettes and even model violins. Before 1700 muffle pigments and gilding were introduced by Rochus Hoppesteyn, in vases with classical figure-subjects, and by Adriaen Pijnacker, in imitations of Japanese polychrome porcelain dominated by a vivid red. Coloured enamel grounds were also occasionally used, notably a fine black in imitation of lacquer. As the 18th century advanced the wares became more commercial in character; the Delft potteries declined, only ten surviving till 1794. Somewhat rustic wares in the Delft style continued to be made till recent times at Makkum and elsewhere in Friesland.

BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM

BRISTOL DELFT DISH, TULIP DESIGN

In Spain the adoption of the renaissance and Italian influences resulted during the 16th century in the production of enamelled earthenware entirely different in character from Hispano-Moresque ware. The settlement of an Italian tile-painter, Nicoloso Pisano, in Seville about 1503 brought about a widespread employment of maiolica tile-pictures for wall-decoration. At the same time Talavera and the neighbouring Puente del Arzobispo became the leading centre of pottery production. They produced, alongside wares in which Netherlandish renaissance ornament can be recognised, others of a strongly native character painted with animated hunting and battle scenes or with large busts or animals amongst loose foliated scrolls, in blue alone or in a limited range of colours dominated by a strong copper-green. From Talavera, potters went out to Mexico and there founded a vigorous industry. The foundation of a faience factory by the Count of Aranda in 1727 at Alcora led to the decline of Talavera. The faience mostly painted in blue and purple made in the 17th century at Lisbon, in which freely-handled Chinese themes are blended with renaissance motives has decorative value.

It is recorded that about 1567 Jasper Andries and Jacob Sanson fled from Antwerp to England to escape religious persecution and set up potteries at Norwich, whence in 1570 they moved to London. Their productions have not been identified, but it is likely that they resembled the maiolica at that time made in the Netherlands, and it is possible that certain jugs with mottled blue, purple and orange colouring over a tin enamel, generally found with silver mounts, were made by them. The earliest piece of maiolica of certain English origin is dated 1601; we may note here that at a later stage such wares were known as "delft," after the chief Dutch centre of production from about 1650 onwards. After 1625 dated pieces made at Lambeth and elsewhere near London become plentiful, chiefly dishes and small mugs with decoration painted either in blue in crude imitation of contemporary Chinese porcelain or with coloured designs of fruit and flowers or arabesques in imitation of Dutch and Italian wares. Wine-bottles painted with the name of the intended contents were also made in quantity. Towards 1650 figure-subjects, mostly scriptural (especially the Fall) become plentiful. Imitations of the "Persian" blue ware of Nevers were also made. From London the maiolica industry was carried to Brislington, near Bristol, where in 1682 we find working one Edward Ward, who in 1683 established a pottery at Temple Back, Bristol. He was succeeded at Brislington in 1697 by Thomas Frank. Other leading Bristol potters of the 18th century were Richard Frank, and Joseph Flower. John Bowen and Michael Edkins were painters employed by several of the potters. The earliest recorded date on Brislington-Bristol ware is 1652. The early designs include tulip and other flower designs in the Dutch manner, Chinese subjects and portraits of sovereigns or celebrities of the day. After 1700 Chinese motives take the lead, but adapted in a free and original manner. Landscapes of a local character with figures, in blue, were also in favour. The third great centre of delft production in England was Liverpool, which in the 18th century exported

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DECORATED POTTERY OF ANCIENT GREECE AND ITALY

1. Attic *oenochoe* or jug, with a moulded design representing a sacrifice. 4th cent. B.C.
2. Roman (Arretine) *krater* or mixing bowl, bearing a design of the Seasons. 1st cent. B.C.
3. Attic black-figure *amphora* or two-handled jar, signed by the potter Exekias, showing Achilles slaying Penthesileia. 6th cent. B.C.
4. Attic red-figure *krater* attributed to the painter Myson, showing Heracles and Apollo struggling for the Delphic Tripod. 5th cent. B.C.

POTTERY AND PORCELAIN

BY COURTESY OF THE TRUSTEES OF THE BRITISH MUSEUM

ANCIENT GREEK POTTERY

1. Chalcidian black-figure krater (vase for mixing wine and water). Height 18″
2. Attic black-figure hydria (water jar). Height 18″
3. Attic kylix (drinking cup), miniature style. Height 5½″
4. Eye kylix. Height 5″
5. Attic red-figure kotylē (drinking cup), signed by Hieron. Height 8¼″
6. Attic red-figure lekythos (oil bottle). Height 10″
7. Attic lekythos. Height 8″
8. Megarian bowl. Height 3½″
9. Vase of red Samian ware. Height 6¼″

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ANCIENT ITALIAN POTTERY

1. Campanian hydria (water jar)
2. Apulian vase
3. Villanova cinerary urn. Height 15"
4. Calene (Campanian) bowl, with potter's signature. Diameter 7"
5. Canosa (Apulian) vase
6. Gnathia (Apulian) bowl with Latin inscription. Diameter 5½"
7. Etruscan bucchero jug and bowl. Height, jug, 16"; bowl 8"
8. Etruscan bucchero cups. Height, central figure, 7½"

POTTERY AND PORCELAIN

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BY COURTESY OF (1) THE DIRECTOR OF THE ROYAL SCOTTISH MUSEUM, EDINBURGH, (2) THE DIRECTOR OF THE VICTORIA AND ALBERT MUSEUM, (3) THE TRUSTEES OF THE BRITISH MUSEUM

ITALIAN MAIOLICA

1. Plate of Italian maiolica, painted with a hunting scene, by Nicola Pellipario. Early 16th century
2. Drug-vase or *albarello*, painted with Gothic foliage; height 8⅛″. Italian maiolica, late 15th century
3. Drug-vase, painted with bust of a youth and monogram TB.; Italian maiolica Faenza. Early 16th century

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BY COURTESY OF THE DIRECTOR OF THE VICTORIA AND ALBERT MUSEUM

EUROPEAN POTTERY

1. Plate of Delft earthenware, with polychrome design of Chinese flowers and birds. Early 18th century
2. Jug with figures in relief, earthenware. Nuremberg, Preuning factory. 16th century
3. Vase with flowers in white and yellow on a blue ground. Nevers faience. 17th century

POTTERY AND PORCELAIN

BY COURTESY OF THE TRUSTEES OF THE BRITISH MUSEUM

ANCIENT ROMAN POTTERY

1. Arretine mould and stamp. Height 4¾″
2. Bowl of *terra sigillata*. Gaulish fabric. Diam. 9″
3. Bowl of *terra sigillata*. Gaulish fabric. Diam. 5½″
4. Jar with *barbotine* and moulded ornament. Height 7½″
5. Arretine saucer with potter's stamp. Diam. 4½″
6. British castor ware. Height 6″
7. Black Rhenish ware. Height 5″
8. Lead-glazed ware. Height, central figure, 7″

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EUROPEAN POTTERIES

1. Bowl with lion supports, *sgraffito* ware. Italian, late 15th century. In the Louvre
2. Side view of bowl shown in fig. 1
3. Dish with rampant lion, Hispano-Moresque ware; diameter 10″
4. Tray, Rouen faience; length 14⅞″, width 9¾″
5. Dish, Frankfort faience; diameter 13½″
6. Tureen, Strasbourg faience; height 19″
7. Jug, Raeren (near Aachen, Germany) stoneware
8. Dish, Palissy ware, second half 16th century; length 11″, width 7⅝″. From the Salting Collection

POTTERY AND PORCELAIN

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EUROPEAN PORCELAIN

1. Spanish group, *buen retiro*, height 7⅜". 2. Meissen cup, height 1¾", and saucer 4⅞" in diameter. 3. Höchst figure, modelled by Melchior; height 7". 4. Chantilly inkstand, figure of a Chinaman; height 7½". 5. Sèvres porcelain vase, *gros bleu*, and green ground, height about 15". 6. Meissen group by Kaendler; Scaramouch and Columbine; height 7"

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ENGLISH PORCELAIN

1. Chelsea (red anchor) figure of a carpenter; height 7¾″
2. Derby cup and saucer painted by Boreman; height 2½″, diameter 5⅜″ respectively
3. Bow figure of a cook; height 6½″
4. Worcester vase, blue ground; height 6″
5. Chelsea (gold anchor) vase with mazarine blue ground; height about 5″
6. Worcester mug (Frank Lloyd Collection); height 5″

POTTERY AND PORCELAIN

BY COURTESY OF THE DIRECTOR OF THE VICTORIA AND ALBERT MUSEUM

EXAMPLES OF ENGLISH POTTERY

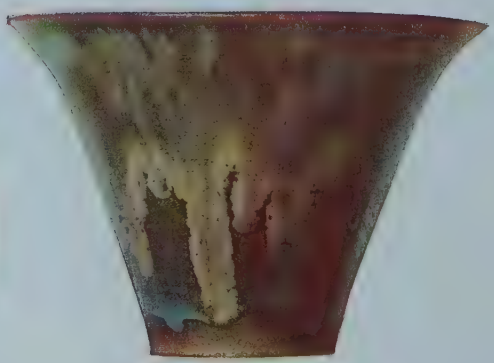
1. Teapot, Staffordshire salt-glazed stoneware. Height 4⅛"
2. Teapot, Wedgwood's lilac jasper ware. Height 6¾"
3. Chestnut basket, Leeds ware. Height 8⅝". W. 9½"

BY COURTESY OF THE DIRECTOR OF THE VICTORIA AND ALBERT MUSEUM

18TH CENTURY GERMAN, AUSTRIAN, FRENCH AND ITALIAN POTTERY

1. Frankenthal figure, after a model by Konrad Link (1732–1802), in the classical manner
2. Sèvres *biscuit* group, after a model by Étienne Maurice Falconet (1716–91)
3. Nymphenburg figure, after a model by Franz Anton Bustelli
4. Vienna teapot, painting in black
5. Doccia cup and saucer
6. Meissen coffee pot, with "German flower" design

POTTERY AND PORCELAIN



BY COURTESY OF (1-7) WIENER WERKSTÄTTE, VIENNA, (8-10) COPR. H. BONNAIRE, FROM THE MUSÉE DES ARTS DECORATIFS, PARIS

MODERN AUSTRIAN AND FRENCH POTTERY

Upper Group: Left to right, Back row: Group by Kitty Rix; Animal (original) by Kitty Rix; Figure by Erna Kopriva; Jar by Josef Hoffmann. Front row: Animal group (original) by Mathilde Flögl; Figure group by Vally Wieselthier; Jar by Josef Hoffmann. All pieces are burnt and afterwards glazed in various colours. *Lower Group:* Left to right, Carriès (*Grès*, about 1890); Auguste Delaherche (*Grès*, 1901); Chaplet (Porcelain *grand feu*, about 1900)

TOP, DELOS CHAPPELL COLLECTION; BOTTOM, WARREN E. COX COLLECTION

CHINESE EARLY POTTERY SCULPTURE

Top: Pottery horse of the T'ang dynasty (A.D. 618–907) decorated with rare blue glaze and touches of red paint on the saddle. It represents the Bactrian horse, a type introduced into China by the Mongols

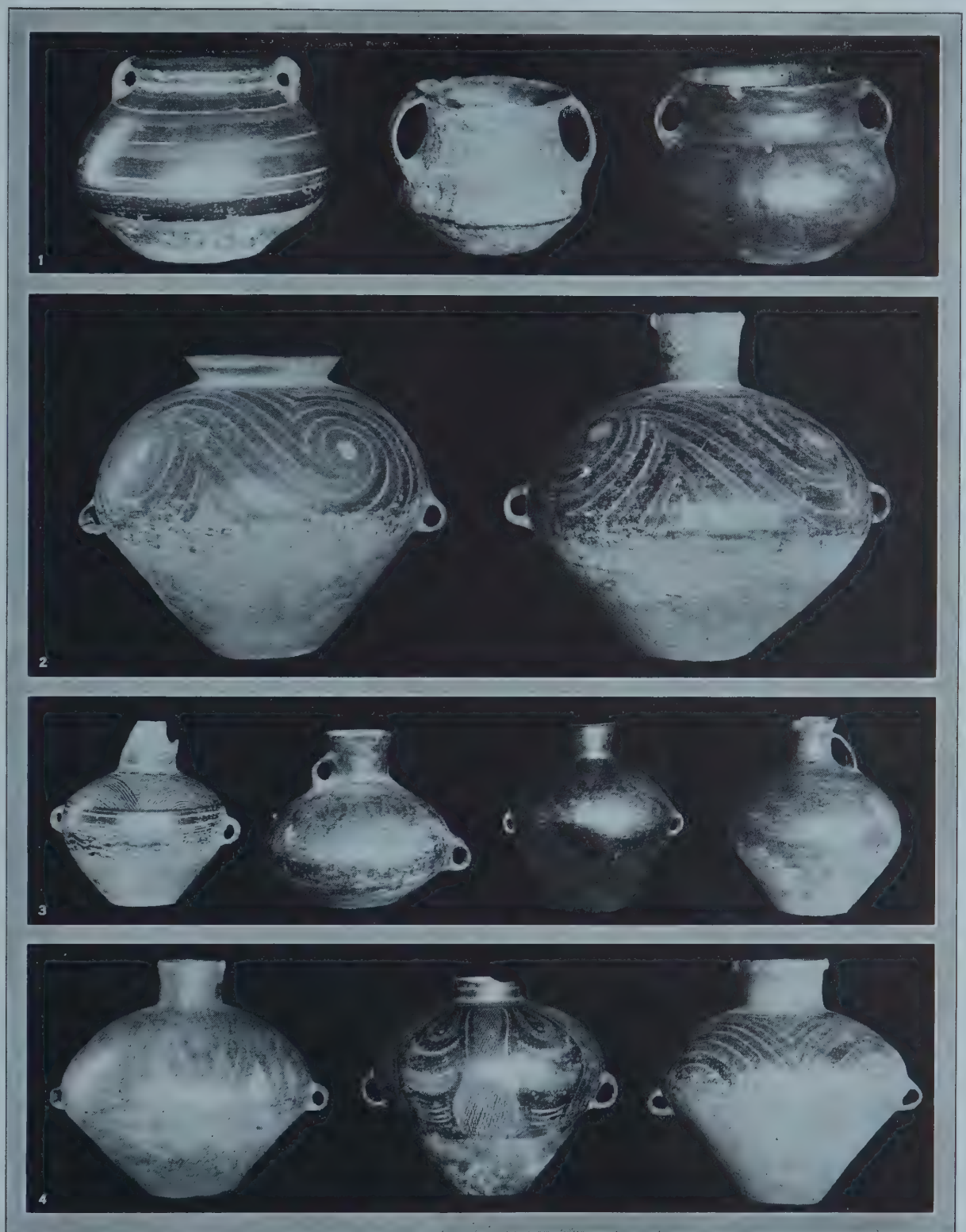
Bottom: Pottery dog with puppy, pre-T'ang, an excellent example of vigorous primitive modelling, showing remnants of red and white paint on dark grey biscuit (unglazed surface)

POTTERY AND PORCELAIN

BY COURTESY OF (1, 9) A. B. GUSTAVSBERGS FABRIKS INTRESSENTER, (3, 4, 5, 6) MANUFACTURE NATIONALÉ DE SEVRES, (8) E. MILNER WHITE; FROM (2, 7, 10) THE JULIUS F. OPPENHEIM COLLECTION

MODERN EUROPEAN POTTERY

1. Grès (kaolinic stoneware), about 1925, by W. Kage
2. Grès, about 1900, by Ernest Chaplet
3. Grès by M. Pihan
4. Vase (*forme Aubert*) underglaze decoration, designed by Guy Loe, made by M. Walter, on silica porcelain
5. "La Peinture" by Chéret, in white biscuit
6. Vase (*forme Rapin*) in faience, designed by M. Patou, made by M. Walter
7. Grès by Emile Lenoble. French
8. Fire Elementals by W. Staite Murray, 1926. Stoneware bowl with ivory glaze and sepia brushwork. English
9. Porcelain, about 1925, by W. Kage
10. Grès by Auguste Delaherche. French



EARLY POTTERY FROM THE PROVINCE OF KANSU, NORTH CHINA

Illustrations of 12 pottery vessels of a very early period (probably 3000 B.C.) discovered in the province of Kansu, North China, by J. G. Andersson, while excavating old sites. The pottery is generally red with black ornaments, clearly of the same family of design as the aeneolithic pottery found on many sites in the Near East

POTTERY AND PORCELAIN

FROM THE GEORGE EUMORFOPOULOS COLLECTION

T'ANG VASE

Covered vase, pottery with coloured glazes. T'ang dynasty (A.D. 618–907). Height 10.15". The blue glaze is exceedingly rare in this period, though some exceptional specimens are found

such wares in quantity to America. Shaw, Pennington and Barnes were the leading potters. Their wares show less individuality than those of Bristol. Notable among them are the punch-bowls made for skippers with polychrome paintings of their vessels; a speciality of Liverpool were the delft tiles with transfer prints in black or red executed by Sadler and Green. Delft was also made at Wincanton, Dublin and Glasgow.

Tin-enamelled earthenware was made by German potters from 1620 onwards. They learnt the art of maiolica in Venice, amongst them Augustin Hirsvogel of Nuremberg; he is believed to have been the maker of the owl shaped jugs made apparently for presentation purposes. The earliest known date on German maiolica is 1526. These early wares were painted in blue, with imitations of Venetian designs, or with figure-subjects derived from contemporary German engravings. Maiolica-painting was applied to the decoration of tilework stoves in the Tyrol, in Austria and especially at Winterthur in Switzerland, where from 1590 to 1740, approximately, a flourishing maiolica industry was carried on by the Pfau family and others. About 1618 the majolica technique was introduced by Lorenz Speckner in the potteries of Kreussen, in Bavaria (of special note are his drug-pots boldly painted with spirals in blue), and about the same time blue-and-white wares, especially narrow-necked pear-shaped jugs, showing Chinese influences, were made at Hamburg. The settlement of two Dutch potters at Hanau in 1661, and the establishment of a factory at Frankfort-on-the-Main in 1666 mark the beginning of a second phase, under Dutch influences, in which the Chinese fashions of the day determined the styles of decoration. Frankfort is notable for large dishes and jars with bold adaptations of late Ming motives in a remarkably clean vivid blue. Faience-factories at Nuremberg, Bayreuth, Ansbach, Dresden, Berlin, Potsdam and elsewhere are witnesses to the spread of these wares in cheap imitation of blue-and-white and five-colour porcelain. Potsdam was the first place to attempt to simulate Chinese "powdered blue" on faience. Tankards with baroque panelled designs or somewhat crude polychrome renderings of Chinese landscapes were made extensively at Erfurt and minor factories in Thuringia. In the 17th century glass-enamellers such as Johann Schaper and Abraham Helmhack of Nuremberg took to decorating in their own homes (as "*Hausmaler*") faience obtained "in the white" from the factories. Their paintings of landscape or scriptural and other figure-subjects in black monochrome (*schwarzlot*) or bright polychrome are often of extraordinary fineness of execution. From their work arose the adoption of overglaze enamel-painting in the potteries themselves. This prepared the way for the third phase, the spread of French influences from Strasbourg and Marseilles, seen in coloured naturalistic floral decoration and French rococo forms for the wares. Disseminators of this technique were Johann Eberhardt, Ludwig Ehrenreich and Johann Tännich; the latter, trained under Hannong at Strasbourg, worked afterwards in several factories, notably at Kiel and Mosbach. From Germany the manufacture of faience spread to Scandinavia; flourishing factories at Copenhagen, Sleswick, Rörstrand near Stockholm and Herreböe in Norway produced chiefly blue-and-white wares showing Dutch and Chinese influences; large tea-trays, sometimes used as table-tops, and punch-bowls in the form of a bishop's mitre are conspicuous amongst their output. At the Marieberg factory, Stockholm, founded in 1758, the enamel-painted faience of Strasbourg was successfully imitated. Hollitsch in Hungary also produced enamel-painted faience of good quality closely resembling that of Strasbourg.

Mediaeval Pottery of North-west Europe.—The mediaeval pottery of western Europe is unpretentious and often crude in technique, but shows at the same time great virility and dignity of form. Glaze had passed entirely out of use in the Dark Ages. On later wares, when present, it is a soft galena glaze, sometimes stained brown with iron or green with copper. Decoration is effected by scratching with a point, or by impression with cut stamps or the application of reliefs such as overlapping scales or strips of clay pressed on with the potter's thumb, or rough floral and heraldic ornaments shaped in moulds; painting with red, brown and white clay pigments is the exception, but clays of various colour are often combined in relief decorations. Vessels such as aquamaniles, in rude human or animal form, and jugs modelled into human features, are not unusual. These characteristics are common to France, Germany and England.

In France the revival of glaze began in the 13th century, when Savignies, in the neighbourhood of Beauvais, began to become an important centre of production, of which in the 15th and 16th centuries the bluish-glazed wares with applied heraldic and floral ornament enjoyed some esteem; from the 14th century La-Chapelle-des-Pots near Saintes, was another important centre. Fine earthenware with inscriptions in Gothic characters and floral designs, made after the Italian manner by the *sgraffito* technique and including Italian shapes such as the *albarello* jar, appear towards 1500, and shortly after polychrome lead-glazed wares began to be made. Ornamental earthenware finials for gables were produced, especially in Normandy, from late mediaeval times onward.

BY COURTESY OF THE YORKSHIRE MUSEUM

MEDIAEVAL ENGLISH JUG

Remains of mediaeval potter's kilns have been found in England at Nottingham, Lincoln and Cheam, and community of characteristics amongst vessels dug up at Oxford indicate local production; the same is true of York, and simple pottery must have been made at many other places. The earliest remaining wares, certain tall slender jugs of light buff earthenware, with a double swell in their profile, are attributed to the 13th century. In the 14th century forms tend to become more squat, glaze and applied or incised decorations appear. Greater refinement of shape is seen in green-glazed jugs of the 15th century, and under the Tudors elaborate moulded heraldic reliefs are found. In Germany the hard-fired semi-vitrified ware known as stoneware was first made, from the 14th century onwards. The earliest specimens are slender jugs, strongly wheel-marked, in a creamy-white body, made at Siegburg near Bonn. Drinking-vessels of great elaboration, often double-walled, the outer wall being pierced with Gothic tracery, were made of a hard brown ware in the 15th century at Dreihausen, Hesse. Floor-tiles form a great part of the output of mediaeval kilns, and were made wherever great churches were being built. Those of France and England have glazed bichromatic inlaid decoration, the German tiles, mostly unglazed, showing stamped or moulded designs. Tilework was used in Germany for architectural details also, and especially for stoves.

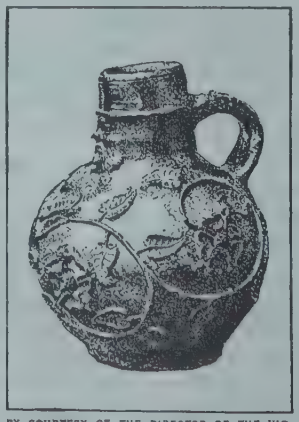
French and German Lead-glazed Earthenware.—With the arrival of the renaissance in France pottery rose in that country to a higher level of general esteem, and two highly specialized experimental developments took place. One of these passed without lasting influence on ceramic history, that of the famous so-called Henri II. ware; the place of its production was for long a mystery but it is now known to have been made at St. Porchaire in Poitou, approximately from 1525 to 1560. It is of a fine whitish clay, with a cream-coloured glaze, and decorated with designs built up from impressions of metal stamps like those of a bookbinder and inlaid in the manner of *niello* with darker clays; in the later examples touches of blue, green and purple pigment are added. The early forms are imitations of metalwork; later, saltcellars, standing cups and ewers were built up like architecture in miniature with applied reliefs and statuettes and inlays imitating tile pavements. Devices of François I. and Henri II. and the crescents of Diane de Poitiers appear on many of the pieces.

Of greater significance was the work of Bernard Palissy (*q.v.*). After years of experiment he made coloured lead glazes, blue, green, purple and brown, of an excellence never attained before. His earlier wares were decorated with casts from the smaller fauna and flora of the district of Saintes. Later he adopted

reliefs of figure subjects or formal designs. He was succeeded by two sons and by several potters who early in the 17th century made wares in his manner, including statuettes after bronze originals, at Avon and Fontainebleau, and at Manerbe (Calvados). Earthenware with a rich dark brown lead glaze. in forms copied from metalwork, was made towards 1600 at Avignon.

Contemporaneously with Palissy various potters in south Germany were making polychrome earthenware of a similar type, but combining a white tin enamel with coloured lead glazes. This technique was employed specially in the production of stove-tiles, which from about 1550 onwards were commonly decorated with figure-subjects of biblical or allegorical reference, reflecting the all-pervading religious pre-occupations of the time, rendered in relief under a renaissance arched recess. Potters known as *Hafner,* who worked in this manner, were settled at Nuremberg (Paul Preuning and others) and also at Salzburg and elsewhere in Austria. Besides stoves they made jugs with applied reliefs (sometimes including figures in the round in a recessed niche) and bright-coloured glazes. An analogous ware, made from about 1550 at Neisse in Silesia, is characterised by designs rendered by means of deeply-incised outlines separating the coloured glazes and enamels. In the 17th century the wares of the *Hafner* in Central Europe fell to the level of peasant pottery, which, however, has often great aesthetic value.

German and Flemish Stoneware.—Artistic stoneware began to be made at Cologne about 1540. It is characterised by the ferruginous brown stain of its salt glaze. Its commonest form is that of a round-bellied jug with a bearded man's mask applied on the front of the narrow neck, a form which under the name *Bartmann* or "greybeard" became common in most stoneware potteries. Small applied medallions resembling the Roman coins frequently dug up in the city and its neighbourhood, and coiled branches with small oak leaves and acorns, are also frequent motives of decoration. About 1566 one of the Cologne workshops was removed to Frechen, where the manufacture especially of greybeards for Rhenish wine, exported in quantity to England and elsewhere, lasted into the 18th century. At Siegburg the mediaeval white stoneware took on a renaissance dress about 1550; the place was famous for its tall slightly-tapering tankards (*Schnellen*) with heraldic and figure reliefs in three adjacent vertical panels, the finest being the work of the Knütgen family. Raeren, near Aix-la-Chapelle, was also a centre of the industry; its wares are deep brown-glazed, and (at a later stage) grey ware with cobalt-blue colouring in places. The characteristic productions are jugs, often of large dimensions, with elaborate mouldings and reliefs which generally take the form of a frieze, either continuous or broken into arcading, round the belly and sometimes also the neck. Jan Emens and Baldem Mennicken were the most gifted of the Raeren potters. Soon after 1600 the potteries of Siegburg (sacked by the Swedes in 1632) and Raeren declined, and many of the potters migrated to the Westerwald district near Coblentz, where at Grenzhausen and Höhr the industry lasted till it was superseded by earthenware of the English type late in the 18th century. The Westerwald stoneware is grey in body, and its relief decorations, in which figure subjects tended to give place to formal floral motives, are picked out with colouring in cobalt blue and occasionally also in manganese purple. Stoneware, mostly inferior imitations of the Rhenish, was made in the 17th and 18th centuries at Bouffoualx and elsewhere in the south Netherlands. Kreussen in Bavaria produced in the 17th century a chocolate-brown stoneware with reliefs (of the Apostles, Electors of the Empire, etc.) painted in the vivid colours of the contemporary enamelled glass. Altenburg in Saxony and Bunzlau in Silesia also made relief-decorated stoneware.



BY COURTESY OF THE DIRECTOR OF THE VICTORIA AND ALBERT MUSEUM

JUG, OF COLOGNE STONEWARE

English Stoneware and Lead-glazed Earthenware.—The importation of German stoneware in the 17th century led to various attempts to imitate it in England. The most conspicuous was that of John Dwight, an Oxford scientist, who set up a pottery at Fulham about 1670 in which he made not only bottles and mugs in stoneware of various colours but also statuettes, modelled by an unknown artist (perhaps the sculptor, Grinling Gibbons), in white or dark brown clay with a thin coating of salt-glaze; these famous works, including busts of Prince Rupert and others and figures of classical deities, are amongst the most remarkable achievements in the history of plastic art. Stoneware of good quality, with a lustrous brown glaze, decorated with stamped, incised and moulded designs, often dated, was made at Nottingham from about 1695 onwards by John Morley and others of that family. Similar ware was made later at Chesterfield and Swinton. Another experimenter in stoneware was Francis Place, who worked about 1685 at York. Dwight had competitors also in the brothers Elers, two Dutch silversmiths who made teapots in a fine red-bodied ware, imitating Chinese boccaro ware, at Bradwell Wood near Newcastle-under-Lyme; their work was of great importance in its revolutionary effect on the output of the North Staffordshire potteries.

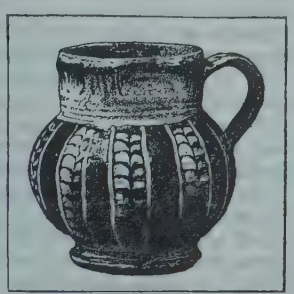
Mediaeval traditions in the production of coarse red earthenware with decoration in white "slip" (that is, clay diluted to a creamy consistency) were followed throughout the 17th and 18th centuries in many small potteries throughout England. Wrotham in Kent produced "tygs" (drinking-vessels with several handles) and posset-pots with neatly applied pads of clay stamped with initials or floral devices, animals and birds. At Bethersden near Ashford the inlay technique of the mediaeval tiles was adopted for pottery. By working with a comb the different coloured clays in a semi-liquid state on the surface of the wares, marbled and feather patterns of real distinction were often produced. No attempt at lightness and refinement of shape was made in the district until the advent of the brothers Elers, which stimulated the local potters to improve their technique. Soon after 1700, in response to the demand newly created by the introduction of tea-drinking, John Astbury was making tea-services, with small stamped reliefs in white on a red ground, and similar wares in a harder fired drab stoneware, from which about 1720, by the introduction of ground flints into the body, the Staffordshire white salt-glaze ware was evolved. A further advance came with the introduction of the process of casting the wares in plaster moulds with relief designs. About 1750 "marbled" wares were made by mixing clays of different colours, also "tortoiseshell" ware with mottled glazes, and tea-services in the form of cauliflowers and pineapples coloured after nature; such wares were produced especially by Thomas Whieldon, who in 1753 took into partnership a young potter destined later to revolutionise the industry. This was Josiah Wedgwood (*q.v.*). His new productions were "black basaltes" ware, an improvement on the black unglazed stoneware of the district, and jasper ware, a fine stoneware stained with blue, green, lilac and other colours and generally decorated with applied cameo reliefs in white. For shapes and decoration he drew upon the recently-published repertories of Greek vases, conforming entirely to the neo-classical taste of the period. He engaged John Flaxman and other sculptors to provide him with designs. An important part of his output were small medallions with portraits or other reliefs, made for mounting in furniture or as jewellery. For decorating his Queen's ware he introduced transfer printing, sending it at first to Liverpool to be printed by Sadler and Green. Wedgwood had many competitors who produced imitations of most of his wares; in Staffordshire, Adams, Neale, Turner and Palmer were the most important. Cream-coloured ware of good quality was made from about 1770 onwards at Leeds and elsewhere in Yorkshire; pierced decoration is its most characteristic feature. Earthenware figures emulating those of the porcelain factories were made at Burslem from about 1765 onwards by Ralph Wood, his son Ralph, and his

grandson Enoch, and by many other Staffordshire potters. The earliest, painted in coloured glazes in the manner of Palissy ware, are mostly from models by a French artist, John Voyez, who generally copied the figures of Cyfflé of Niderviller; they have considerable artistic merit. Lead-glazed earthenware of good quality was also made in the late 18th century at Liverpool, Bristol, Swansea, Newcastle-on-Tyne and Sunderland. A variety made in many places is the so-called silver lustre ware, coated with platinum, in imitation of silver plate. After 1800 the English earthenwares were rapidly degraded. (B. Ra.)

EUROPEAN PORCELAIN TO END OF 18TH CENTURY

From the time of its first appearance in Europe, at the latest in the 15th century, Chinese porcelain was regarded by potters as in the highest degree worthy of imitation. Admiration for its whiteness led to the use of a white enamel or slip-covering on the earthenwares of Italy and other countries, whilst its translucency and vitrified texture misled the potters into supposing that a substance of the nature of common glass entered into its composition. Attempts to imitate it in this way were made in small manufactories at several places—as at the glass-making centre of Venice and elsewhere in Italy, more particularly at Florence, where a factory was started under the patronage of Francesco de' Medici, not later than 1581. Medici porcelain was decorated, as a rule in a soft blue only, with motives drawn from Italian maiolica in combination with Chinese elements imitated from wares of the type made for export to Persia. The manufacture is supposed to have been continued at Pisa; later and not dissimilar porcelain is to be attributed to Candiana near Padua. No settled manufacture was, however, in existence before the latter part of the 17th century. Edme Poterat of Rouen and his son Louis were granted a privilege in 1673, whilst another factory founded in 1677 at St. Cloud near Paris had by the end of the century grown to considerable size. These artificial porcelains, fired at a low temperature and made translucent with the aid of a previously fired glassy mixture or frit, were of the type now known as soft-paste (*pâte tendre*). They remained the characteristic porcelains of France for nearly a hundred years, and somewhat similar compositions were widely used in England, Italy and Spain during the 18th century.

Meanwhile in Germany the insight of Tschirnhausen and Böttger (see below) had perceived that porcelain of Chinese type could be made only with potters' materials, and by experiments with the fusing of clays were discovered, first, a hard red stoneware, and in 1709 true, that is, hard-paste, porcelain, which is essentially a high-fired mixture of the fusible and non-fusible silicates of alumina, called by the Chinese *petuntse* and *kaolin*, and in English china-stone and china-clay. From the manufacture founded at Meissen upon Böttger's discovery sprang others making hard-paste at Vienna and other places in Germany, at Venice, St. Petersburg and elsewhere. Hard-paste began to be made at Sèvres in 1769 but did not entirely displace the *pâte tendre* until the beginning of the 19th century. In England hard-paste was independently rediscovered before 1768, but it was used in a single manufacture only and was superseded towards the end of the 18th century by a universally-adopted hybrid composition in which china-clay was partially replaced by the ashes of calcined bones, an ingredient which had for some time previously been used in a characteristic type of English soft-paste.



STAFFORDSHIRE SLIP WARE: DECORATION MADE WITH WHITE CLAY DILUTED TO CREAMY CONSISTENCY

France.—The rare porcelain attributed to the Poterats of Rouen resembles in decoration the blue-painted faience of the same city, and similar painting in *Louis Quatorze* style is characteristic also of much of the St. Cloud porcelain. Jugs, cups and saucers, pomade-pots and other small objects, as well as flower-pots of considerable size, were the chief productions of St. Cloud: they were as a rule tastefully and substantially potted with a fine feeling for the qualities of a rather yellowish but pleasant-toned material. Plum-sprays amongst other motives in relief were sometimes copied from *blanc de Chine*, for which this French porcelain has often been mistaken. Fluting and scale-pattern were also favourite decorations. Painting in turquoise-blue, red, yellow and green was inspired by Japanese Kakiemon porcelain. Boldly modelled figures inclining to the grotesque were done. St. Cloud (which was founded by Pierre Chicaneau in 1677) came to an end in 1768. Very similar porcelain, as a rule indistinguishable from the St. Cloud, was made in Paris at a factory in the Rue de la Ville-l'Evêque and at Lille.

Porcelain of distinctive character was made at Chantilly, where a factory was founded in 1725 by Louis-Henri of Bourbon, duc de Condé. Here for the first twenty years or so the material was singular in being covered with a glaze made opaque with oxide of tin At its best Chantilly is of a beautiful creamy white colour. "Kakiemon" patterns were freely copied in designs of great charm. The Meissen styles of flower painting (*q.v.*) and the formal "Indian" and naturalistic "German" flowers were adapted in the French taste, as were some of the figure-models of the same factory. In the later Chantilly, coloured grounds were imitated from Sèvres and the tin-glaze was given up; slight decoration in underglaze blue was favoured for cheaper wares. The factory ceased to make soft-paste about the end of the century.

The factory at Mennecy-Villeroy, near Paris, was a continuation of one in the Rue de Charonne in Paris, founded in 1735 by François Barbin, who removed his establishment to Mennecy in 1748 to place it under the patronage of Louis François de Neufville, duc de Villeroy. The earliest of Barbin's productions were in Rouen-St. Cloud style, but later a great variety of small objects was made and enamelled in colours of a singular freshness, amongst which a purplish rose-pink is prominent. At its best, Mennecy porcelain is of unsurpassed quality, mellow in tone and texture and of a warm white colour. Some charming figures were made. The factory was removed in 1773 to Bourg-la-Reine and ceased to make porcelain about 1790.

The beauty of material characteristic of the French soft-pastes was achieved in the highest degree in the productions of the royal factory at Vincennes, which was removed to Sèvres, between Paris and Versailles, in 1756. This factory was established in 1738, under the patronage of Orry de Fulvy, by two workmen named Dubois, who, however, failed to produce porcelain. A workman named Gravant eventually succeeded, in 1745, and a company was formed with a subvention from Louis XV., who finally in 1759 took over the factory, which enjoyed certain exclusive privileges (such as the use of gilding) amounting to a monopoly. The Royal proprietorship ended, with the Revolution, in 1793, but the establishment has continued under State control to the present day. The Vincennes productions at first consisted chiefly of porcelain flowers in imitation of those of Meissen, intended for mounting in ormolu. Meissen styles of painting were copied in this early period, though the forms, largely in rococo style, were designed by the court-goldsmith Duplessis. Jean-Jacques Bachelier supervised the painting and gilding, whilst the chemist Hellot was in charge of the technical side. Painting in panels reserved on a coloured or diapered ground enriched with gilding, soon became the characteristic Sèvres decoration, and the succession of the ground colours is the chief feature in the chronology of the great period of 40 years from 1749 onwards. The dark *gros bleu*, probably imitating Chinese powdered-blue, was introduced in 1749 and abandoned in favour of the brighter *bleu de roi* about 1756. Turquoise-blue (*bleu céleste*), yellow (*jaune jonquille*) and green grounds made their appearance in 1752, 1753 and 1756. The *rose Pompadour* (miscalled in England *rose du Barry*), invented by Chrouet, appeared in 1757 and went out of fashion in seven years. The favourite painting in monochrome (*en camaieu*) was at first generally in crimson, later in blue. Particulars of many of the painters and the marks used by them

may be found in several books of reference. Late in the period, about 1780, an enameller named Cotteau invented the so-called jewelled decoration in which drops of coloured enamel were fused over gilding. Glazed and coloured figures were made in the early years of the factory in rivalry with Meissen, but about 1751 Bachelier introduced *biscuit* or unglazed porcelain as a medium for novel work for which the painter Boucher made designs to be executed by Blondeau and others. The sculptors Falconet and la Rue in the earlier period, and Pajou and Boizot in the later, created many models for execution in Sèvres biscuit. The influence of Boucher is apparent throughout in the painting and modelling, whilst the so-called *Louis Seize* neo-classical style began to replace the rococo soon after the transfer to Sèvres in 1756. For technical skill and perfection, and for delicacy and taste (if not for more vital qualities) Sèvres porcelain is unsurpassed. Soft-paste at all times has the merit of absorbing enamel-colours into its easily-fusible glaze, and this is nowhere more evident than on Sèvres china.

Though soft-paste was the medium of the finest Sèvres productions, hard-paste was made occasionally (from kaolin found after long search at St. Yrieix near Limoges) as early as 1769 and finally superseded the other altogether in 1804, when the newly appointed director Brongniart gave up the manufacture of the more costly material with a view to repairing the financial distress of the factory, caused by the Revolution. Hard-paste became the medium of a style marked by a severe and even pompous classicism, shared also by a number of other factories which had sprung up in the latter part of the 18th century in Paris and the neighbourhood, largely under the patronage of members of the Royal family. Rue Thiroux, La Courtille, Rue de Bondy ("Manufacture d'Angoulême") and Rue Popincourt (Nast's factory) were the chief. Other French factories making hard-paste and equally concerned to imitate Sèvres, were at Lille, Étiolles, La Seynie, Boissette, Limoges and Valenciennes.

Hard-paste of distinctive character was made at the faience factories of Strasbourg and Niderviller and of Joseph Robert at Marseilles. The first-named was closed at the instance of Vincennes in 1753 and Paul Hannong, its proprietor, crossed the frontier to found the Frankenthal factory.

Some soft-paste of fine quality was made also at Sceaux, Orleans, Arras and St. Amand-les-Eaux, whilst at Tournai (which was part of France in the 18th century) soft-paste was used for wares inspired as much by Meissen as by Sèvres.

Germany.—The discovery of hard-paste by Johann Friedrich Böttger was the result of experiments into the vitrification by heat of clays and rocks, conducted by him in association with Ehrenfried Walther Tschirnhausen, with whom he had been concerned in the establishment of a faience factory at Dresden. Like almost all scientists of the time, Böttger believed in the possibility of transmuting base metals into gold, and he was kept, virtually a prisoner, in the service of Augustus the Strong, King of Saxony, who hoped to benefit by the exclusive property of his alchemist's secrets. The first important product of Böttger's labours was a hard red stoneware, comparable with the so-called *buccaro* of Yi-hsing in China. First produced in 1708, it was quickly developed into a medium capable, by cutting and polishing, of expressing much of the baroque taste of the time. Silvering and gilding and a black glaze, invented by Böttger, were sometimes added to it. Imitations were made at Plaue-an-der-Havel, and at Bayreuth. The first glazed white porcelain was produced by Böttger alone in 1709; its regular manufacture did not begin until four years later. The earliest specimens inclined to a smoky tone, and the decoration (for which Irminger, a goldsmith, was responsible) of applied acanthus leaves, masks and rich mouldings, was similar to that of the red ware.

In 1710 the manufacture was removed to the Albrechtsberg at Meissen, but the making of the white porcelain was not fully mastered until 1715. Though without adequate financial support, Böttger succeeded in the four years before his death in 1719 in perfecting his material and in inventing a wide range of enamel colours, including a rare pale-violet lustre-colour almost peculiar to the factory and much used in the subsequent period.

In 1720 the painter Johann Gregor Heroldt was appointed director, and in the next 20 years introduced many new decorations—*chinoiseries* in gold and colours, landscape- and figure-subjects, as well as adaptations of Japanese and Chinese flowers (*indianische Blumen*) and other designs. Purple and red monochromes were used in a novel style. About 1740 Heroldt introduced the naturalistic *deutsche Blumen*. Though underglaze blue was never thoroughly mastered, many new colours were compounded for use as grounds, often richly gilt in *baroque* style, with panelled decoration. Almost every ground colour used elsewhere later on was employed at Meissen under Heroldt.

The appointment as modeller of Johann Joachim Kaendler in 1731 marked the beginning of a period of great development in the plastic decoration. The king had constantly pressed for colossal figures in porcelain which Kaendler's predecessor, Gottlob Kirchner, had failed to produce to his satisfaction. Kaendler succeeded with these so far as the natural unfitness of the medium would allow; and then proceeded to create a succession of new forms for table-ware—plates, tureens, sweetmeat-stands, candelabra, etc.—with modelled ornament, as well as a range of highly individual small figures. It was the court custom to group wax or sugar models on the dinner-tables, and Kaendler, helped by Friedrich Elias Meyer, Johann Friedrich Eberlein and Peter Reinicke, created many porcelain figures for use in the same way. Some subjects were novel in being drawn from contemporary life, embodying a satirical or witty commentary. Kaendler was the first to understand the potentialities of glaze and colour in the make-up of the porcelain figure, which in his hands was never merely monumental sculpture reduced in scale. French rococo was not without influence on Kaendler's style after about 1740, but he remained essentially a baroque sculptor, and continued to work for the factory until his death in 1775.

Meissen remained the premier porcelain factory in Europe until the Seven Years' War, which broke out in 1756, when Frederick the Great virtually sacked the place. Technically excellent work was done under the direction of Count Marcolini (1774–1813), but the former position was never regained. Sèvres fashions were copied, and an artist actually from Sèvres, Michel-Victor Acier, made many characteristic models in the sentimental style, whilst an academic sculptor, Christoph Jüchtzer, made biscuit figures in the classical manner.

Following the fashion set in Saxony, many other German princes sought to establish or patronise china-factories, and by 1760 no fewer than eight had come into existence in this way. Broadly, Meissen styles prevailed until about 1760, when Sèvres fashions and the neo-classical began to predominate. The dependence upon Meissen and Sèvres, however, was very much less than a superficial view would indicate.

In 1718 a runaway Meissen workman, Christoph Konrad Hunger, enabled Claude du Paquier to start a factory at Vienna, which was in 1744 sold to the state. Much of du Paquier's china was decorated by independent enamellers (*Hausmaler*); the factory's own styles were remarkable for the frequent use of a black (*Schwarzlot*) and other monochromes in rich baroque designs. Mayerhofer became director in 1751. Vienna figures of the period about 1760 have a very distinct and airy charm. In 1784 a prosperous period began under the directorship of Konrad von Sorgenthal. A modeller Anton Grassi (who had previously made some lively enamelled figures) began to use biscuit with success, whilst in the last decade of the century was made the porcelain with elaborate miniature pictures in the style of oil paintings, with rich gilding and coloured grounds which was formerly considered the best, and still is the most famous, Vienna work.

At Berlin, a wool manufacturer Wilhelm Kaspar Wegely made porcelain of fine quality, including figures, from 1752 to 1757. A few years later, a financier named Gotzkowsky started a factory which in 1763 was taken over by Frederick the Great. Berlin table-wares tend to favour simple colouring with a special fondness for pink diaper (*Mosäik*) borders. Some good figures were made by Friedrich Elias Meyer (brought from Meissen in the Seven Years' War), his brother, Christoph, and others.

With the help of one Löwenfinck from Meissen, porcelain was

made at a faience-factory at Höchst as early as 1746, under the patronage of the Elector of Mainz, but not in any quantity until 1760. Very lively figures in Meissen rococo styles preceded those made by Johann Peter Melchior (appointed 1767), upon which the factory's fame chiefly rests. Melchior's very personal style shares the same inspiration as the contemporary Sèvres models: he showed an equal mastery in the treatment of the nude, in figures of children, and in portrait busts and plaques. All have the smooth, not glossy surface and soft colouring that are characteristic of Höchst.

The factory at Fürstenberg in Brunswick was established in 1753 by Duke Charles I. with the help of Johann Benckgraff of Höchst. A feature of the early porcelain was the use of elaborate moulded patterns designed to disguise the imperfections of the material. In the last twenty years of the 18th century biscuit was used for a series of portrait medallions in white on blue.

The Bavarian state factory, founded in 1747 at Neudeck, and transferred in 1761 to Nymphenburg, is chiefly famous for its figures, for which Franz Anton Bustelli (*fl.* 1754–63) made models which are perhaps the finest plastic expression of rococo. The same qualities, however, distinguish the delicately painted table-wares and vases of the factory. Bustelli was followed by Auliczek, who in turn gave place in 1797 to the Höchst and Frankenthal modeller J. P. Melchior.

The Frankenthal factory was founded by Paul Hannong of Strasbourg in 1755 under the patronage of the Elector Palatine. The early figures modelled by J. W. Lanz, their subjects chiefly drawn from contemporary life, are amongst the best produced in Germany, whilst the classical models of Konrad Link (made 1762–66) share the largeness of style of the best later work of Kaendler. Other able modellers were J. G. Lück, and Karl Gottlieb Lück, and in 1779 J. P. Melchior came to Frankenthal from Höchst.

Though the porcelain of Ludwigsburg is seldom free from imperfections and generally grey in tone, it was the medium of some excellent figures, for which amongst others the sculptor J. C. W. Beyer (1764–67) made some models combining rococo character with the classical style. The factory was founded in 1756 and taken over in 1758 by Charles Eugene, Duke of Württemberg.

Amongst the minor German factories founded in 1756 by the Prince-Bishop of Fulda has a deserved reputation for high quality both in the modelling of figures and the painting of table-wares. Another factory, started in 1758 at Ansbach and transferred four years later to Bruckberg, closely followed Meissen models. Others of some importance were at Ottweiler in Nassau-Saarbrücken (founded 1763), Cassel in Hesse (founded 1766), Pfalz-Zweibrücken (founded 1767), Baden-Baden and Kelsterbach. In the forest region of Thuringia, many private factories sprang up soon after 1760 making cheap useful wares, as well as imitations (often definitely fraudulent) of the better Meissen china. Very good porcelain, however, was made at Kloster-Veilsdorf, Gotha, Ilmenau and Volkstedt. The rather crude figures of Limbach sometimes have an attractive simplicity. Porcelain was also made at Gera, Gross-Breitenbach and Rauenstein.

In the earlier days of Meissen and Vienna no serious attempt was made to prevent undecorated porcelain from reaching the hands of independent enamellers, though eventually the Meissen factory adopted the plan of cancelling its mark (by a cut in the paste) on all defective pieces sold in the white. Amongst many excellent *Hausmaler* may be mentioned J. Aufenwerth of Augsburg and J. F. Metsch of Bayreuth; Preussler, Ignaz Bottengruber and his pupils H. G. von Bressler and C. F. von Wolfsburg, all of Breslau, who specialized in monochrome painting, chiefly in red and in black, in which last also Jacob Helchis decorated Vienna porcelain in a distinctive manner. The wandering arcanist C. K. Hunger of Meissen, Vienna and Venice, practised a style of painting in thick gold, and about the middle of the century, F. Mayer of Pressnitz worked in several styles, and Canon Busch of Hildesheim made original engravings on porcelain with a diamond-point and coloured them with black.

Switzerland.—In Switzerland, porcelain was made at a factory at Schoren near Zürich, founded in 1763. Though smoky in tone and painted in subdued colours, Zürich china has a very distinct charm and delicacy. Another Swiss factory at Nyon made hard porcelain in French style in the late 18th century.

Belgium and Holland.—Hard-paste factories of no great importance were in existence in the 18th century at Weesp (afterwards transferred to Oude Loosdrecht and Oude Amstel) and The Hague, where, however, Tournai and other porcelain was sometimes decorated and marked. Paris styles were followed at Etterbeek near Brussels.

Denmark and Sweden.—At Copenhagen as at Marieberg (Stockholm) soft-paste was made at first. At the former from about 1760 Louis Fournier from Vincennes made wares in French style until hard-paste began to be made about 1772: in this last a series of Norwegian peasant-figures is noteworthy. At Marieberg, Pierre Berthevin from Mennecy made soft-paste from 1766 to 1769, and a hybrid porcelain was used for the next twenty years.

Russia.—Hard porcelain in German style was made in Russia as early as 1745, but was scarcely an established manufacture until the time of Catherine II. (1762–96). Amongst the little that is distinctive in the Imperial porcelain from the St. Petersburg factory a series of figures of Russian folk-types may be mentioned. Other factories included one conducted by an Englishman, Gardner, at Verbilki and Tver near Moscow.

Italy.—Venice shares with Meissen and Vienna the distinction of a porcelain factory established in the first quarter of the 18th century, in the period of the baroque style. Two brothers, Francesco and Giuseppe Vezzi, founded their factory in 1720 with the aid of the Meissen and Vienna workman Hunger. It ceased to exist soon after the death of the first-named in 1740. The Vezzi porcelain resembles Meissen in its technique of painting, in which iron-red plays a prominent part, but a certain Italian fantasy and irresponsibility distinguishes it. Another Venetian factory seems to have been in operation from 1758 to 1763 under one Hewilcke of Dresden, but little is known of it, and that founded by Geminiano Cozzi in 1765 made most of the porcelain for which Venice is celebrated. Meissen was again much imitated, but the fantastic Italian rococo and a freshness of colour mark much of the Cozzi china, which was a kind of soft-paste. The existing Doccia factory was founded about 1735 by the Marchese Carlo Ginori, with the help of a chemist from Vienna, Karl Wendelin Anreiter. Its earliest work included some distinctive baroque decoration, and later on in the 18th century some highly dramatic groups were made. Factories at Nove, Vinovo near Turin, and Treviso produced more or less original work, whilst at Capo-di-Monte near Naples, a celebrated factory was in operation from 1743 until 1759, when its patron Charles, king of Naples, succeeded to the Spanish throne and the establishment was transferred to Buen Retiro. Typical Capo-di-Monte china is a glassy soft-paste, extravagantly decorated with reliefs, often of figure-subjects; it was much imitated at the Naples factory which was in a sense its successor (1771–1821), and at Doccia and elsewhere in the 19th century.

Spain and Portugal.—The Madrid or Buen Retiro porcelain (1759–1808) was of various quality but included some of the most beautifully modelled and coloured figures ever made in Europe. For these the modeller Giuseppe Gricci was probably responsible. Amongst many styles of painting on vases and table-wares there is much that is of a minute but significant delicacy. The manufacture was revived at La Moncloa from 1817 to 1849. Porcelain was also made at the count of Aranda's faience-factory at Alcora from 1774, and at Vista Alegre in Portugal from 1790.

England.—No certain English porcelain is known of earlier date than the so-called "goat and bee" jugs, made of a soft paste resembling milk-white glass and incised with the name of the Chelsea factory, the date 1745 and a triangle. This "triangle-period" of the Chelsea factory is believed to have ended about 1750, when Nicholas Sprimont apparently displaced Charles Gouyn as manager. Chelsea china of the next eight years is the finest ever made in England. Of a smooth soft-paste capable of giving the most delicate quality to enamel-painting, Chelsea is more often original than any other English porcelain, though its *styles* were largely inspired by Meissen. The figures in particular

are unsurpassed for beauty of modelling. The mark of an anchor, at first in relief, later painted in red, belongs to this period, 1750–58, which ended with the death of the proprietor, Sir Everard Fawkener. In the subsequent period, when Sprimont was proprietor as well as manager, the rococo style (at the time outmoded at Sèvres) survived for ten years in extravagant forms of great interest. Coloured grounds, including a dark "mazarine" blue and a rich broken crimson were inspired by Sèvres, as were figure-subjects, *chinoiseries*, and other styles of painting. Profuse gilding of fine quality, richly brocaded costumes and *bocages* or backgrounds of flowers and foliage were characteristic of the boldly modelled figures, some of which were at one time erroneously attributed to the sculptor Roubiliac. The beautiful Chelsea toys—scent-bottles, seals, bonbonnières and the like—were made from about 1750 onwards and even continued to be done at the factory after its sale in 1770 to William Duesbury, the proprietor of the Derby factory. This had been in existence since 1750 and had made figures and other porcelain in Chelsea styles, but of comparatively little merit. The productions of the period 1770–1784 (when the Chelsea works were closed) are often known as Chelsea-Derby china. The pseudo-classical vases and the figures (including some in biscuit) in the fashionable sentimental Sèvres styles are of less importance than the table-wares which are the chief title to fame of the Derby factory. Later porcelain in the same excellent tradition was painted by artists whose names are known, such as Zachariah Boreman and William Billingsley. Derby declined after the succession to the management of Robert Bloor in 1811, and came to an end in 1848.

The Bow factory was perhaps in existence in 1744, but its productions before 1750 have not been certainly identified. From 1749 (when a distinctive bone-ash paste was adopted) to about 1760 its productions were largely inspired by, and often close copies of Meissen, but rank next to Chelsea for delicacy of modelling, and have the attraction of a beautiful ivory-toned material and clean strong colouring. Later Bow, which was marked with an anchor and a dagger, shows a distinct falling off in these respects. Lowestoft was an offshoot of Bow and largely imitated the productions of other factories, as well as Chinese models, in soft-paste. At Longton Hall in Staffordshire from about 1750 to 1760 William Littler made excellent figures and other wares of a soft porcelain in which are apparent some of the attractive qualities of the more rustic Staffordshire earthenware. A rich blue enamel used as a ground, and a fondness for dishes and vessels in the form of folded leaves were characteristic of Longton Hall. At Lowdin's factory at Bristol, transferred to Worcester in 1752, soapstone (steatite) was used in the paste, and Chinese, Japanese and Meissen motives were employed with an attractive simplicity. Amongst the best Worcester china, made between 1755 and 1765, may be singled out the beautiful armorial mugs. Transfer-printing was adopted very largely as a mode of decoration at Worcester. About 1768, painters from Chelsea were engaged, and a showy style with rich gilding and coloured grounds, including a distinctive "scale-blue," became the fashion of the day. The painting of highly-coloured "exotic birds" was inspired by Chelsea. The later "Flight" and "Flight and Barr" periods of Worcester (which succeeded the so-called Dr. Wall period, 1751–83) show a marked decline in taste. Some Liverpool factories and that at Caughley (the "Salopian" factory), making porcelain from about 1760 to 1772 respectively, may be regarded as offshoots of Worcester. At Plymouth, William Cookworthy had discovered the secret of hard-paste before 1768 (when he took out a patent), and made figures and useful ware employing Chinese, rococo and classical motives. His factory was transferred to Bristol in 1770, and sold in 1773 to Richard Champion, who made much handsome table-ware as well as figures in the classical style. The Plymouth and Bristol china often fails in effect on account of its comparatively hard glaze, into which the colours have not fused. Champion sold his patent in 1782 to a Staffordshire syndicate who continued to make hard-paste in "cottage style" at the New Hall factory until about 1810. Meanwhile a hybrid porcelain made of hard-paste materials in combination with bone-ash had been introduced before the end of the century by Spode and others. The history of this china, like that of a beautiful but unpractical soft-paste made by William Billingsley, at first at Pinxton (1796) and afterwards at Nantgarw and Swansea (1814–17), belongs to the 19th century.

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NINETEENTH CENTURY EUROPEAN POTTERY AND PORCELAIN

The period of the Napoleonic Wars marks a definite break with the older traditions of craftsmanship: European civilization emerged impoverished and found the Industrial Revolution complete. In the more pretentious wares, the Empire style was a pompous and frigid continuation of the neo-classical, and the "revived rococo" of 1820–50 was one of the first of the series of revivals that make up the greater part of the "styles" of the century. Some of the older factories, such as Meissen and Vienna, were even content to reproduce their former inventions, whilst the Great Exhibition of 1851 saw a general attempt to outdo in "exquisiteness" the most costly Sèvres productions of the 18th century. At Sèvres itself work of a high order of technical accomplishment was done under the management of Brongniart, who remained director until his death in 1847. In England the porcelain made by the Spodes and their successors Copeland's, of Stoke-on-Trent, by Minton's of the same place, and at Coalport and Swinton (Rockingham factory) was often very creditable technically but artistically of little account.

Amongst the cheaper types of pottery, the cream-coloured earthenware of Staffordshire commanded at the beginning of the century a world-market which it retained for a long time despite Continental rivals perforce driven to make the so-called *faïence anglaise.* In France the English method of transfer-printed decoration was also adopted, notably at Creil and Montereau, and the development of the deposits of kaolin in the neighbourhood of Limoges led to a rapid growth of the pottery industry in that part of the country. In Italy, some distinguished and fanciful painting was done on cream-ware by the firm of Giustiniani of Naples.

After the Great Exhibition, manufacturers began to be aware of "Art," and pottery inspired by Renaissance models—by maiolica, "Palissy ware" and Limoges enamels—made its appearance. The Paris Exhibition of 1867 introduced a fashion for Japanese naturalism and asymmetry, and some European porcelain was even made (as at Worcester) in imitation of the degraded "export Satsuma" of the period. The collecting of Turkish and Syrian pottery (called at the time "Rhodian" and "Persian") brought a vogue for designs in the same style, from which issued the work of William de Morgan who at a later stage began to make ruby-lustred wares inspired by Italian maiolica; he was also in a sense the representative in pottery of the Morris movement towards handicraft as against industrial machine-work. In France Théodore Deck made similar essays towards the rich colour of the "Damascus" wares; and indeed the most noteworthy pottery of the last forty years of the century was the work of individual artists striving to emulate the great achievements of past times. In particular, Chinese single-coloured and *flambé* glazes inspired the high-fired stonewares and porcelain of Chaplet, Lachenal, Delaherche and Dalpayrat in France, and of Mr. Bernard Moore in England. Mr. William Burton developed some distinctive single-coloured glazes and lustre-pigments for Pilkingtons of Manchester, and similar lustred effects were

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CHINESE MORTUARY POTTERY, HAN DYNASTY (206 B.C. TO A.D. 220)

1. Covered bowl in imitation of bronze form. 2. Ladle. 3. Hill jar decorated in relief with mythological animals, ring handles, and with usual mountain cover surrounded by waves. 4. Barnyard with goats, and man playing piccolo just in front of the little gable. 5. Example of the rare octagonal base type of wine jar with unusual strength. 6. Hill censer modelled in low relief. 7. Pavilion. Height 20¼ inches. 8. Pottery dog vigorously modelled. 9. Well-head. Height 14¾ inches

POTTERY AND PORCELAIN

BY COURTESY OF (5, 6) YAMANAKA AND COMPANY, (4) THE ART INSTITUTE OF CHICAGO; FROM (1, 3) THE GEORGE EUMORFOPOULOS COLLECTION, (2) THE WARREN E. COX COLLECTION

PRE-T'ANG POTTERIES

1. Figure with long robe folded in front, spreading below to form a hollow base; holes for hands. Grey pottery with dressing of white slip and remains of pigment; hair painted black. Ht. 28.5". Six dynasties (A.D. 220–618). 2. Mythological animal resembling prehistoric triceratops, possibly suggested by discoveries of fossils in the Mongolian desert. 3. Figure of a lady, with double peaked cap, holding a lotus, with bird-shaped flower. Hard grey pottery, wash of white slip, pigmentation in red and black. Ht. 30.75". Companion figure, with crown-like head-dress. Ht. 30.75". Northern Wei (A.D. 386–636). 4. House with sliding doors. 5 and 6. Men with Bactrian horse and camel, animals introduced into China by the Mongols

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GROUP OF T'ANG GLAZED POTTERY INCLUDING TWO MORTUARY FIGURES

1. Mortuary figure representing the God of War
2. A "wood-grain" vase made of two coloured intermingled clays and covered with brown glaze
3. Pale green glazed vase showing Greek influence
4. Bulb bowl decorated with cream, yellow and brown glazes
5. Pitcher-like vase, suggested Near Eastern influences, covered with olive green glaze
6. Mortuary figure representing a court dignitary

POTTERY AND PORCELAIN

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POTTERY AND PORCELAIN OF THE SUNG DYNASTY (A.D. 960–1279)

1. Ko ware, pale *café au lait*
2. Northern Celadon with characteristic incised design, olive green
3 and 5. Ting ware, pure white
4. Tu Ting ware with lightly incised design
6. Kuan ware, pale bluish grey
7. Ting ware, pure white

also obtained by Zéolnay of Pecs (Fünfkirchen) in Hungary, and by the Massiers of Golfe Juan in France. The so-called Arts and Crafts movement in England, by drawing attention to the virtues of peasant art, brought a sentimental fashion for simpler lead-glazed decorative wares; at Florence the Montelupo style was revived, whilst more or less exact copies of Hispano-Moresque and later Italian maiolica were made by Cantagalli and also by various other potters.

At the older porcelain factories in the latter part of the century some innovations of importance included the crystalline glazes and subdued green, grey, mauve and blue underglaze colours introduced at the Royal Copenhagen factory, and used for delicately painted vases and figures of Danish peasants and animals, modelled by some able sculptors. Similar work was and is being done by Bing and Gröndahl of the same city, by Heubach of Lichte in Thuringia, and by the Meissen and Rörstrand (Stockholm) factories. A mode of impasto decoration, known as *pâte sur pâte*, in which successive layers of white or coloured slip were applied to a dark ground, was skilfully practised at Sèvres by several artists, notably by Taxile Doat, and was brought to England by M. L. Solon, who worked for Minton's of Stoke-on-Trent. This was perhaps the foremost English factory, where Léon Arnoux was director, and the well-known sculptor, A. Carrier-Belleuse (afterwards at Sèvres) a principal modeller. At Wedgwood's another French artist, Emile Lessore (who had also been at Minton's), developed a delicate and individual manner of painting on cream-coloured earthenware.

Salt-glazed stoneware was revived in national styles by Villeroy and Boch of Mettlach, and by Doulton's of Lambeth, one of whose modellers, R. W. Martin, with his brothers Edwin and Walter, employed the material for grotesque figures and vases which have the merit of attractive colour in their sombre browns and greens, and show, moreover, a true feeling for pottery technique. Equally attractive work in stoneware was done by the French sculptor, Jean Carriès, and by E. Bigot of Paris. In Germany, Max Läuger of Karlsruhe developed an interesting style of decoration modelled in slip under coloured glazes. At the national factories of Berlin and Sèvres, highly accomplished work was done in many styles, with the support of up-to-date scientific knowledge, and the Paris Exhibition of 1900 marked the culmination of what may be called the eclectic period of European ceramic art. (W. B. Ho.)

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MODERN CONTINENTAL

At the end of the 19th century the movement in the domain of the applied arts, with which the names of Ruskin, William Morris, Walter Crane and their fellow-artists are connected, wrought a great change. At first this tendency scrupulously supported the preservation of the methods of handicraft, and strongly opposed manufactured articles. But the same principles with which it originated, and which were indeed identical with those out of which the applied arts had developed in all previous periods, gained ground in the meantime, and the possibility of having artistic articles for practical use came once more within the purview of increasingly larger groups. Gradually also there came into being a desire to bring them within the reach of the many by changing the expensive handmade articles for manufactured goods, but such production was to be led by artists. But in proportion as these ideas became more general, a reaction set in against their excessive rationalistic elements. Consequently, after the beginning of the 20th century taste inclined towards the ornamental, the lively, the richly coloured, though the basic principle that the shape and appearance of the object should be determined by the requirements of material, technique and purpose was not neglected.

Artists, sensitive to shape and colour, could be satisfied with the ceramic production, for working the soft clay on a potter's wheel allows scope for the most individual expression. So far as the continent of Europe was concerned, there were two centres whence the above described development sprang: France and Denmark, or, more strictly speaking Copenhagen. An important development in Holland has exerted little influence outside its own boundaries, and similarly in Germany, while both have undoubtedly profited from French and Danish artists.

MODERN CERAMIC TECHNIQUES

By ceramics is meant all production of which the final result is baked clay in different grades of hardness and purity.

Porcelain.—The composition of European hard porcelain has remained about the same since the 18th century. The ingredients consist of the plastic material, kaolin, and the non-plastic quartz and felspar, which, in the process of working, is used as a diluting element, and in firing, as a cement. The kaolin is principally found in Germany, but always mixed with another soil. It has to be purified by washing. The quartz and felspar must be cleaned. The fragments of iron, in particular, have to be removed, as they are dangerous to the product. By mixing these ingredients the plastic material is obtained. This is made homogeneous by a mechanical method, and it frequently lies unmoved for some months in a special cellar in order to be moulded once again. Then the shaping can begin. It is not usual to shape this fine material by hand, but moulds are used which have been made of plaster after the models fashioned out by artists. The plastic material is pressed into these moulds or poured out in them as a pulp. In the latter case the plaster absorbs so much liquid that a sheath is formed alongside the inside of the mould, out of which the superfluous pulp can be poured. Shaping is followed by drying. After that there is the controlling and the removing of the casting seam and other unevenness. If the object consists of more than one part these are joined together. They are then put in the kiln in sagars or clay boxes so that the heat is more evenly distributed over the piece, and heated to about 950 degrees. The porcelain has then become hard and water-tight but dull. This is therefore followed by glazing. The objects are dipped into a liquid consisting of the same ingredients as the material, but in which felspar and quartz predominate. The objects which have been glazed in this way must then be fired in a heat of 1,370°–1,458°, again in sagars. This heating lasts from 20 to 30 hours, and is followed by a gradual cooling which takes three days. A full kiln never produces everything perfect, the many dangers in the firing—for example all objects shrink about one-sixth of their volume—result in articles being spoiled by exploding, warping, etc.

The porcelain is then ready to be painted with dyes, with which a very lightly fusible glass-powder has been mixed. In order to make these melt together with the glazing and become durable the painted objects are heated in an enamelling-furnace to a heat of 700°–800°. This heat must be reached quickly and the cooling takes place equally rapidly in order to keep the colours bright. The old porcelain bakers painted on the so-called biscuit-ware, *i.e.*, after the first baking and before the glazing, but they could only make use of very few colours at this stage—really only cobalt blue, as most other colours could not endure the heat of the second firing. Modern ceramic technique, however, has considerably extended this process of painting before the glazing. Since Copenhagen's success with it, it has been more generally used and imitated. In these cases the paint is put on the material in a different way, viz., as a liquid with a brush or squirt and then engraved in order to increase the plastic impression of depths. After that the objects are glazed. In a high temperature the colours under the glazing mix with the material, except in the case of cobalt blue, which mixes with the glaze. This process has the technical advantage of making the colours durable, but on the other hand it has a disadvantage in the artistic sense, in that the covering colour reduces the lustre of the porcelain itself by breaking the

rays of light which cause the minute crystals in the porcelain to glitter. This is not the case with painting after glazing. Another way of ornamenting, which, however, has the same artistic disadvantage, is to coat with coloured glaze, which is applied in one colour. By adding metals the glazing can be made what is known as "streaming"; or, by choosing a glazing compound, the coefficient of expansion of which is smaller than that of the material, irregular fissures or artificial crackles can be obtained with the cooling.

Grès.—Grès has many qualities in common with porcelain, but it is grey or ash-coloured and not translucent. The material needs less working in order to purify it. As this clay is already fairly hard after being dried in the open air the first firing can be omitted and the ornamenting begun at once. After being painted the objects can be put in the furnace without sagars and may be baked at a temperature of 1,190°. Throwing salt in the furnace causes an evaporation which brings a glaze on the objects. The colour is then ash-like, or, with a higher temperature, red-brown. The modern ceramist, however, prefers a superior kind of grès, which is more carefully washed, has the colour of ivory, and to which kaolin can be added (French grès kaoliné). The painting takes place as with the ordinary grès before the glazing, after which it is baked and is coated with lead glazing. The grès can also be coated with an engobe-like pulp glaze.

Earthenware.—In England, at the end of the 18th century, this imitation and rival of porcelain was invented. In the course of the 19th century it obtained a prominent place in ceramic production, especially for domestic use. It consists of a plastic clay, freed as much as possible from iron and white-burning, but with which some quartz and felspar are mixed. Sometimes some kaolin also is added. The washing must be done very carefully. The exact shape is obtained by the moulding of the liquefied clay. Both during the first and second firing the objects are placed in sagars. Between the two firings the painting and the glazing take place. The ornamenting can also be done by coating the whole object with a pulp glaze.

Maiolica.—This is the name of a kind of porous pottery which after the drying and firing is coated with a tin glazing, either by immersion or squirting. On this non-transparent coating decoration is painted with dyes consisting of metallic oxides—a work that requires great skill, as retouching is impossible. During the process of baking the colours mix with the glaze. The effect is sometimes improved by coating the colours with a second glaze, this time a transparent lead glaze. So-called lustres can also be obtained by means of metallic reductions.

Pottery.—Pottery is the earliest ceramic production of mankind. For this a slightly calcareous potter's clay is used, which when baked becomes a red or yellow shard that still has to be glazed to render it water-tight. Decoration can be done in different ways—for instance by putting on ornaments of clay in a different colour (*barbotine décor*), or by painting them. The whole object can also be coated with another kind of clay and the décor in the original reproduced by scratching away the outer coating. It can also be engraved (*graffite décor*). In all these cases a transparent lead glaze is applied. By a combination of the different techniques all kinds of variety are possible and usual.

Historical Survey.—Interest in this fine old handicraft was revived in the period beginning with the Great Exhibition in London in 1851. Museums of industrial art were opened, and applied-art schools followed the lead, by the imitation of old models. Imitation led to a revival and improvement of old techniques and this was fostered by chemical science which in these years grew more and more important. People grew tired of imitation, however, and inspiration was sought elsewhere. It was found in the closer acquaintance with Japanese ceramic art at the Paris exhibition in 1867 and more especially in that of 1878. This inspiration took effect in two directions. First, it showed the possibility of another attitude towards nature and the reproduction of nature, and so pointed out a new way to porcelain; a new way to which Denmark was to lead a few years later. Secondly, it demonstrated the splendid ceramic qualities of the old Japanese grès. From this originated the new ceramic art of the French. This is the starting point of the history of modern ceramics.

FRANCE

The revival of French ceramic art was initiated by Ernest Chaplet, who was born at Sèvres in 1835 and whose work became world famous 20 years before Jean Carriès, the sculptor, became a ceramist, under the influence of the exhibition of 1878. Chaplet entered the Sèvres factory in 1848, and at the exhibition of 1855 he produced work of his own. Afterwards he worked at Laurin's at Bourg la Reine, where he reapplied the old barbotine technique. For it he used very white earth mixed with colour-oxides, which he painted on ordinary potter's earth. The success he had with this at the exhibition of 1878 did not last. In 1875 he became manager of the ceramic factory of Haviland in Paris, which factory he took over in 1885, and in 1887 he went to Choisy-le-Roi, where he lived and worked until his death in 1909. His great merit is the application of "flammés"—colour glazes without real figure ornamentation that cover his grès and sometimes his porcelain, copper-red, white, violet and blue in all varieties and combinations. First Japanese grès, and later the monochromatic Chinese porcelains inspired him, but his own work retains an independent quality. His trade mark is the rosary (*chapelet*). By the time that Chaplet reached the high-water mark of his fame Carriès had already achieved success. Jean Carriès was born in 1855. As a sculptor, with strong leanings to the decorative, he sought for picturesque effects. Deeply influenced by the charm of the Japanese work exhibited in 1878, he decided to devote himself to ceramic art, and to use grès as his material. Far from Paris, in St. Amand-en-Puisaye and Montriveau, in the neighbourhood of Nevers, where he found his material, he began to experiment in a furnace of his own, and in the exhibition of 1889 he showed the results which won universal admiration. The Japanese influence is strong, especially in his vases and bowls that are ornamented with streaming glazes. But his work has a character of its own, and he avoids what he considers the too great brightness of the Japanese glazes, and so obtains a better harmony between the colours of the glazes and the clay.

Besides numerous vases and bowls, simple and with no ornamentation other than the glaze, Carriès created a great number of plastic works such as masks, heads, figures of animals, etc., which please not only by their construction, their exquisite colour and beautiful surface, but also by their subtle characterization. His last work was a monumental hall which the Princess de Sccy-Montbeliard had made in her hotel in the Avenue St. Martin. But he did not live to see it completed. He was ill when the work began, and on July 1, 1894, he died. His friend, the architect G. Hoentschel, who made china after the same method as Carriès, gave a large collection of the latter's work to Paris (Musée du Petit Palais). Another disciple was Paul Jeanneny (1861–1920), who took over Carriès' atelier in St. Amand. Neither he nor Hoentschel has done any plastic work. Jeanneny's work is even more closely connected with Japanese ceramics than is the work of the others.

In the meantime Chaplet had started a school, and the most prominent of the artists, who with their master formed the group of "L'Art du Feu," was Auguste Delaherche, who, when Chaplet went to live at Choisy-le-Roi, took over his furnace at Vaugirard in 1887. At first he worked with streaming glazes, and sometimes combined these with designs in relief. But gradually he simplified his methods. In the museum at Sèvres there is an early dish of his with a motif of oak leaves; but his later work is remarkable only for the dull glow of his warm-coloured émails, strong and deep, dark and velvety. Other disciples of Chaplet are: Adrien Dalpayrat, born at Limoges, who collaborated first with Voisin-Delacroix and later with Mlle. Lesbros. His work can be recognized by the deeply coloured blue, blood-red or yellow opaque glazing, reminiscent of oil painting. Technically his workshop was very highly developed; sometimes he made vases several yards high in blue and red spotted grès.

Edmond Lachenal was much more under Japanese influence. For ornamentation, especially in his dull green glazed pots, he used naturalistic branches and flowers or blossoms, brought out in relief, and tinged with white or rose red. By giving his works an acid bath he succeeded in making the surface peculiarly velvety

—*émail velouté*. Albert Dammouse considered the material more, and his work at the Sèvres factory has a character entirely its own. For the decorating of his rather simple forms he used plant motifs, and often those of mosses and seaweeds. In so-called *pâte-décor*, the glaze and the pâte material are applied side by side or one over the other, as in enamel painting. Dammouse avoided bright colours and tried to get dark, deep harmonic tinges. In connection with this the Englishman Taxile Doat might also be mentioned. He worked at the Sèvres factory and produced *pâte-décor* Especially remarkable are his grès articles on the surface of which have been affixed small porcelain insets with heads of animals. Alexandre Bigot, who has carried out designs for Henri van der Velden, and J. C. and M. Cazin (father and son), attained fame with their richly coloured running-glazes. They are inferior, however, to some of the younger artists, who in closer association with Chaplet and Delaherche, raised, with the help of the latter, French grès to a height not reached by the older artists. First among these are Emile Lenoble and Emile Decoeur. Lenoble, Chaplet's son-in-law, not only took over Chaplet's furnaces, but also inherited his preference for grès. But his work is quite different. Except in some of his Japanese-like products with a half coating of brown-black glaze, he specialized in engobes, in which he knew how to produce simple but very strong straight-lined ornaments by erasing. The colours of his engobes are of a blackish brown, grey, deep blue, green, orange-red, and white, and always of a quiet tone that harmonizes with the simplicity of the grey clay material. Decoeur is finer and more complicated with his dim, delicate glazes, occasionally bright, but generally dull, in which colour is more important than with Lenoble. Other ornament is lacking in his work or is reduced to a minimum, such as a few simple lines, a small cufic motif in relief, or a margin of leaves reminiscent of Chinese celadons. His bowls and pots are covered with a soft brown-yellow, a delicate green or blue glaze, usually rather thick and applied in a somewhat streaming manner. For softness of surface, his work equals the very best old Chinese and Japanese wares. Raoul Lachenal, the son of Edmond Lachenal, follows after Decoeur, and sometimes his work is equally good. Henri Simmen does the same, but he often imitates Japanese examples too servilely. Jean Mayodon decorates his work with figures like those on antique and Persian examples; *e.g.*, slender, leaping deer. René Buthaud has another technique—his decoration is of large flat human figures and a strong relief produced by deep incisions.

Of the artists who work in earthenware André Methey must be particularly mentioned. He is the greatest lover of colour and the greatest decorator, an artist who seeks inspiration not in Chinese or Japanese work, but in the rich ceramic production of ancient Persia whose metallic lustres he tries to equal. He is at his best when he builds up his décors from rhythmical repetition of very simple motifs taken from nature. Etienne Avenard follows his example. Félix Massoul uses in his work much heavier colours, his décor is more geometric and not so delicate as Methey's. Finally, the very simple but always fine forms and décors of Jean Besnard are not without merit.

While French ceramic artists were following new paths and bringing French work into world-wide prominence the development of the porcelain factory at Sèvres—the former glory of France—was negligible save in one respect, that of technique. At the Great Exhibition of 1851, Sèvres created a very bad impression. In 1852 Regnault was made director. An improvement resulted, but only in so far as the art director Dieterlé (till 1856) and after him Nicolle tried to make very clever imitations of the 18th century examples, instead of the dull repetition of the old traditions. Under L. Robert who was in charge from 1872 the old post of "directeur des travaux d'art" was reinstituted, and Carrier-Belleuse was appointed to it; new men were engaged, amongst others the young Rodin from 1880–82. But, in spite of these efforts and the experiments of the able and resourceful T. Deck a new ceramic art was not born. After Deck's death in 1891 the factory was reorganized, and in 1896, in anticipation of the Paris Exhibition of 1900, an extensive working scheme was drawn up as the basis for more modern and artistic development.

By a decree of Oct. 1, 1926, greater independence was granted to this factory.

Outside the Sèvres factory the only names worthy of note are those of Taxile Doat who has already been mentioned, and Camille Naudot, who about 1900 did some fine work in porcelain tendre. Haviland, in Limoges, worked at painting-before-glazing and also tried to produce artistic earthenware, but without producing anything special. A group of artists in Glatigny, near Versailles, who called themselves after this place, produced porcelains with streaming glazes reminiscent of grès. Their example was followed by Pillivuyt in Paris. The first to attempt to make artistic stoneware of this kind in France was G. de Feure. In general, however, few good things have been produced. There were several tea and dinner sets at the exhibition of 1925, designed by decorative artists, but they seldom had a cachet of their own. Good work was done by Robert Bonfils, Maurice Dufresne, Suzanne Lalique and, probably the best of all, Marcel Goupy.

GERMANY

In connection with the revival of the German ceramic industry in the 20th century two names may be mentioned here, Th. Schmuz-Baudisz and Max Läuger. Both were attracted to the ceramic industry by knowledge of the so-called peasant pottery, and both learned the industry in its simplest forms from potters in Bavaria or the Black Forest. In this way it was impressed on them that the first thing a ceramist should know is that the shape and decoration of any object must depend very largely on the nature and composition of the material and on the technique of firing.

Max Läuger, who worked at Karlsruhe, decorated his vases and jugs, which were simple in shape and of a deep and even colour, with motifs from nature applied in clay of a different colour. His work resembles the *barbotine décor*. Working for a factory in Kandern he also designed, with the technical expert C. Mayer, architectonically applied earthenware, a great number of tiles, tile-tableaux, and mural coverings. Later, he worked in maiolica for the Majolica Manufaktur at Karlsruhe, and produced articles decorated in strong colours. These have greatly influenced younger artists, such as Ludwig Koenig and Georg Schrimpf, who, however, are inclined to an affected naïveté. Th. Schmuz-Baudisz was a painter at Munich, who after 1896 devoted himself to ceramics. He began to shape his objects himself and decorated them with motifs of flora and fauna which he cut out in the engobes that covered his pots. His decorations are much more strongly stylized than those of Läuger. In 1902 he became director of the Staatliche Porzellan Manufaktur at Berlin. The work of Elisabeth Schmidt-Pecht must also be mentioned; it is simple in decoration and form. In the meantime the porcelain factories took some interest in modern work. The Berlin factory, although strongly dependent on the taste of the court, had already, under Dr. Seger, about 1884, made experiments with copper-oxide glazes, and had even obtained good results in red and blue on the so-called flammés and running-glazes. The plastic articles, however, remained of little importance in spite of some successful products by Franz Metzner. But when Schmuz-Baudisz, who had started making domestic porcelain with simple decorations at the factory of Swaine and Company in Hüttensteinach, moved to the factory at Berlin, the example of Copenhagen was soon followed and painting-before-glazing was applied. Of the artists, Adolf Flad and Max Dürschke must be mentioned. Schmuz-Baudisz, who set himself the task of designing landscapes in colour on large porcelain tiles, attempted a difficult technique which was not always justifiable from an artistic point of view. For many years the plastic work at Berlin could not free itself from the influence of the court. Since that time, however, Hermann Hubatsch has made clever statuettes, and in animal pieces Anton Pachegger (1917) and Edmund Otto have done sensitive work. But a great deal has not been accomplished, and in this respect Berlin is just as unimportant as Meissen for the same period, in that, although technically very clever, it produced nothing really important until 1918.

In 1918 Max Adolf Pfeiffer was made director; he brought new life into the factory and made a great improvement especially

in plastic work, to which some of the younger artists, for instance E. P. Borner, Max Esser and Paul Scheurich have contributed. More important than Meissen and Berlin in modern ceramics has been Nymphenburg in Bavaria. In 1888 Albert Bäuml became director, and he soon attached some young artists to his establishment who, so far as plastic work is concerned, have obtained astonishing results. Jozef Wackerle was especially prominent here. He made beautiful types of peasant pottery, and also humorous groups from 18th century life. He fully mastered the possibilities of porcelain, and made some clever models in maiolica. For some years Wackerle worked at Berlin. Theodor Kärner has done animal pieces which are in the first rank; of his disciples W. Neuhäuser must be mentioned.

Among other important factories may be mentioned the Schwarzburger Werkstätten für Porzellankunst at Unterweissbach, later combined with those at Volkstedt, of which M. A. Pfeiffer was director. He knew how to escape the influence of Copenhagen and sought to produce original work. Jozef Wackerle first worked here and also Ernst Barlach, who with his figures of Russian peasants introduced an entirely new style. Moritz Pfeiffer's table decoration "Hunting scene" also deserves mention. Besides these, good plastic models have been made by Hugo Meisch and by Arthur Storch, while Hans Poelzig has succeeded in making porcelain subservient to modern interior decoration.

Andreas at Leipzig has attempted to make expressionist porcelain pieces, but so far the fine qualities of porcelain have not been adapted to this method of expression. Maiolica offers a better field, and is better adapted to painting. The somewhat affectedly naïve products of L. Koenig and G. Schrimpf have already been mentioned. They work at the Majolica Manufaktur at Karlsruhe, where other younger artists are also engaged. Another and smaller workshop is that of the women ceramists J. Biehler and M. Goossen at Nymphenburg. They have made good reliefs and also free pieces. Two other Munich workers deserve mention, Georg Kemper, who produces miniature pieces, sensitive in form and colour, of *putti* and such like; while Königsbauer attempts a close resemblance to mediaeval forms with his double-surfaced sided jugs of which the outer one is open-worked. Something like this is also found in the maiolica work of Otto Müller who was inspired by Chinese examples, and in the pottery of Kurt Feuerriegel who is more inspired by 16th century models, though both of them, especially the former, produce work with a character of their own. The same can be said of Auguste Papendieck who works independently in the neighbourhood of Bremen, and who, in her monochrome, slightly glazed vases, aims at great simplicity and pure technique.

Finally some important progressive features can be seen in the development of stoneware. The domestic pottery of the firm of Villeroy and Boch, who have factories in various places, is frequently meritorious work. In particular their Dresden factory has obtained good results. J. Kühne and Jean Beck design forms and décors. The Wächtersbacher Steingutfabrik at Schlierbach has had as art directors Chr. Neureuther and, after his death, Ed. Schweitzer. Good plastics have been made by Ernst Riegel.

AUSTRIA

During the 19th century there was no artistic ceramic work to speak of in Austria. The revival dates from the first years of the 20th century. Following an exhibition of simple and brightly coloured ceramics at the Viennese Secession in 1902, Bertold Löffler began his attempts to create something new with ordinary red clay, and was joined soon after by Michael Powolny, the most important person in Austrian ceramics. They established a workshop, the Wiener Keramik, where Powolny's pieces of ordinary clay, fired and brightly glazed, were produced. In 1907 there followed the collaboration with the Wiener Werkstätte, where Josef Hoffmann sought and found new possibilities for the entire industrial art. On the ceramic side he was helped by Kolo Moser (d. 1918). The Werkbund exhibition of 1912 showed not only the *putti* and other figures wreathed and surrounded by flowers, but also the ceramics in black and white under-glaze which has become a special Viennese type and has been imitated endlessly. In the same year the Wiener Keramik collaborated with the Gmundener Keramische Werkstätte, where, under the directorship of Franz and Emile Schleisz, peasant pottery developed into an artistic product. An important side of this industry was practised by Powolny, who made work for interior decoration and tiles for stoves at Gmunden. One of the most prolific designers is Otto Prutscher. Meanwhile, Powolny has a number of disciples at the Wiener Kunstgewerbeschule, who work at the Wiener Werkstätte or in small studios of their own. The Wiener Porzellan Manufaktur has come under the influence of the revival in earthenware. Multi-coloured décors by Franz Zulow cover its products. In general, however, lively and dainty as the whole of Austrian ceramic production may be, it is always in danger of becoming affected.

HOLLAND

In the 19th century the famous ceramic traditions of the early maiolica and Delft ware, with its cream pâte, had completely disappeared. That which had taste imported from elsewhere flourished. In the last quarter of the century there was a revival. J. Thooft in 1876 bought the last remaining Delft factory, De Porceleyne Fles, and, together with Ad. Lecomte, he applied himself to the revival of Dutch artistic pottery. Unfortunately at first this usually consisted of an imitation of old Delft ware,—blue and, later on, coloured; but shortly after, in 1884 at The Hague, the German ceramist W. Von Gudenberg together with the decorative artist Th. Colenbrander, began to make more original work in the Rozenburg factory. Colenbrander's designs were novel and distinguished, his décors sometimes under Japanese influence, but usually completely his own, were in rich colours and usually had phantasies of plant motifs. There are amongst these bright and slightly too brilliantly glazed pieces of faience hints of futuristic compositions, but they are purer from a decorative point of view. Production of this kind at the Rozenburg factory lasted only until 1889 when Colenbrander left it. It was not revived until 1916, when the vogue was for rather heavy, darkly painted faience. A peculiar product was a kind of very thin pseudo-porcelain, in pale colours, shaped and painted in Jugend style. Japanese influence can be recognized in the ornament. The material, as thin as paper, has not been generally used. Meanwhile the De Porceleyne Fles found two clever artists in L. Senf and E. L. F. Bodart who made various experiments, including dark brown earthenware with running glazes and graffite ornaments, and glass-covered faience with painting inspired by Persian colour and décor. Gold and silver lustre ware has also been successful.

A third tendency became apparent, the influence of the English movement in industrial art inspired by Morris and Crane. On the one hand this was seen in the workshops when first at Amstelhoek and later at Distel an attempt was made to produce beautiful domestic ware with simple materials and old ceramic techniques. On the other hand an independent potter, W. C. Brouwer, turned original shapes on a potter's wheel, which, coated with self-made glazes, were simple but elegant objects. Very little plastic work was done, but the sculptor J. Mendes Da Costa made very delicate and typical small groups of Jewish women and animals in lead-glazed grès.

An important figure in the 20th century was C. J. Lanooy, who, as an independent ceramist, imitated the grès flambés of the French, and produced very original and most beautifully coloured pieces. His glazes in which metallic oxides play an important part, are frequently very fortunate discoveries. B. Nienhuys, for a long time a teacher at Hagen, Westphalia, and later at the industrial school at Amsterdam, has a fine feeling for harmonious colouring, and his pots and vases certainly have good and original shapes. Th. Nieuwenhuys and C. Lion Cachet, who as decorative artists occupied themselves with many forms of art, designed faience for the Distel which is deserving of attention. About 1912 Colenbrander, for a short time, made faience covered with dull glazes on which his peculiar décors, principally in blue and brown, were painted. Again, about 1925, in his old age, he designed under-glaze décors on the faience of the Arnhem factory Ram. At the same time the factory of Eskaf produced beautiful domestic ware with white streaming glazes, sometimes decorated in black in a

plastic manner, and also miniature plastics, both by H. Krop. At the factory of Z. Holland at Gouda, domestic ware of good shape and colour was made by C. De Lorm. Brouwer still continues his work and also frequently designs ware for interior decoration. Besides those of Senf and Bodart and their disciples the De Porceleyne Fles produces very good tiles, usually in monochrome, but also in fine colours. Generally speaking, Dutch faience—no porcelain or grès is produced—has a distinct character of its own.

(H. E. VAN GE.)

SCANDINAVIA

Interest in ceramics in Scandinavia was renewed with unusual vigour about the end of the 19th century. This movement, particularly in Denmark, may be attributed to Philip Schou, for some time the manager of the Royal Porcelain works. The white underglaze porcelain, introduced at the end of the 19th century by Arnold Krog, by virtue of its plastic qualities and the depth and perspective it can give to a picture, demands decorations taken from nature and everyday life. The decorations and the more severe ornamental lines which in other ceramic art attain such beauty of perfection, are out of place here; but a sentiment from the air, from the water, from bird, animal or plant life, is reproduced by this underglaze porcelain as by nothing else. This school, which is thus of a national character, is bound up with a great development in sculpture, especially of animals portrayed as they are in life, and of figures, which also reproduce Danish atmospheres, whether taken from life or literature, as for example, Hans Andersen's fairy tales. Another type, the fluted porcelain, which in English-speaking countries is called "the blue Danish pattern," is akin to the underglaze porcelain. The pattern originally came from China, but in course of time has become entirely Danish and has undergone an interesting development. All the models, even the plainest, are the work of the best and most artistic designers and thus the whole set is stamped with a refinement which makes it probably the most popular dinner-service in the world at the present moment.

It is interesting to note that the first great novelty which appeared after underglaze porcelain had made its mark was its direct antithesis—the overglaze. It is interesting also to see how three different artists solved the problem of creating modern overglaze porcelain and its sculpture. Henning, imaginative, artistically great, with a cosmopolitan stimulus, conjures up romance by blending the cultures of East and West in beautiful, rather voluptuous figures; whereas Carl Martin Hansen takes his themes from the almost forgotten national dresses of men, women and children in the various parts of his native country; and A. Malinowski seeks the ideal of his art in white porcelain, only very discreetly and very slightly decorated with a little sepia and gold.

Biscuit, a peculiar material, was at one time, particularly towards the close of the 18th century, admired over the whole world. And then the taste for it died away, probably because the ceramic importance of the material was not sufficiently appreciated. Compare old Sèvres with modern Sèvres, old Wedgwood with modern Wedgwood, and the difference will be seen—and this difference is not due solely to age, for all porcelain changes slightly with age; it is presumably due to the failure to recognize the importance of the question of material. Even when biscuit was introduced in the reproduction of the works of Thorvaldsen, this recognition was lacking, and it was only after more than 20 years of research and experiment that the Royal Porcelain works in Denmark discovered a faintly cream-coloured biscuit—amber against the light—which artists, particularly Malinowski, have endeavoured to mould to their work.

Only three principal colours can be used on underglaze porcelain, blue, green and a reddish tone, and painters have therefore had recourse to overglaze technique where every colour is available, especially gold. However, after numerous experiments with white and grey porcelain, and with stoneware, etc., our artists have found in greyish crackled porcelain a background for painting that inspires them to break new ground. In this porcelain the artist works with vigour, and his decorations possess at the same time a sweetness, a charm, a freshness and a freedom made possible by the employment of this new material, and it is an interesting fact that to attain their effects the artists are not content with crackled porcelain; they want the crackled large or small, square or round, according to the motifs they have created; and the potter knows how to satisfy these demands. A closer collaboration between technique and art scarcely exists.

Of late years unusual interest has been taken in celadon, that remarkable old Chinese porcelain which was discovered through iron having become mixed in the glaze, the effect being that the glaze became green when the porcelain was baked in a certain way. The material is not easy to work with; it requires its own artistic treatment, its own particular shapes, a very special glazing and a special glaze. The material gives opportunity for line effects, architectural effects and reliefs. Often it assumes a jade-like character and is in the closest harmony with the old Chinese culture.

Almost simultaneously with the renaissance of overglaze technique, work was started upon stoneware, a ceramic material that is between porcelain and faience. Porcelain is a siliceous, translucent material; stoneware is a siliceous, opaque material; faience is a porous material. It is interesting to see the strange and unexpected effects which appear gradually as one studies the material more and more. There are the coloured glazes, the fine surface aptly termed *peau de vierge* in France; Jais Nielsen's strong, turquoise-blue glazes, which make one think of the ceramic wonders of Persia and Samarcand, and Kyhn's splendid animals.

From the beginning of the 20th century the Copenhagen Faience works has endeavoured to create a modern style of faience of high artistic merit. It must be remembered that present-day faience is generally different from faiences which delighted the world in mediaeval times. The fine collections of Italian and French and Moorish faience all have tin glazes. These tin glazes are less used in modern faience; for technical reasons potters have turned to a lead glaze or a hydric borate glaze, and attention has principally been devoted to finding an artistic expression for a product of this kind. Here, too, the work is under the glaze where, in contrast to porcelain, one can employ the whole of the colour scale. The designs produced under the leadership of Joachim are gay and lively, rich and glowing, and characteristically Danish. The ground colour resembles that of English faience; but it will not be denied that the artistic treatment of faience in this modern material is much more difficult than tin faience and porcelain, because the glaze is a clearer and lighter glass than the glaze upon porcelain and tin faience, and it has required great trouble to obtain the proper harmony between body, colour and glaze. Joachim has attained great heights with this remarkable faience. The simplicity of decoration and colour, and the definite glaze shades are a constant source of pleasure.

There is in Denmark another very important pottery, Bing and Gröndahl's Porcelain works, which were established in 1853. The same desire which seized Philip Schou to ennoble the material on the basis of Danish artistic culture also animated Harald Bing, who was manager at that time. He engaged the artist, Peitro Krohn, whose finest work is, perhaps, the beautiful heron set, in which he has created something extremely decorative by means of a combination of underglaze and gold. In 1900, at the exhibition in Paris, it entered upon entirely new paths. Later on Bing and Gröndahl attached such artists to their establishment as Kai Nielsen, whose Venus seems to be a symbol of complete harmony between art and material. In 1925, at the exhibition at Paris, Jean Gauguin exhibited a number of works in stoneware with chamotte, in which he proved himself a very gifted artist. By various chemical means, he created peculiar and beautiful works which, in stoneware, may to some extent correspond to biscuit in porcelain. Jean Gauguin's latest works, in faience with tin glaze, demonstrate the fresh and bold imagination of the artist in a sculptural sense.

A beautiful and peculiar art which has arisen in Denmark is the manufacture of earthenware, particularly at Kähler's works at Nastved, where two generations have succeeded in showing novel and interesting results in refined glazed earthenware. The material itself is ordinary clay from the fields near the factory. The work lies in the baking, the painting and the glaze, in which much is done with lustres—the red copper lustres ranking higher, in

some ways, than both Clément Massier's from Golfe de Juan and the Hungarian lustres from Fünfkirchen. The factory has extended the colour range of these lustre glazes and has some grey lustres which, in the hands of the painter Tirslund, have attained the finest effects.

On the island of Bornholm there is a small factory, Hjort's pottery. It is, perhaps, not very well known outside of Denmark, but Hjort's stoneware is of excellent quality, even though the output is limited. He turns out small vases and figures with coloured glazes, with a charm characteristic of his own touch. His glazes excel by their great thickness. And finally, we must not neglect to name the artist, Hansen-Jacobsen, who has dreamed of creating ceramic wonders and so often realized his dreams.

Sweden has worked on different lines. Whereas Denmark has, perhaps, devoted herself principally to the free ceramic art, Sweden has had a background for her ceramic development that might well be envied by other countries. Sweden has always possessed a great folk-art which has produced distinguished work, especially in her textile wares, her wood-carving and her iron, and this art has influenced the great factories, such as Gustafsberg, Rorstrand and Gafle, in their production of characteristic dinner-sets which are in the closest possible harmony with Swedish home-life. There is no doubt that this art is very desirable and peculiar to Sweden, and that the highest ceramic ideal lies in raising the artistic level of such dinner-sets, where the scope of the artist is so much more limited than in free art.

Norway, in the two factories, Porsgrund and Egernsund, the one porcelain and the other faience, has repeatedly been on the verge of creating something national and unique, but has unfortunately abandoned it uncompleted.

The factory, "Arabia," in Finland, has attempted to achieve the same end, but stern necessity has doubtless confined its production within the boundaries set by the economic life of the country. (F. Da.)

ENGLAND

English cream-coloured earthenware still retains much of the market it gained by its excellent quality in the latter part of the 18th century, and modern taste has reverted to slight graceful patterns not at all unlike those on Wedgwood's early "Queen's ware." Some noteworthy private decorators have contributed to this. Alfred and Louise Powell have painted some interesting designs on Wedgwood pottery, and latterly on wares of their own making. Dora Billington's fancifully decorated table-wares should also be mentioned here, amongst the work of a small group of people whose efforts, though slight in themselves, are significant as determining the styles eventually adopted by the manufacturers. Standing apart from all other "useful wares" are the charming and original things designed by John and Truda Adams and made by Carter, Stabler and Adams of Poole: a novel and pleasant half-glossy surface and distinctive clean colour are amongst their good qualities.

The decorative styles first inspired, late in the 19th century, by the Chinese *flambé* and other glazes have been continued by (amongst others) W. Moorcroft of Stoke-on-Trent, Doulton's of Burslem, W. Howson Taylor (Ruskin Pottery, Smethwick), Bernard Moore and Pilkington's of Manchester. The last-named have continued their work in lustre-painting, and in 1928 introduced some very pleasant grey glazes, with effective slight designs in black by Gwladys Rodgers. The later work of the Martin brothers in salt-glazed stoneware showed a praiseworthy advance in simplicity. Doulton's Lambeth stoneware with coloured glazes has been used for statuary by Gilbert Bayes in a manner practised also with success by Mr. and Mrs. Harold Stabler. Perhaps the best and certainly the most promising work in glazed pottery-sculpture has been done by John Skeaping. Interesting figures on a smaller scale, inspired by 18th century china, have been made by Charles Vyse and Gwendolen Parnell.

Amongst the studio-potters, W. Staite Murray's genius has produced much work superficially resembling the early Chinese but highly personal in its low-toned glazes and austerely beautiful forms and decorations. Of equal importance is the fine work in stoneware of Bernard Leach, also inspired by Far Eastern models. The art of Reginald Wells is less simple and direct, stressing colour rather than form, but capable of charming effects. Amongst the other artist-potters, Frances Richards has produced some interesting glazes on stoneware and three other women, Nora Braden, K. Pleydell-Bouverie and Sylvia Fox-Strangways, deserve mention for original work. Mr. Leach and his pupil, Michael Cardew, have revived with success the interesting English slip-ware technique, but high-fired stoneware is likely to be the most fruitful medium in this branch of the potter's art. (W. B. Ho.)

Other Countries.—There has been no important development in ceramics in countries other than those dealt with above. Neither Spain nor Italy has produced more than imitations of the old Spanish-Mauresque and Italian styles; Czechoslovakia and Switzerland are endeavouring to produce a distinctive native pottery, but with no very remarkable results.

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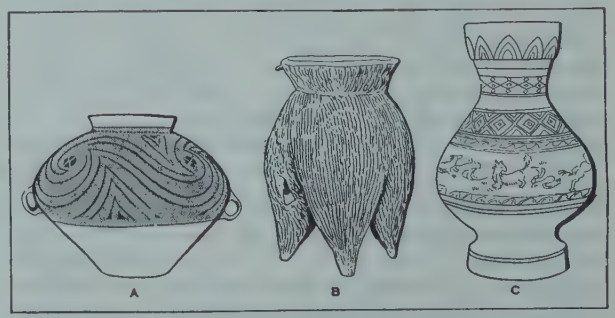
NEAR AND FAR EAST

CHINA

The supreme excellence of Chinese pottery in mediaeval and later times gives an unusual zest to the enquiry into the first phases of Chinese ceramic history; and we welcome the new light recently shed on them by Prof. J. G. Andersson's discoveries in Honan and Kansu which reveal the existence of two distinct kinds of pottery in pre-dynastic times. The Andersson finds have been provisionally divided into six periods; and the earliest and, oddly enough, the most artistic of his pottery can hardly be later in time than 3000 B.C. It consists both of funerary wares and pottery for general use, made by hand (helped perhaps by a slow wheel) of



(A AND B) FROM ANDREWS, "MEMOIRS OF THE GEOLOGICAL SURVEY OF CHINA" (C) BY COURTESY OF THE BRITISH MUSEUM

EARLY CHINESE POTTERY: (A) NEOLITHIC POTTERY FROM KANSU, (B) NEOLITHIC MAT-MARKED POTTERY FROM HONAN, (C) PAINTED POTTERY OF THE 4TH CENTURY B.C.

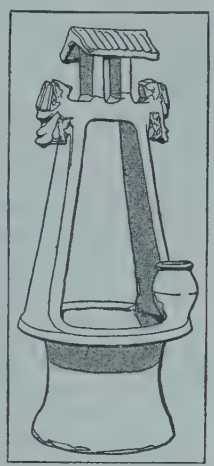
finely levigated, thin and strongly baked buff and red clays, shaped in pleasing, and often quite imposing, forms and decorated with elegant painted designs in red, black, purple and white clays which have been submitted to the fire of the kiln. This painted ware, which is superior in technique to any of the pre-Han pottery of dynastic times so far known, has interesting, if superficial, resemblances to the painted pottery found at Anau, Susa and other western Asiatic sites of late neolithic date.

Alongside this painted ware Andersson found another type of pottery, a coarser, grey earthenware made without the wheel and often impressed on the exterior with markings which suggest that

the wet clay had been wrapped in matting or some coarse textile. This mat-marked pottery evidently had a long life, for it was still made in Chou and Han times.

The next important discovery belongs to the Yin dynasty (1765–1122 B.C.). On the site of the Yin tombs near An-yang in Honan were found pieces of a white pottery and of carved ivory and bone. The pottery, doubtless made of kaolinic earth, has been carved like the ivory and bone with the conventional designs and angular fret patterns which are usually associated with pre-Han bronzes. Complete vessels of this kind of carved white ware must have had a striking appearance, if indeed the fragments ever formed part of pottery vessels and were not, as has been suggested, moulds for the use of the bronze maker.

All the rest of the pre-Han pottery which is known is funeral ware of a rough and not very interesting type, generally following the forms of the more precious bronze vessels for which it was doubtless a substitute. It is frequently mat-marked, and much of it is roughly coloured with unfired pigments.



BY COURTESY OF GEORGE EUMORFOPOULOS, ESQ.

HAN WELL JAR
From the George Eumorfopoulos collection

The Han Dynasty (206 B.C.–A.D. 220).—The Han pottery, though the knowledge of it is still confined to the funeral wares recovered from tombs, shows a considerable advance in ceramic technique. Many of the Han vessels, such as the wine vases, are of elegant form, and they are ornamented with artistic designs in a variety of ways, by painting with unfired pigments, by stamping, by the application of reliefs which have been separately formed in moulds, and by incising.

Glaze is now used, apparently for the first time, a transparent lead glaze of yellowish tone which is coloured green with copper oxide and variegated by the use of liquid clays or slips of different colours. The underlying body of the glazed ware is usually red and this showing through the transparent glaze gives a brown or reddish brown surface when the glaze has not been coloured green by the use of copper.

Probably this lead glaze was introduced from western Asia, where it was in use in late Roman times; for the Chinese were in touch with the Roman empire in the Han dynasty.

Many of the pottery objects recovered from Han tombs are of deep archaeological interest, for they include, besides the household and ritual vessels, models of the buildings, implements, livestock and even human beings which had belonged to the household of the deceased. Further, it is noteworthy that the potters who supplied this funeral furniture evinced much artistic skill in the way in which they conventionalized their models. Thus the granary tower and the wellhead are transformed into picturesque objects, and even the model of the kitchen stove is not devoid of ornamental qualities.

BY COURTESY OF THE BRITISH MUSEUM

PROTOPORCELAIN VASE (3RD OR 4TH CENTURY)

Han to T'ang (A.D. 220–618).—To the interval between Han and T'ang belongs a considerable group of figures and other beings. Animals are in many ways the most attractive of all the Chinese grave goods. Some of them are little later in date than the Han dynasty; but they evidently range over a long period, for whole sets of figurines of this class in the Toronto museum are known to have been found in tombs of the Liang dynasty (A.D. 502–557).

There are, besides, wine jars, vases, incense burners and toilet boxes of the 3rd and 4th centuries which are finely painted in unfired pigments with a style and execution not unworthy of the paintings on silk. The Han lead glaze continued in use, and it is by no means easy to differentiate the glazed pottery of the Han and of the immediately succeeding periods. There are, however, certain flask-shaped bottles with green and brown lead glaze over well-moulded reliefs which, though certainly post-Han, are probably earlier than the T'ang dynasty. Some of them are remarkable for their western types of ornament, such as dancing and piping figures, which would be at home in a Herculaneum frieze, surrounded by vine scrolls. Similar designs are seen on late Hellenistic pottery; and this doubtless was the source from which the Chinese potters drew their inspiration.

There is yet another kind of glazed ware which belongs to this interval, and which is apparently of purely Chinese origin. It is a kaolinic stoneware of hard gray body with a high-fired glaze of greenish brown tint. Specimens of this ware analyzed by H. W. Nichols of Chicago were pronounced to be a kind of proto-porcelain. In other words they are believed to contain the elements of porcelain, though in an unperfected state. M. Nakao held that the glaze of this ware is a wood-ash glaze evolved from the accidental gloss which often forms on pottery fired to a high temperature in a wood-fed furnace, as in the case of the early Korean pottery. It is practically certain that this kaolinic pottery with its glaze of feldspar and wood ashes forms a stage in the evolution of true porcelain which the Chinese had discovered by the T'ang dynasty. Indeed it is highly probable that porcelain was evolved from this material at some period in the interval between Han and T'ang. The colour of the glaze was probably caused by iron impurities in the clay, and this glaze is the beginning of the celadon green glazes which owe their colour to iron.

The T'ang Dynasty (618–907).—In the great T'ang dynasty the Chinese empire reached its widest expansion, and China was without doubt the greatest and most civilized power in the world. It was an age of splendour for all the arts, and the potter's art was in no way behind the rest. Oddly enough, Chinese ceramic literature has little to tell of the T'ang potters. But Chinese ceramic literature is a comparatively modern growth and the secrets of T'ang pottery, laid bare only in modern times, were known in Europe almost as early as in China.

It was in fact largely as a result of the excavations made by European railway engineers that the contents of many T'ang tombs came to light, and what is known of T'ang pottery, as in the case of the earlier wares, is practically limited to the sepulchral wares. Naturally these do not show the T'ang potters in the most favourable light, but they characterize the great progress which had been made in ceramic technique and demonstrate the artistic capabilities of T'ang craftsmen. They make it clear, too, that western influences were active in China in this enlightened age, for traces of late Hellenistic, Sassanian and Persian art are frequently found in the forms and designs of the pottery of this period.

FROM THE GEORGE EUMORFOPOULOS COLLECTION

FLASK OF BUFF STONEWARE WITH BROWN GLAZE; T'ANG PERIOD OR EARLIER

On the T'ang funeral pottery the figures of human beings, birds and animals are modelled in a lively and spirited fashion, especially those of horses and camels, dancing girls and musicians. They are usually of a white or pinkish white clay, soft where lightly fired, but some occasionally are baked to considerable hardness. Some of them are unglazed and tricked out with red, black and blue pigments. Others are covered with a thin, transparent, lead glaze of faint yellowish tint, while on the more elaborate this glaze is coloured with washes, streaks or mottling of green, amber yellow or blue. The flesh parts of the glazed figures are commonly left without glaze, and in this case they are painted with the pigments mentioned above. Besides the figures, vases,

ewers, bowls, cups and dishes of various kinds are found in the tombs; and among them are amphora-shaped jars of strikingly Hellenistic form and ewers of Sassanian type with a bird's head below the lip, a form common again in Persian pottery of a slightly later date.

The glazes used on the figures appear also on these vessels, sometimes in monochrome, more often in mottled colours, but they rarely cover the whole exterior of the vessel, stopping as a rule in a wavy line short of the base. The base of the T'ang vase is usually flat and shaved at the edge.

FROM THE GEORGE EUMORFOPOULOS COLLECTION
DISH OF THE T'ANG DYNASTY

The decoration of T'ang pottery is chiefly effected by moulding in relief, by applying reliefs which have been stamped out separately, by carving the surface or by incising it with a pointed instrument.

Painting with a brush was also used not only for the application of pigments on unglazed wares, but in rare instances for decorating in black under a green glaze.

The T'ang pottery so far discussed shows a considerable advance on its predecessors in the use of coloured lead glazes; but it is also apparent that great strides were now made with the harder, feldspathic glazes which were fired at a much higher temperature. The important excavations on the 9th century site of Samarra on the Tigris (*see* F. Sarre, *Die Keramik von Samarra,*

FROM THE GEORGE EUMORFOPOULOS COLLECTION
LEFT, PORCELAIN EWER WITH WHITE GLAZE, T'ANG PERIOD; RIGHT, WHITE PORCELAIN BOTTLE WITH UNGLAZED BASE, T'ANG PERIOD

1925, and also below under Persian pottery) revealed quite a number of fragments of porcellanous stoneware and even true porcelain of Chinese make. From them we gather that these advanced ceramic products were not only made, but had actually become articles of overseas trade in the T'ang dynasty. They include a semi-porcelain with closely crackled, yellowish white glaze or with green and mottled glazes, or again with the sea-green glaze which we distinguish by the name of celadon; besides pure porcelain with white or ivory glaze. Other high-fired T'ang glazes are a chocolate brown, verging on black, a watery green and a brown splashed with frothy grey.

But the progress of the T'ang potter is not to be measured by improved technique alone. The beauty of the vase-forms which he threw on the wheel places him in the front rank of potters, and his incised and moulded ornaments prove him to have been a true ceramic artist.

In the half century which intervened between the T'ang and Sung dynasties ceramic history records the manufacture of two interesting wares, both of which are still a puzzle to the student. One is the celebrated Ch'ai ware which was reputed to have been "thin as paper, resonant as a musical stone and blue as the sky seen between the clouds after rain." This was an imperial ware made for a few years only in the neighbourhood of K'ai-fêng Fu in Honan; and apparently no complete specimen of it remained above ground even in the 16th century. The traditional description of it suggests a kind of porcelain, and modern opinion holds that it probably belonged to the *ying ch'ing* class of ware which will be described presently. But this is only a theory and, it must be added, a theory which is by no means universally accepted.

The other is the *pi sê* (secret colour) ware made at Yüeh Chou, the modern Shao-hsing Fu in Chekiang, for the princely house of Chien. It is generally agreed that this was a porcelain or semi-porcelain with grey green glaze of the celadon type.

The Sung Dynasty (960–1279).—The Sung dynasty was another Augustan age of Chinese art, and ceramic writers in after years described the Sung porcelains in reverential terms as the classic wares of China. Collectors treasured them with loving care, so that not a few have survived above the ground and we are not dependent entirely on excavated funeral goods for our estimate of the Sung potter's skill. Something too is recorded of the history of the more noted Sung factories, and slender as is the information given it has enabled the modern student to attempt a reasoned, though not yet assured, classification of the principal types, namely the Ju, Kuan, Ko, Ting, Lung-ch'üan, Chün, Chien and Tz'ŭ Chou, with a few subsidiary wares in addition.

The Imperial Ju ware was made at Ju Chou, near K'ai-fêng Fu in Honan, for a brief period at the beginning of the 12th century; but we gather that it belongs to a type of ware which was made at several potteries, *e.g.*, in the districts of T'ang Têng and Yao on the north of the Yellow river—besides at Ju Chou itself. The Ju Chou ware, however, excelled the rest and doubtless the imperial works were manned by picked Ju Chou potters. The Chinese descriptions of the Imperial Ju ware, which was already extremely scarce in the 16th century, leave us in some doubt as to its exact nature, but the most plausible theory is that it was of the *ying ch'ing* type. The term *ying ch'ing,* which means misty blue or green (the colour word *ch'ing* connoting both blue and green), is applied by the Chinese to-day to a soft-looking, bubbly porcelain glaze, white in colour, but with a faint tinge of blue or greenish blue which sometimes develops a definite blue tint.

This tinge of colour has been traced to the presence of a minute quantity of iron in the ware. The *ying ch'ing* porcelain is a relatively low-fired ware and the body has a somewhat granular texture. It varies much in quality, from a coarse material with impure, pearly grey glaze to an exquisite eggshell porcelain thin and translucent and of a deliciously soft and melting quality. The best specimens are skilfully potted and of elegant shape, and the decoration, if any, is carved in low relief, incised with a fine point or pressed out in moulds. It is surmised that some of the finer *ying ch'ing* porcelain may have been made at the Imperial Ju Chou factory, while the rest comes from the numerous private factories working with more or less skill on the same lines. It must however be understood that the identification of this ware with the famous Ju porcelain is not yet proved.

Another type which is still problematical is the Kuan. The name itself leaves room for various interpretations, and the description of it in Chinese works, like most Chinese descriptions, is full of ambiguities. Kuan means imperial, and Kuan ware may be nothing more than imperial ware of whatever kind. But Chinese writers evidently intended the Kuan wares of the Sung dynasty to be distinctive types. They describe first of all a Kuan ware

made in the neighbourhood of the capital, K'ai-fêng Fu, for a short time before 1127, when the Sung court was driven south of the Yangtze by the Kin Tartars. The identification of this northern Kuan is extremely uncertain, though there are reasons for thinking that it had the opalescent, blue-grey type of glaze which was developed to its full on the Chün Chou ware (*see* p. 364). The southern Kuan, made after 1127 in the precincts of the imperial palace at Hang-chou, whither the Sung court had been transferred, so closely resembled the Ko ware that many Chinese writers do not attempt to discriminate between the Ko and Kuan.

FROM THE GEORGE EUMORFOPOULOS COLLECTION

TZ'U CHOU VASE, YUAN DYNASTY
A band of lotus scroll with one of foliage below ornaments this buff grey vase which has a black finish

The Ko ware is described in some detail in Chinese books. It got its name from the elder of two potter brothers Chang who lived in the Lung-ch'üan district in Chekiang in the Southern Sung period, being in fact the ware of the "elder brother" (*ko*). It is evident, however, that the term Ko ware was not confined to any individual's work, but passed into general use as a generic term for a group of wares made over a long period at various places. Like the Hang Chou Kuan, the Sung Ko ware was made of a dark-coloured clay (we are told by one writer that this clay was actually brought from Hang Chou to the Lung-ch'üan district), and for this reason it has a dark brown edge on the unglazed foot-rim and a brown mouth-rim where the glaze is thin enough to allow the body material to show through it. The glaze itself was crackled, sometimes in a wide network of cracks, sometimes in a close pattern of small crackle which was likened to fish roe. The crackle was further emphasized by staining it with red or black. The colours of the Ko glaze are described as *fên ch'ing, hui sê, mi sê,* which may be rendered grey green, ash colour and millet colour or yellowish, and less intelligibly as *tan pai,* which was probably something of the *ying ch'ing* colour.

Well accredited specimens in Western collections have a blackish body material which gives the traditional "brown mouth and iron foot," a thick opaque glaze, lustrous and fat, with crackle stained red or black, and of bluish grey, greenish grey or buff grey colours, which tally well with the Chinese descriptions. We read of Ko ware made in the Yüan and even the early Ming periods; and in later times the term Ko glaze was current for all the grey and buff crackled glazes which figure so largely in the Chinese potter's output.

The crackle affected by the Chinese potter from the Sung dynasty onwards was deliberately sought by definite processes and was eventually got under perfect control, so that large or small crackle could be produced at will. It is unlikely that the earlier processes were very reliable, such as the plunging of the ware while still warm into cold water; but the Chinese eventually discovered that the mixing of a certain kind of stone (apparently pegmatite) with the glaze disturbed the relationship of body and glaze sufficiently to ensure crackle, and they learnt to prepare a crackle glaze which was applied in single, double or treble doses according to the size of the crackle desired.

Lung-ch'üan Celadon.—The Lung-ch'üan district in Chekiang, the home of the original Ko ware, had long been noted for a beautiful ware which is familiar to us under the name of celadon.

It is a porcelain or semi-porcelain of greyish white body with a thick translucent glaze varying from greyish and bluish green to sea-green and grass-green.

The most precious of the Lung-ch'üan celadons has a delicate bluish grey or greenish grey glaze over a finely potted porcelain body which is almost white. Such was the ware reputed to have been made by the younger Chang at the village of Liu-t'ien in the Southern Sung period; and collectors distinguish it by the Japanese name *kinuta,* after a famous vase in shape of a mallet (*kinuta*), which is preserved in a Japanese temple. Nothing could be more subtly beautiful than this soft, misty bluish grey porcelain.

It is not known how far back the industry of Lung-ch'üan dates; but the fragments of celadon found on the 9th century site of Samarra, in Mesopotamia, may well have been made there. On the other hand, we are told that the kilns were transferred to the neighbouring Ch'u-chou at the beginning of the Ming period and that they flourished there till the end of that dynasty. The output must have been large, and it formed from the earliest time an important item of Chinese export trade. Fragments of celadon are found in the ruins of ancient cities all over the Near East, and we know from actual records that celadon was imported into Egypt and carried thence along the Mediterranean coasts as far as Morocco. Fragments too have been found on the coastal sites of East Africa as far south as Zanzibar. India and the East Indies had their share of the trade, and a few pieces of celadon found their way even to western Europe in the middle ages. This justly celebrated ware, the export celadon, was a stoutly built greyish porcelain with a beautiful sea-green glaze of considerable thickness but transparent enough to allow the carved, moulded or incised designs to show through clearly.

FROM THE GEORGE EUMORFOPOULOS COLLECTION

HSÜAN TÊ PORCELAIN STEM-CUP
One of the three crimson red fishes painted on the outside is shown

Besides the carved and incised designs which are of great beauty, reliefs moulded or applied were effectively used. Sometimes these reliefs—floral medallions, fishes and even figure subjects—were left uncovered by the glaze, and in this case they invariably took on a red or reddish brown colour as a result of exposure to the fire in the kiln.

This browning, caused by the presence of iron in the clay, is in all parts of the ware which were unprotected by the glaze, such as the base-rims and the large unglazed ring which is often seen on the bottoms of dishes. It was thought at one time that the presence of this ring was a sign of Ming origin, but it is very doubtful if this rule holds good; and the distinction between Ming, Yüan and Sung celadons, no easy matter, must depend on an appreciation of style and finish. Much help in this delicate task of connoisseurship can be obtained from a study of the other Sung wares, especially the Ting porcelain (*see* below) with its carved and engraved floral designs which closely resemble those used on the celadons. In the hands of the Sung artists these designs had a freshness and spontaneity which is dulled by repetition on the Ming wares. A special type of celadon is variegated by patches of reddish brown derived from iron. This is known as "spotted celadon," the *tobi seiji* of the Japanese.

BY COURTESY OF THE BRITISH MUSEUM

PORCELAIN VASE WITH DRAGONS

Other Celadons.—Though the industry in Chekiang is said to have died out in the 17th century, it was not to be expected that such a beautiful glaze as the sea-green celadon would be allowed to disappear. It was, in fact, made with slight variations in many other pottery centres. At Ching-tê Chên it was used over the white porcelain body for which that place is noted, and the Ching-tê Chên celadons have the ordinary white glaze,

and sometimes a reign mark in blue, on their bases. A celadon glaze was used on the Kwangtung stoneware; and there are many specimens with glaze of celadon type but so different in body from the typical Chekiang ware that one must perforce look to some other centre for their origin. Consulting Chinese books provides little help in this quest. It is true that they speak of a certain T'ung ware, made near K'ai-fêng Fu in Honan, as if it were of the celadon class. But the identification of the T'ung is quite conjectural. In the absence of definite indications, the term "northern celadon" has been adopted for one large and important group. It comprises bowls, small dishes, vases, incense burners, etc., with a dry buff-gray stoneware body and an olive-green celadon glaze. The decoration is carved, incised or moulded, often with much skill and taste; and it closely resembles that of the *ying ch'ing*, or Ju type of porcelain, a fact which suggests a Honan origin for the ware.

This northern origin, however, is not accepted by all authorities. Nakao, for instance, held that it is only a variety of the Chekiang celadons, in spite of the very obvious difference between it and the usual Lung-ch'üan types, and he is probably right in supposing that the art of celadon manufacture was introduced into southern Korea from Chekiang, the most accessible Chinese ceramic centre. And it must be admitted that the resemblance between the so-called northern celadon and the Korean is remarkably close.

A stoneware of celadon type but with a pale and watery glaze was made at Sawankhalok in Siam as early as the 14th century; and in more recent times good celadon wares, scarcely distinguishable from the Lung-ch'üan, have been made in several parts of Japan. It may be added that the imported celadon wares were freely imitated in Persia and Egypt, but these imitations, made with the soft near eastern pottery, are easily recognizable for what they are.

Ting Ware.—Another of the classic Sung types is the ivory-white porcelain made at Ting Chou in southern Chihli. It is a singularly pure and beautiful ware with a flour-white body, slightly translucent, and a glaze of cream or ivory tint, which, however, tends to run in tears or drops on the outside of the bowls and dishes. A peculiarity of the ware, which it shares with the *ying ch'ing*, or Ju type, is that the mouth rims of bowls and dishes are often unglazed while the base is covered with glaze, thus reversing the usual conditions. The rough rims of such vessels are generally concealed by a band of silver or copper. The Ting ware was exquisitely decorated with carved or incised designs, largely floral, and in some cases, especially in the later periods, the more mechanical method of pressing out the designs in moulds was used with good effect.

Besides the fine ivory-white Ting ware there are several varieties. One is known as *t'u* (earthy) Ting because it has a more opaque and earthy-looking body. This kind has a soft, cream-white glaze which is usually covered with faint crackle. Chinese writers also speak of Ting wares with black, red and brown or purple glazes.

The two first are probably glazes of the Honan *temmoku* type; but the purple Ting has so far eluded recognition. There is also mention of a painted Ting ware, which must have resembled the painted stoneware of Tz'ŭ Chou.

The beauty of the white Ting porcelain encouraged, while its simplicity abetted, numerous imitations, some of which are admitted by Chinese writers to be practically indistinguishable from the original. There was, for instance, the southern Ting, made by Ting Chou potters who moved south with the Sung court in 1127 and who seem to have settled in the neighbourhood of Ching-tê Chên. Then there were the famous imitations made by P'êng Chün-pao at Ho Chou in Shansi; and the Ssŭ Chou and Su Chou wares of Anhwei which were bought for Ting ware in the Sung dynasty "by persons who liked a bargain." There are the white wares of Hsüan Chou, and those made at the "white earth village" near Hsiao Hsien in northern Kiangsu. There were the cream-white wares made at Tz'ŭ Chou which were regarded as equal to Ting, and another of a singularly pleasing stoneware with gray or light buff body covered with a wash of white slip and a beautiful waxen white glaze closely crackled and recalling the finer *t'u* Ting wares. Much of this ware has been excavated on the site of the submerged town of Küluhsien (destroyed by flood in 1108), and many of the specimens have been made additionally attractive by pinkish gray stains acquired during burial.

The Ting Chou factories themselves, though their fame died down after the Sung period, continued in operation, and Ting ware is mentioned in court records as late as the middle of the 16th century. About this time too a celebrated potter at Ching-tê Chên, Chou Tan-ch'üan, made himself a name by his wonderful imitations of Sung Ting vessels, and apparently he had many followers who kept up the traditions of his work at Ching-tê Chên long after his death.

Chün Ware.—Yet another celebrated ware was the Chün, which was made at Chün Chou in the K'ai-fêng Fu district of Honan. It was in fact, like the white Ting and the green celadon, one of the key wares of the Sung dynasty. According to Nakao it is the type of ware which would naturally result from the firing of a kaolinic body and feldspathic glaze coloured by copper in the oxidizing flame of the typical round kiln of northern China.

The finer Chün wares have a gray porcellanous body and a thick opalescent glaze full of bubbles and minute pinholes (caused by the bursting of bubbles), and displaying a wonderful variety of colours which are the result in part of the protean changes of copper oxide in an oxidizing flame, in part of a trace of iron which is present in the body material, and in part of the play of light in a highly opalescent glaze. Copper under the conditions prevailing in the Chün Chou kilns was capable of producing a range of colour from blue to blood red, and the Chün glazes display endless combinations of these colours suffusing a basically gray glaze. Thus there are in the extremes an even lavender gray and an almost uniform purplish red, and between these a variety of splashed, streaked and mottled effects of blue, gray, purple and crushed strawberry red. Again the interior of shallow dishes is often frosted over with an opaque, greenish gray; and the Chün glaze is apt to break into irregular V-shaped lines known as earthworm marks, which the Chinese connoisseurs regard as a sign of genuine Sung make. The Chün ware is strong and heavy, and the finer specimens consist mainly of flowerpots and shallow bowls which could serve as stands for the flowerpots or alternatively as bulb bowls. This class of Chün ware has a wash of brown glaze on the base and a ring of "spur" marks formed by the pointed stilts on which the vessel rested in the kiln. It is moreover usually incised with a series number which ranges from one to ten and apparently indicates the size, No. 1 being the largest.

An "outsize" is indicated by addition of the character *ta* which means *large*.

It is known that the Chün factories continued active through the Sung and Yüan dynasties and as late as the 16th century. In fact it is not established when their activity ended. Consequently there is much difficulty in distinguishing the Sung and later Chün wares; and the tendency is to call the finer specimens Sung and the coarser Yüan, too little regard being paid to the fact that much of the ware must be as late as Ming. All that can be said for certain is that the heyday of the Chün factories was in the Sung and that their reputation faded after the Yüan dynasty.

There is a peculiarly beautiful group of wares which belong to the Chün class, and, if fineness is a criterion, also to the Sung period. They have the gray porcellanous body of the numbered Chün wares, and an opalescent glaze which is, however, thinner and smoother than the usual Chün glaze. Its colour is lavender gray, but it is richly suffused, or splashed, with a lovely plum purple and this purple sometimes dominates the whole surface. The glaze flows more or less evenly down to the edge of the base rims, and it usually reappears on a small patch on the base. Sometimes the purple splashes on this ware are symmetrically disposed and even deliberately designed to suggest the forms of fishes, birds, animals or fruits, showing clearly that these patches, though doubtless at first accidental, were later brought under control. To what factory does this group belong? Is it merely a variety of the Chün Chou ware or is it something else? One of

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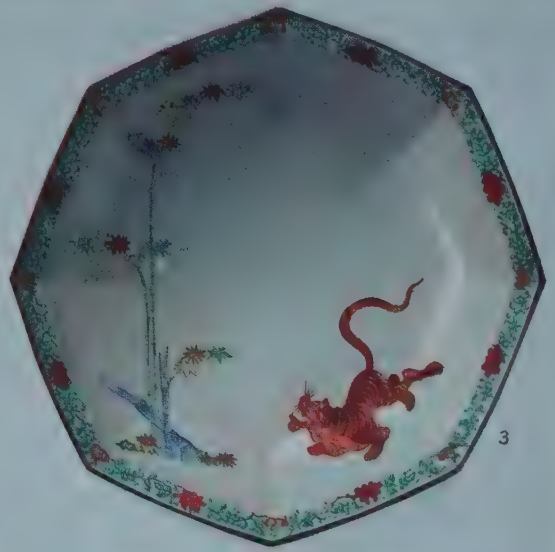

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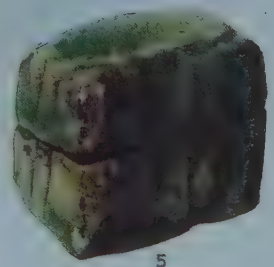

5

FROM THE COLLECTION OF POTTERY AND PORCELAIN PREPARED ESPECIALLY BY THE TOKYO IMPERIAL HOUSEHOLD MUSEUM

JAPANESE POTTERY

1. Square dish designed by Ogata Kenzan, one of the most famous potters of Japan, and painted by his brother, Ogata Korin (*c.* 1657–1716). Given to the Imperial Household Museum by the Dowager Empress Shoken
2. Water jar used in the tea ceremony (*q.v.*), by Nomura Ninsei, one of Japan's greatest ceramists. He worked chiefly at Awata in Kyoto and produced beautiful examples of jewelled faience. 17th century
3. Octagonal bowl by Sakaida Kakiemon, noted for his enamelled porcelain. Height, 13.6 cm. 17th century
4. Teapot used in *Sen-cha*, or steeped tea, by Aoki Mokubei, a celebrated Kiyomizu artist. 17th century
5. Incense case of Iga ware, used in the tea ceremony (*Chan-no-yu*). The incense often consists of small chips of wood or ground-up wood burnt in the charcoal fire which heats the water for making the tea

POTTERY AND PORCELAIN

BY COURTESY OF (2, 6) THE FREER GALLERY OF ART, (5) OTTO FUKUSHIMA; FROM (1, 3, 4, 7, 8-11) THE WARREN E. COX COLLECTION, (12, 13) THE GEORGE EUMORFOPOULOS COLLECTION

VASES OF THE SUNG DYNASTY (960–1279)

1, 4, 13. Show vigorous painted designs in brown on cream slip and glaze
2. "Temmoku" type
3. Pure, perfect vase form covered with cream coloured slip and glaze
5. Low relief decoration with background in brown "Temmoku" glaze
6, 11. Vases decorated with painting in brown and covered with blue glaze
7, 8, 9, 10. Vases decorated with incised slip and glaze
12. Vase decorated with incised brown or "Temmoku" glaze

BY COURTESY OF (11) THE TRUSTEES OF THE BRITISH MUSEUM; FROM (1-10, 12) THE WARREN E. COX COLLECTION

HONAN TEMMOKU POTTERY, SUNG PERIOD (960–1279) HAVING GREYISH WHITE, LIGHT BUFF AND BROWN BODIES

1. Brushholder with brown "oil spot" glaze applied so as to leave an open pattern. 2. Gallipot with incised light brown glaze. 3. Gallipot with grooves from the turning and speckled "tea dust" glaze. 4. Gallipot with even lustrous black glaze. 5. Gallipot jar in dark "tea dust" with silvery design. 6. Jar with beautiful tortoise shell doubly applied glaze and silvery pattern. 7. Graceful bottle with dark lustrous brown glaze and silvery pattern of bird. 8. Jar with thick glaze running black, dark blue and brown. 9. Jar with thick black glaze leaving lower part exposed. Each handle consists of two loops. 10. Pear shaped vase with lustrous black glaze over glaze running thin to a deep blue near base and splashed with iron rust brown patches. 11. Tea bowl with thick "hare's fur" glaze. 12. Exceptional jar of the deepest plum shade glaze, almost black, on dark brown body

POTTERY AND PORCELAIN

FROM THE GEORGE EUMORFOPOULOS COLLECTION

PORCELAIN OF THE SUNG PERIOD

1. Vase, Ju type, Sung period (A.D. 960–1279) or Yüan period (1280–1368). Height 7½″
2. Ewer, Ju type, Sung or Yüan period. Diameter 5¾″
3. Bulb-bowl, Lung-ch'üan celadon, Sung period. Diameter 11¼″

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FROM THE GEORGE EUMORFOPOULOS COLLECTION

MING THREE-COLOUR ENAMEL WARE

1. Incense bowl with low relief decoration. Height 7″
2. Bottle-shaped vase with usual ridges on outlines of design to keep colours from running in firing. Height 10.75″
3. Vase from bronze form. Height 13.7″

POTTERY AND PORCELAIN

BY COURTESY OF (1, 5, 9, 10) THE METROPOLITAN MUSEUM OF ART, NEW YORK, (3, 6, 8) THE MUSEUM OF FINE ARTS, BOSTON, (7) JOHN PLATT; FROM (2, 4) THE WARREN E. COX COLLECTION

KOREAN POTTERY

1. Wine pot and cover of gray porcellanous clay, green celadon glaze, Koraï period (918–1392 A.D.). Height 8½". 2. Mishima ware. 3. Vase, dragon design, Koraï period. 4. Rare saki bottle with reticulated superstructure. 5. Vase dark brown painted design on gray clay, greenish glaze. Height 10½". 6. Jar, lotus design, Koraï period. 7. Plaque, celadon with black and white inlay. 8. Vase, Koraï period. 9. Winepot with spout and handle, buff clay, coffee brown glaze of *temmoku* type, probably Korean, Koraï period. Height 7". 10. Box, inlaid design, Koraï period. Height 3"

BY COURTESY OF (1, 3) THE FREER GALLERY OF ART, (4, 5, 6, 11) THE MUSEUM OF FINE ARTS, BOSTON, (2, 7, 8, 9, 10) THE TRUSTEES OF THE BRITISH MUSEUM

JAPANESE POTTERY

1. Jar, Hagi, Nagato province, 18th century
2. Jar, Kutani, Kaga province, 17th century
3. Jar, Karatsu, Hizen province
4. Tea bowl, by Goroshichi, Hizen province, *c.* 1530
5. Wine bottle for offerings, Imbe, Bizen province, *c.* 1780
6. Bowl, by Ninsei, Yamashiro province, *c.* 1650
7. Teajar, Seto, Owari province
8. Incense box, Raku
9. Bottle, Karatsu, Hizen province, 17th century
10. Dish, Kakiemon, Hizen province, 18th century
11. Jar for cake, Tada, Suo province, *c.* 1770

POTTERY AND PORCELAIN

CENTRE VASE—WARREN E. COX COLLECTION; OTHERS—THE METROPOLITAN MUSEUM OF ART, NEW YORK

CHINESE POTTERY AND PORCELAIN, MING DYNASTY (1368–1644)

Upper left: Black rectangular vase bearing Wan Li mark (1573–1619) decorated with enamels. *Upper right:* three-colour vase and bowl with aubergine ground; 16th–17th century. *Centre:* Large deep peach-bloom glazed vase decorated with enamels and bearing Hsüan Tê mark (1426–35). *Lower left:* Three-colour jar and cover with turquoise ground; 15th century. *Lower right:* Five-colour jar and cover; 16th century

FROM THE GEORGE EUMORFOPOULOS COLLECTION

CHINESE VASE

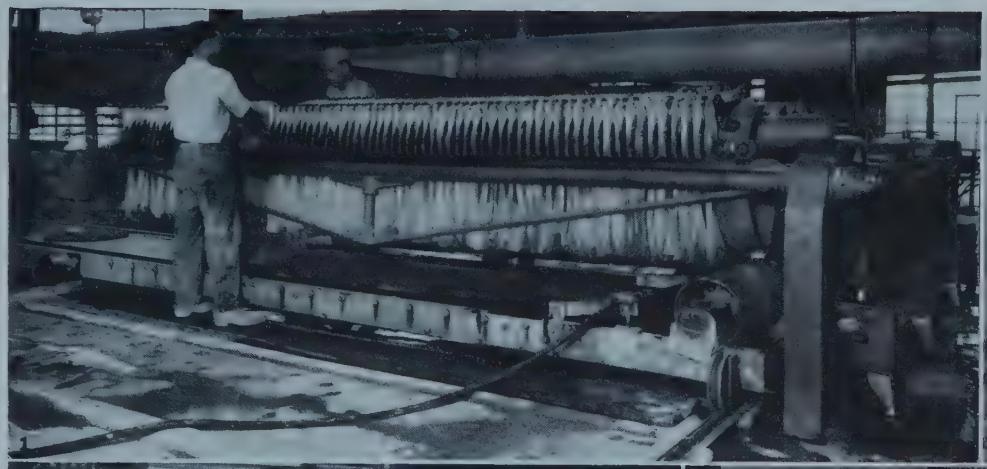
Lang Yao *sang-de-boeuf* vase of the K'ang Hsi period (1662–1722). Height 17½ Inches

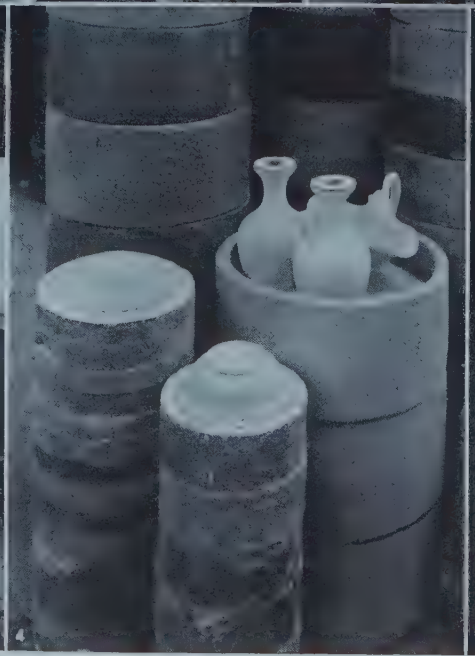
POTTERY AND PORCELAIN

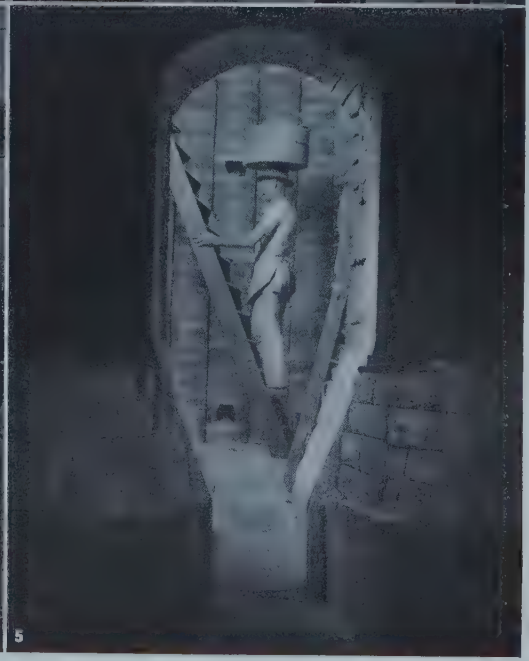
BY COURTESY OF (1) THE HALLIDAY HISTORIC PHOTOGRAPH CO., (2) LENOX, INC., (3) THE NEW YORK HISTORICAL SOCIETY, (4) SEBRING POTTERY COMPANY, (5) AMERICAN LIMOGES CHINA COMPANY

EARLY AMERICAN POTTERY AND MODERN U.S. INDUSTRIAL WARE

1. Salt glaze saltcellar, an example of U.S. colonial pottery from the Mary H. Northend collection
2. Service plate of fine china, designed by Frank G. Holmes
3. Stoneware pottery churn made about 1800 in New York city by Clarkson Crolius, Sr. (1773–1843)
4. "Metropolitan" shape designed by Belle Caldwell, New York city
5. "Manhattan" shape designed by Viktor Schreckengost







BY COURTESY OF (1) WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, (2-5) LENOX, INC.

INITIAL STAGES IN THE MANUFACTURE OF PORCELAIN

1. A filter press preparing the clay
2. The first step in the manufacture of a vase—making the model in plaster or clay
3. A mould is made from the model, then the piece is cast from "slip"—a mixture of ground clay and water poured into the revolving mould
4. After the ware is removed from the mould, dried and cleaned, it is placed in rough clay "saggars" and given its first firing, which hardens and transforms it from slip into porcelain. In this "biscuit fire" the ware shrinks one-sixth in size
5. "Placing" a periodic kiln for the first fire

POTTERY AND PORCELAIN

BY COURTESY OF THE METROPOLITAN MUSEUM OF ART, NEW YORK

CHINESE PORCELAINS OF THE K'ANG HSI (1662–1722) AND CH'IEN LUNG (1736–95) PERIODS

Top Row: Peach-bloom chrysanthemum vase marked Ta Ch'ang K'ang Hsi Nein Chih, and rouge cup. *Clair-de-lune* Amphora. Mirror black Amphora, later period. Blue and White Hawthorn Ginger Jar. Apple Green Galley pot. Celadon Chrysanthemum Vase. Coral red enamel vase of the later period. Second Row: Temple Jars of the so-called *Famille Verte* type painted with enamels, the two at the left being called *Famille Jaune*, and *Famille Noire* because of their back-ground colouration. Bottom Row: Powder blue Temple Jar with reserved medallions in enamel decoration. *Famille Noire* Temple Jar. *Famille Rose* Temple Jar of later period with enamel decorations

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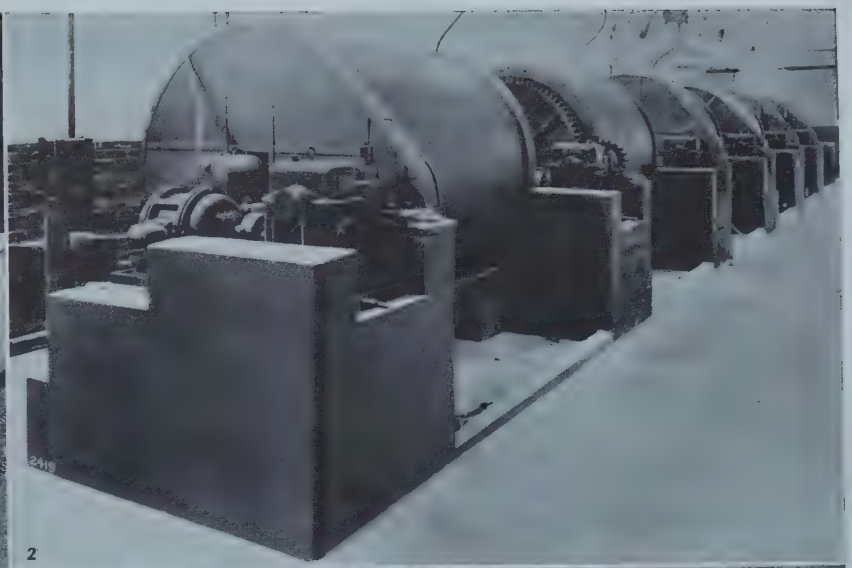
BY COURTESY OF THE TRUSTEES OF THE BRITISH MUSEUM

PERSIAN POTTERY

1. Jug from Sultanabad, 13th century, decorated with metallic lustre and turquoise glaze. Height 7½"
2. Mihrab tile, 13th century, modelled in low relief and decorated with glaze and lustre. Length 12"
3. Dish, Rakka or Rhages, 12th century, incised and decorated with glaze. Diameter 16¾"
4. Star tile, 13th century. Length 8"

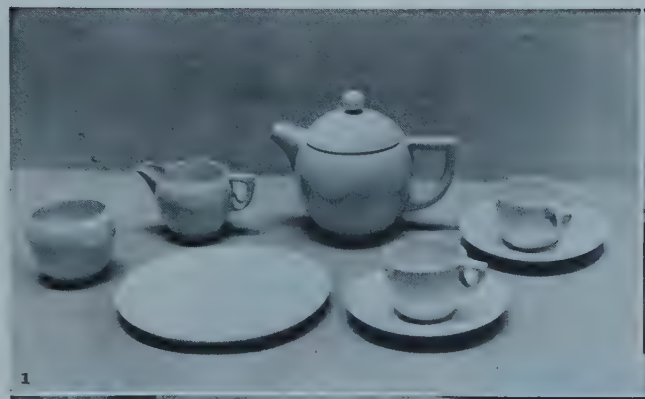
POTTERY AND PORCELAIN

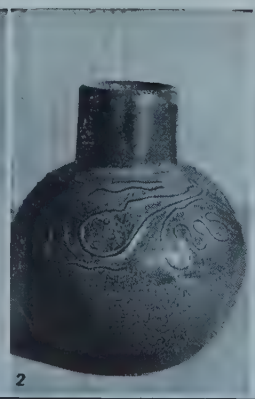


BY COURTESY OF (1, 2) CERAMIC INDUSTRY, (3-5) LENOX, INC.

LATER STEPS IN PORCELAIN MANUFACTURE

1. Car stacked with ware ready to enter a continuous or tunnel kiln. This type of kiln is used in large factories
2. Ball mills which grind the glazes
3. After the first firing, the ware is dipped in the glazing mixture. It is then returned to a kiln, where heat melts the glaze and forms a hard, transparent coating
4. Decorating chinaware with raised gold, applied by brush
5. Printing designs by transfer on china. After decoration, the ware is fired again before undergoing final inspection





BY COURTESY OF (1-3, 5) MYRTLE MERITT FRENCH, (4) WPA FEDERAL ART PROJECT, ILLINOIS; PHOTOGRAPHS, (2) GOODNOW, (6) HAVEMAN, CHICAGO

WARE MADE BY CRAFTSMEN OR DESIGNERS USING THE TOOLS AND METHODS OF INDUSTRY

1. Tea set designed and made by Ramsey Wieland
2. Pottery vase made by Jane Curtis, using the casting method
3. Plate and bowl made by Elizabeth Simmons on jigger machine and decorated with coloured slip
4. "Kangaroo," by Mario Ubaldi; ceramic bisque with slip decoration
5. Student making a plate on a jigger machine at the School of the Art Institute of Chicago
6. Bowls and vases by Myrtle Meritt French

POTTERY AND PORCELAIN

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BY COURTESY OF THE TRUSTEES OF THE BRITISH MUSEUM

PERSIAN DISHES

1. Rhages dish, decorated in gold and red on cobalt blue ground. Diameter 14″. 13th century
2. Rakka dish, showing strong virile design in black on turquoise and gold iridescence caused by time. Diameter 10″. 11th century
3. Rhages dish, incised and glazed. Diameter 15″. 12th century
4. Sultanabad dish, incised and glazed. Diameter 10¾″. 13th century

14TH CENTURY SYRIAN VASE

Syrian vase with typical tapering neck, made of light buff pottery covered with a deep blue glaze and then decorated and refired with metallic lustre. Now in the Victoria and Albert Museum

POTTERY AND PORCELAIN

BY COURTESY OF (1, 2, 3, 7, 8) MYRTLE MERITT FRENCH, (4, 11) NATIONAL CERAMIC EXHIBITION, SYRACUSE MUSEUM OF FINE ARTS, (5) AMERICAN CERAMIC SOCIETY, (6) ARTHUR BAGGS, (9, 10) THE SYRACUSE MUSEUM OF FINE ARTS; PHOTOGRAPHS, (2) WINGATE, (4, 6, 11) WILLIAM H. ALLEN, (8) FRED G. KORTH

WARE THROWN ON POTTER'S WHEEL OR MODELLED BY AMERICAN CRAFTSMEN

1. Pottery by Peggy Beck. The plate was made on the jigger machine; other pieces were thrown on the potter's wheel
2. Crackle-glazed stoneware jar by Marion L. Fosdick
3. Charles Fergus Binns (1857–1934) throwing at the potter's wheel
4. Group of bowls by Glen Lukens
5. Stoneware vase and bowl by Charles F. Binns
6. Salt-glaze jar by Arthur Baggs
7. Vase by Ramsey Wieland
8. Turquoise-glazed ceramic sculpture modelled by Miguel Juarez
9. Adelaide Alsop Robineau (1865–1929) in her workshop at Syracuse, New York
10. Scarab vase by Adelaide Alsop Robineau—white porcelain with excised carving
11. Vases by Edgar Littlefield

the descriptions given of the Northern Kuan ware suggests that it may belong to that obscure category; and some collectors distinguish it as Chün ware of Kuan type.

It is evident that many kilns were at work on the Chün type of ware, and probably in other districts besides Chün Chou, but we have little or no information on this point. We do, however, know that the Chün wares had many imitators. Good copies were made at Ching-tê Chên, probably as early as the Ming dynasty, certainly in the Yung Chêng period of the Ch'ing dynasty (1723–35); but there is little difficulty in distinguishing these later copies which have a white porcelain body and sometimes even a reign-mark. Other imitations made elsewhere can also be detected by variations of the body material and peculiarities of the glaze. Such are the Fatshan Chün ware made at the famous stoneware factories at Shekwan near Fatshan, in Kwangtung (*q.v.*), in Ming and later times; and the Yi-hsing Chüns which were made at Yi-hsing near the Great Lake in Kiangsu, the home of the red stoneware tea-pots. The Yi-hsing imitations have a buff or red stoneware body and a thick opalescent glaze of lavender turquoise colour with or without obviously artificial splashes of purple and crimson. While easily distinguished from the real Chün wares, they are often mistaken for another type which remains to be considered. This is the "soft Chün" (also called *ma chün* by Chinese traders), an attractive ware with light buff body and a beautiful, opaque turquoise or lavender blue glaze closely crackled and suffused here and there with purple or crimson splashes. Where it was made and when are by no means certain; but the shapes of the ware suggest in some cases the Sung and in others the Ming period, and the glaze is of the northern type. A degenerate descendant of this soft Chün is still made at Yü Chou which is the modern name of Chün Chou, and probably this was the original home of the ware.

Chien Wares.—Another large and widely distributed group of stoneware is commonly called, for want of a better general term, by the Japanese name *temmoku*. This name was first given to the black tea bowls for which Chien-an and afterwards Chien-yang, in Fukien, were noted in the Sung dynasty and even earlier. They are made of a blackish stoneware with a thick treacly glaze of purplish black shot with brown lines like hare's fur or mottled with brown like the breast feathers of a partridge. Their glaze stops in a thick irregular welt short of the base outside and forms in a deep pool on the bottom inside. The "hare's-fur or partridge" cups were commonly preferred for use in the tea-testing competitions, as their thick structure made the cup cool to handle and their dark glaze showed up the least trace of the green tea dust. In Japan they have always been fashionable in the tea ceremonies. The Chien glaze owes its colour to iron, which under varying conditions produces a reddish brown as well as a black colour. Indeed the brown and black seem to be always struggling for the mastery in the Chien glaze. Sometimes the brown completely dominates the black: sometimes it only emerges in streaks and spots, and sometimes again these spots are crystalline and have a silvery sheen.

The black ferruginous glaze is by no means confined to the Fukien factories. It was, and still is, made in many parts of China, chiefly in the north; and one of the northern wares which has this black and brown glaze over a whitish stoneware body is known to collectors as Honan *temmoku*. The northern black glazes are often of a peculiarly rich and luscious quality, and sometimes they are boldly flecked with lustrous brown and even painted with sketchy designs of flowers and birds in the same brown. On rare specimens the glaze is strewn more or less regularly with silvery crystals, the "oil spots" so greatly prized by the Japanese; while on others it comes out a uniform reddish brown, the *kaki temmoku* of the Japanese. Another ware which is commonly grouped with the *temmoku* is that believed to have been found on the site of the old Sung potteries at Yung-ho Chên near Ch'i-an Fu, in Kiangsi. In this case the body is a buff stoneware and the glaze is a rather thin blackish brown which flows evenly to the base and is often mottled with golden brown in tortoise-shell fashion or streaked and dappled with frothy grey. A further feature is painted ornament—prunus blossoms and sprays, birds, butterflies, inscribed medallions and symmetrical designs—in dull golden brown in the black or dappled glaze.

Tz'u Chou.—The last important group of Sung wares takes its name from the great pottery centre Tz'ŭ Chou, once in Honan and now in the south-west corner of Chihli. The Tz'ŭ Chou ware is a grey or buff-grey stoneware, which is usually coated with white slip and covered with creamy glaze. The plain cream white Tz'ŭ Chou stoneware has been mentioned among the Ting types, but the ware is more usually decorated with painted or incised designs.

The painted designs, floral or otherwise, are laid on with a bold brush in black or brown slip, sometimes supplemented by an ochreous red under the cream glaze. Painting in enamels—green, yellow and red—over the glaze was also used, occasionally in the Sung period and frequently in later times. The incised, or *graffiato*, Tz'ŭ Chou ware has many varieties. Simple incised designs are comparatively scarce, the more usual practice being to coat the vessel with white or brown slip which was then scraped away so as to leave the design slightly relieved in white or brown against a buff-grey body. A coating of transparent cream glaze over this produced cream white design on a mouse grey ground, if the slip was white. Where brown was used the slip usually contained the glazing material and the design appeared in brown or black glaze against an unglazed ground. Both of these *graffiato* types have great decorative value. The black and brown painted Tz'ŭ Chou is the commonest type and its merits vary with the quality of the drawing.

The Tz'ŭ Chou potteries have a history which can be traced from the 6th century to the present day, and there will always be room for debate as to the age of particular specimens. Further, most of the Tz'ŭ Chou types were made at other potteries scattered over northern China, and doubtless much that we call Tz'ŭ Chou really belongs to other potteries which worked on similar lines. This will explain variations in the body material of wares of the Tz'ŭ Chou type, and why a red body, quite unlike the original buff grey, is found on some of the most beautiful members of the group, such as the vases with black painted and *graffiato* designs under transparent green glaze or with black painted designs under a lovely peacock blue.

The potters who made these choice objects must have been among the foremost of their craft, but, though they used the Tz'ŭ Chou methods, their wares differ fundamentally from what we know as Tz'ŭ Chou.

Chinese ceramic records name several other Sung potteries in various parts of China, but they are hardly more than names to us and we know little or nothing of their productions. Practically all the Sung wares which we know, however, are comprised in the types already described. The forms, except where they were moulded after those of old bronzes, are simple and elegant, such as come naturally from the hands of a gifted "thrower" on the potter's wheel. The character of the classic Sung wares may be summed up in two words, simplicity and refinement.

FROM THE GEORGE EUMORFOPOULOS COLLECTION

MING EWER (1368-1644): INCISED DECORATION AND TURQUOISE GLAZE

For the purpose of this brief sketch the Yüan dynasty (1279–1368) may be regarded as a continuation of the Sung. The Mongol conquerors had nothing to bring into the stock in trade of the Chinese potter except a taste for certain Western forms and designs acquired in the other extreme of their transcontinental empire. Further we are told that they were hard task-masters and that the ceramic industry, in common with many others, especially the more artistic crafts, lost ground under their unsympathetic rule.

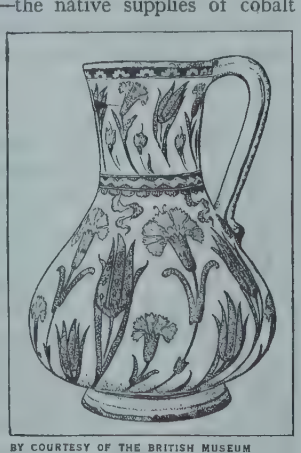
The Ming Dynasty (1368–1644).—In 1368 the Yüan was replaced by the native dynasty of the Ming, which ruled China till 1644; and, when the country had recovered from the inter-dynastic struggles, the ceramic art took a new lease of life, though under somewhat changed conditions. The Sung monochrome wares, the celadons, Chün wares, etc., went out of

favour and the old factories sank into obscurity, while the fame and importance of the great porcelain town of Ching-tê Chên, near the Po-yang lake in Kiangsi, overshadowed all the rest. The first Ming emperors had their capital in Nanking and the proximity of Ching-tê Chên to the seat of government doubtless helped its development. At any rate from this time onwards the fine white porcelain of Ching-tê Chên was in general demand and the imperial factory there was rebuilt and reorganized to keep the court supplied with it; and Chinese ceramic writers thenceforward speak of Ching-tê Chên and little else.

The neighbourhood of Ching-tê Chên had long been noted for its excellent ceramic wares. It was ordered to supply goods to the court as early as the 6th century, and it received its present name in the Ching Tê period of the Sung dynasty (1004–07). All that the industry required in the way of material was lavishly supplied by the neighbouring hills, *kaolin* (china clay) for the body of the porcelain and *petuntse* (china stone) to mix with it and to form the glaze, wood ashes to soften the glaze, and cobaltiferous ore of manganese to make the blue for the underglaze painting and the blue glazes. The staple product of Ching-tê Chên is the fine white porcelain which has made China a household word throughout the world; and as this ware lent itself peculiarly well to painted decoration, the vogue for painted porcelain rapidly replaced the old Sung taste for monochromes. They fall into three chief groups, namely blue and white, enamelled wares and three-colour glazed wares, all of which are essentially pictorial in their decoration.

Blue and White.—The beautiful cobalt blue is one of the few ceramic colours which will stand the high temperature required to melt the porcelain glaze, and which consequently can be used under the glaze. Thus the blue colour, painted on the body of the ware and covered with a transparent sheet of glaze, gives a perfectly protected picture which will last as long as the porcelain itself. The idea of painting porcelain in this fashion was not new in the Ming dynasty. It was known to the Sung potters, but it was only in the Ming dynasty that blue and white became fashionable. Nor is the idea necessarily of Chinese origin, for blue painting was certainly known to the Near-Eastern potters as early as the 9th century, and we have as yet no indication of its use in China at so early a date. In the Ming dynasty, however, the Ching-tê Chên potters made it specially their own, and their blue and white was not only supplied in large quantities to the imperial court but was exported all over the eastern hemisphere.

During certain reigns—Hsüan Tê (1426–35), Chêng Tê (1506–21) and Chia Ching (1522–66)—the native supplies of cobalt blue were supplemented by a superior blue imported from the Near East and known as Mohammedan blue. This imported material was scarce and costly and was at first reserved for the imperial factory, and even so it was usually diluted with the common native cobalt. Later on supplies of it found their way into the hands of the private manufacturers. According to Chinese accounts it varied much in tone, but the kind best known to us is the Mohammedan blue of the Chia Ching period which is a dark violet blue of great strength and intensity. In general the Ming blue is painted in one of two ways, either in finely pencilled line drawing or in strongly outlined designs filled in with flat washes. The better class of Ming porcelain, made for imperial and native use, was potted thin and finely shaped; and this is now rare and only to be acquired from Chinese collections. But there is a commoner class which was more strongly and roughly fashioned to meet the exigencies of the export trade, and this has been found in considerable quantities in India, the East Indies, Persia, Egypt and even in Europe. But all the Ming blue and white, whether made for home or foreign consumption, is distinguished by a freshness and freedom of design which make the commonest specimen a desirable possession.



BY COURTESY OF THE BRITISH MUSEUM

TURKISH POTTERY JUG

Another colour used, like the cobalt blue, under the glaze, is a red derived from copper. It was a difficult colour to control but it was used with success in several Ming reigns, notably the Hsüan Te (*see* page 363) and Ch'êng Hua, both as monochrome and in designs painted in the same way as the blue and white.

Ming Enamelled Wares.—Pictorial designs having become fashionable, means were found to paint them on the glaze as well as under it. The chief advantage in on-glaze painting lies in the wider range of colours available. The over-glaze colours, commonly distinguished as enamels, are made of coloured glass ground to powder and liquefied so as to be usable on a brush. They are "fixed" in a small stove, or muffle, at a low temperature which is sufficient to melt the enamel powder and make it adhere to the glaze without actually melting the latter.

The colours used are leaf green and turquoise green derived from copper, a brownish yellow derived from iron, and aubergine purple derived from manganese, besides which a dry black pigment was obtained from manganese and a thin tomato red (halfway between a pigment and an enamel) from iron. The Ming red is apt to become iridescent and lustrous; both it and the black are used for painting outlines, and the latter was sometimes washed on and covered with transparent green to form a composite black. Gilding was also used. With this palette the Ming potters produced richly coloured porcelain, decorated with pictorial designs and formal brocade patterns. In some cases the enamels were combined with underglaze blue and this colour scheme, though known in the 15th century, was so popular in the Wan Li period (1573–1619) that it has come to be known as the *wan li wu ts'ai* or Wan Li polychrome. Another type, known as the "red and green family," is characterized by the absence of blue and the predominance of red and green, and again there are effective combinations of two colours such as red and yellow, blue and yellow, blue and green, red and green, red and gold and more rarely green and gold.

Besides being painted on the glaze the enamel colours were sometimes painted on the biscuit, *i.e.*, the fired but unglazed porcelain body; but this technique was commoner in the succeeding dynasty and will be discussed later.

"Three-colour" Ming Wares.—There are few kinds of ceramic ware, Chinese or otherwise, that make such a brave show as the Ming three-colour (*san ts'ai*) porcelain. Though nominally combinations of three, the glazes which make up the colour scheme of this group are dark violet blue, turquoise, aubergine purple, yellow and a neutral white; and they are used in washes over designs set in single-colour ground which is usually dark blue or turquoise. To prevent the colours from overrunning each other the designs are outlined by incised lines or by threads of clay, or they are carved in open work. The glazes themselves, though harder than the enamels discussed in the last section, do not require the full heat of the porcelain kiln to melt them, and consequently the ware has to be "biscuited" (subjected to a preliminary firing) and then, when the glazes have been applied, fired again in the cooler parts of the kiln.

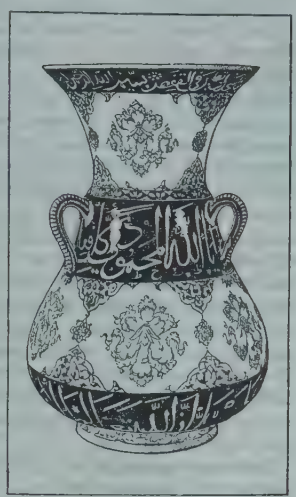
They are, in fact, what the French call them, glazes *du demi-grand feu.*

The decoration of the three-colour ware is bold; it includes large floral subjects, lotus and cranes, peonies and peacocks, and a few set figure subjects such as the Eight Immortals paying court to the God of Longevity, Wang Chih watching the game of chess, etc. The details are often built up in slight relief, certain parts such as faces and hands of human figures being left unglazed. The glazes are thick and inclined to be opaque. Much of the three-colour ware dates from the 15th century. In the 16th century the glazes tend to become sleeker, smoother and more transparent, and incised decoration is used.

The three-colour decoration was not confined to porcelain. Excellent specimens of it are seen on both stoneware and earthenware bodies. Indeed some of the most beautiful three-colour

vases have a buff stoneware body and bold floral designs in minutely crackled glazes which include a peacock blue of peculiarly attractive tone. Where this group of fine pottery was made is not known; but it is found in widely separated parts of China and may have been made in several factories.

Other Ming Wares.—Though monochrome porcelains no longer held the premier position, they were still made in considerable quantity and some of them received special notice from Chinese writers. The sacrificial red (*chi hung*) of the Hsüan Te and Ch'êng Hua periods, a brilliant underglaze red derived from copper, was most noted; and next came the *chi ch'ing*, an intense blue glaze of the Hsüan Te period; and a lovely blue glaze of slightly mottled texture is found on some of the Chia Ching porcelains. There were, besides, celadon green, lustrous black and brown glazes; and all the *demi-grand feu* glazes of the three-colour porcelains were used individually as monochromes, the turquoise blue being especially effective.



BY COURTESY OF THE BRITISH MUSEUM

LAMP FROM THE MOSQUE OF OMAR

Beautiful, too, are the pure white porcelains (white was the colour required in certain forms of ritual and also by the court during periods of mourning); and special mention is made of the exquisite white "egg-shell" bowls of the reign of Yung Lo (1403–24) and of the white altar cups of the Hsüan Te and Chia Ching periods. If any decoration was added to these white wares it was faintly carved, incised or traced in white slip under the glaze, a subtle form of ornament known as *an hua* or secret decoration. Another and more conspicuous form of slip decoration is traced in white on blue or green glazes in a manner resembling the modern *pâte sur pâte*. Reliefs in white biscuit and remarkably fine open work distinguish some of the later Ming porcelains, the open work being of such superhuman delicacy that it was called *kuei kung* or devil's work. A quantity of stoneware and earthenware was made all over China in the Ming period. The best known are the tile work and architectural pottery which are often finely modelled: they are usually glazed with green, yellow, aubergine purple, turquoise or blue. On parts of the famous Nanking pagoda, built in the beginning of the 15th century, white porcelain was also employed for the same purpose. Many vases and vessels of everyday use were also made as by-products of the tile works which existed in all large centres of population to supply local needs; but it is hard to distinguish the common pottery of the Ming from that of the earlier and later periods, except where there is a close analogy with some known type of Ming porcelain to help us.

In the early years of the 16th century direct contact was established between Europe and China; and Chinese porcelain, together with silk and tea, soon became an important item of European trade. From this time onwards we note the influence of European taste affecting the Chinese porcelain to a steadily increasing extent.

The Ch'ing Dynasty (1644–1911).—The Ch'ing dynasty of the Manchus replaced the Ming in 1644; but it was not till about 1680 that its rule was firmly established over a pacified country. A succession of three able and enlightened emperors—K'ang Hsi (1662–1722), Yung Chêng (1723–35) and Ch'ien Lung (1736–95)—gave China a long period of good rule and the ideal conditions for the development of the arts, which indeed enjoyed at this time an unusual amount of imperial patronage. The imperial porcelain factory at Ching-tê Chên was managed by a series of exceptionally capable directors. Ts'ang Ying-hsüan, appointed in 1682, remained in charge till the end of the K'ang Hsi period. Nien Hsi-yao was appointed by the Emperor Yung Chêng and in 1728 he was given as an assistant the celebrated T'ang Ying, who succeeded him in 1736 and held the post with great distinction till 1749. T'ang Ying left behind him several treatises on the manufacture under his control, and in addition to these we have the letters of the Jesuit father d'Entrecolles which were written from Ching-tê Chên in 1712 and 1722, giving us an intimate picture of the life and industry of the great porcelain centre with its 3,000 furnaces.

The period from 1680 to 1749 must be regarded as the most fertile in the annals of Chinese ceramics. The porcelains of this time are distinguished by fine finish and perfect command of material and technique. They do not, however, differ basically from those of the Ming potters, who had little to learn in the essentials of their craft; and on the whole they suffer by comparison with the Ming in the matter of originality and freshness. The Ch'ing wares indeed are often a trifle stale and mechanical. Still they have enjoyed a long period of popularity in Europe, and their relative weakness has only recently become apparent; for we have only recently made acquaintance with the better types of Ming porcelain.

Ch'ing Blue and White.—Old Nanking is a household phrase in Europe for Chinese blue and white. None the less it is a misnomer, for while much of that ware was transhipped from Nanking, none of it was actually made there. Old Nanking is in fact the blue and white porcelain of Ching-tê Chên and chiefly that made in the K'ang Hsi period and imported into Europe by the Dutch and other East India merchants. It was justly famous, for never was more care expended on the preparation of the ware and the refining of the blue. The best K'ang Hsi blue is pure sapphire, without the tinge of violet or grey so often observable in the Ming blue; and it is usually laid on in graded washes which give it its splendid, vibrating depths. As to the painted designs they are mainly Ming themes, when they are not of the formal arabesque type; but some of them are of outstanding beauty, such as the design of ascending and descending branches of flowering prunus reserved in white in a ground of marbled blue which is netted over with lines suggesting cracked ice.

The prunus blossom falling on the breaking ice is a symbol of returning spring; and this motive is a favourite one for the decoration of the jars in which gifts of fragrant tea and sweetmeats were sent at the new year—a festival which falls in China three to seven weeks later than in our calendar. The vogue of blue and white seems to have died down at the end of the K'ang Hsi period, for after that time the ware in general sank into mediocrity, though exceptions must be made of two types. One is the close imitations of Ming blue and white made in the Yung Chêng period; and the other is the so-called "soft paste" blue and white, a ware prepared with "soapy rock" (*hua shih*), a kind of pegmatite, and exquisitely painted with the finest brushwork and the purest blue under a soft-looking crackled glaze. Another name given to this porcelain is "steatitic," in the belief that the *hua shih* was soap-stone or steatite. It was an expensive ware and chiefly used for small objects such as snuff bottles and the furniture of the writing table, in which the Chinese *literati* take special delight.

Famille Verte.—This is the name given to the K'ang Hsi porcelain decorated in transparent enamels. These enamels are in the main the same as those used in the Ming period, but there are a few differences. The iron red is a coral rather than a tomato red, the yellow is clearer than the brownish Ming yellow, there are additional shades of green, and the Ming turquoise green is replaced by a beautiful violet blue enamel.

The enamels are either painted over the glaze or are washed over black-outlined designs painted direct on the unglazed porcelain or biscuit. The latter process was not unknown in the Ming period, but most of the existing specimens, though often miscalled Ming, belong to the Ch'ing dynasty. Some of the finest Ch'ing porcelains are enamelled on the biscuit, such as the sumptuous vases with grounds of green-black (*famille noire*), figures and groups.

Not unlike the porcelain enamelled on the biscuit is that

decorated with washes of coloured glazes, chiefly green, yellow and aubergine. This is the Ch'ing version of the Ming three-colour ware; but the Ch'ing glazes are sleek and transparent. Sometimes they are laid on in patches making a motley decoration which is known in the trade as "egg and spinach" glaze.

Ch'ing Monochromes.—The Ch'ing monochromes comprise the Ming types, close imitations of the old Sung glazes, and many novelties.

Among the best known is the *lang yao* red, which follows the Ming *chi hung* but has a character of its own, varying from bright cherry red and deep ox-blood (*sang de boeuf*) colour to a dappled glaze of crushed strawberry tint. This red is called after a potter family of the name of Lang; and, though imitated in subsequent reigns, it was never so well controlled or so fine in colour as on the K'ang Hsi porcelain. Another success of the K'ang Hsi period was the "peach bloom" glaze, pinkish red in colour but flecked with russet spots and broken by passages of green. Between the peach red and *lang yao* are many shades of maroon and liver colour. Other K'ang Hsi glazes are the mirror-black, the powder-blue and the pale lavender or *clair de lune;* and Chinese writers mention turquoise, eel-skin yellow and snake-skin green as specialties of the period.

We need not dwell on the many other monochromes—whites, celadons, lustrous browns, aubergine purples, violet blues and so forth; but there is a group of composite glazes which requires notice.

They are formed by washes of enamel over a stone-coloured crackled glaze; and they include "apple-green," camellia leaf green, sage green and mustard yellow. Coral red was also used in monochrome, but this and many enamels of the *famille rose* types belong chiefly to the Ch'ien Lung period, as also do the splashed or *flambé reds* which came at first by accident but which T'ang Ying succeeded in getting under perfect control.

Famille Rose.—In the third decade of the 18th century a revolution took place in the enamelled porcelains. A new palette of colours was introduced, opaque enamels among which rose pinks (derived from gold) are most conspicuous. The Chinese called these new colours *juan ts'ai* (soft colours) or *yang ts'ai* (foreign colours), and we have adopted for them the French name *famille rose*. The *famille rose* displaced the *famille verte,* and it brought with it a new and more effeminate type of decoration with delicate designs executed with a miniature-like refinement. The colours are seen at their best on the Yung Chêng porcelain with a few sprays of flowers thrown artistically across the white surface. The more elaborate ruby-back dishes and table services with crowded figure-subjects and complicated borders are less satisfactory; but these were painted in the Canton enamelling establishments and were destined for the European trade. At Canton, too, were decorated large quantities of Ching-tê Chên porcelain with coats of arms and other European designs directly ordered by the foreign merchants.

The *famille verte* enamels, though eclipsed by the *famille* rose, were not entirely suppressed; and they emerged again in a mixed palette of transparent and opaque colours. These mixed enamels were effectively used by a school of painters who worked in the style of one Ku Yüeh-hsüan, a maker and decorator of glass in the early years of Ch'ien Lung's reign. Good specimens are rare, for they are prized by Chinese collectors. Other specialities of the Ch'ien Lung period are "lace-work" porcelain with designs deeply incised and forming semi-transparencies; and "rice-grain" porcelain in which the designs are actually cut out of the side of the vessel though allowed to fill up with glaze. A third type, known as *graviata,* has a covering of opaque *famille rose* enamel which is diapered with incised scroll-work.

The monochromes of the Yung Chêng and Ch'ien Lung periods include those of the K'ang Hsi with numerous additions, some of which have already been mentioned. Great ingenuity was exercised by the Ch'ien Lung potters in the imitation of natural substances in glaze; the effects of tea dust, iron-rust and bronze are cleverly produced, and enamelled metal, shells, birds' eggs, grained wood, jade, ivory, etc., are copied so closely as to deceive the eye. But these *tours de force* are symptoms of an art which had passed its maturity; and after the 18th century the porcelain has little interest, being mainly of an imitative kind. Exceptions may be made of the Peking medallion bowls, the finer snuff bottles of the Tao Kuang period (1820–50) and some of the imperial porcelains which maintained a high standard of technique. The devastation of Ching-tê Chên during the T'ai-p'ing rebellion in 1853 was a crowning disaster to the ceramic industry of China.

Provincial Porcelains and Pottery.—The bulk of the Ch'ing dynasty porcelains which have reached Europe is of Ching-tê Chên make; but there were many provincial factories which supplied local needs and which also catered for the sea-borne trade to India and the East Indies. These provincial wares are generally of a coarse type; but a shining exception is the white porcelain made at Tê-hua in the province of Fukien. This is the *blanc de Chine* of the old French catalogues, which was freely exported from Amoy in the 17th and 18th centuries, and which served as a model for most of the early European porcelains. It is a beautiful, translucent ware with a soft-looking, melting glaze of milk or cream white, sometimes warmed with a pinkish tinge; and it was chiefly used for ornamental objects such as vases, libation cups, incense burners, figures and groups, less often for table wares. It is decorated, if at all, with slight, applied reliefs, moulded or incised designs, rarely with painted enamels. The Tê-hua factories are known to have existed in the last half of the Ming dynasty, and they are still active to-day; and as the character of the ware has changed very little, the dating of specimens will always be difficult.

Immense quantities of earthenware and stoneware have been and are still made in every part of China. We know little of the individual potteries, but there are two centres which must be mentioned. Yi-hsing, on the west side of the Great Lake in Kiangsu, has been noted since the 16th century for a fine stoneware, chiefly red but also buff, grey and of other colours formed by clever blending of the local clays. The red tea ware of Yi-hsing came to Europe with China tea as early as the 17th century. It was classed at that time with the American *buccaro* ware; and it was copied closely by Dutch, English and German potters, notably by Böttger at Dresden and by Dwight and Elers in England. The Yi-hsing tea-pots were cleverly fashioned, often in fanciful shapes, and decorated with reliefs, moulded and incised designs and in some cases with glazes and even enamels.

The second centre lies in the province of Kwangtung, the principal potteries being at Shekwan near Fatshan, a few miles west of Canton. The Shekwan ware is a stoneware verging on porcelain; and the standard type has a thick flocculent glaze of brown mottled with blue and grey and sometimes with vivid red. Glazes of the Sung Chün type and celadon green, as already mentioned, besides *flambé* red were also used; and some of the Shekwan stoneware dates back to the Ming period, though the bulk of it is of comparatively recent date.

The reader is reminded that true Chinese decoration is never meaningless. Its meaning may be directly expressed in semi-religious emblems such as the Eight Buddhist Symbols, the attributes of the Eight Immortals, the Eight Precious Things, etc.; or indirectly by motives which suggest good wishes, such as the peach, crane, tortoise and pine (long life), the bat (happiness), the pomegranate (fertility). Again combinations of flowers, animals, etc., can be read rebus-fashion into auspicious phrases; for the Chinese language abounds in homophones and the Chinese delight in puns. They also delight in themes of religious and historical import; and the understanding of their decorative designs involves a deep study of their religion, history and folk-lore.

Numerous marks and seals are used on Chinese pottery and porcelain; but for these again the reader must consult special books. The most important and the most frequent of the marks are the reign-names (*nien hao*) of the emperors; but there are also potters' names, phrases of good omen, symbols and the names of halls and workshops, which it would be futile to enumerate without giving the actual marks and their readings.

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KOREA

The geographical position of Korea makes it a natural link between China and Japan. In close contact with China the Koreans were absorbing Chinese influences from the Han dynasty onwards; and Chinese graves of the Han period excavated in Korea prove by their contents that the Koreans must have been familiar with the arts of their great western neighbour. But in actual fact the early Korean pottery, though doubtless its essentials were learnt from the Chinese, developed on lines of its own. It is a hard, slate-grey ware, unglazed except for an accidental smear of glossy brown which probably came from the wood ashes in the kiln, and ornamented with large perforations, rather crude reliefs and simple incised patterns. This is the ruling type found in the tombs of the Silla period, which is generally regarded as extending from the 1st to the 10th century, though the Silla state did not actually become paramount till the 7th century. Naturally the Silla pottery varies considerably in such a great space of time, and some of it is potted thin, fired hard and of a neat and almost ornamental appearance.

The Korai Period (918–1392).—But the heyday of Korean ceramics belongs to the succeeding Koryu or Korai period, when the Korean potters suddenly developed a skill which was the admiration of the Chinese themselves. There can be little doubt that this sudden change was wrought either by Chinese refugees or by Koreans who had gone to China to study. For the home of the new industry was in southern Korea, in the Zenra district; and, as Dr. Nakao has pointed out, this district is connected by the most convenient sea route with the coast of Chekiang, the home of the Chinese celadon in the imitation of which the Koreans specialized. The characteristic Korean ware of the Korai period is a porcellanous stoneware with a celadon glaze which at its best resembles blue green ice, but which varies in tone to olive green and brown. A Chinese writer, Hsü Ching, who visited Korea in 1125 compared this ware in one passage with the secret-colour (*pi sê*) ware of Yüeh Chou and the contemporary Ju Chou porcelain, and in another passage with the celadon of Lung-ch'üan. The same writer adds that in form and style it resembled Ting Chou porcelain, a statement of which we quickly realize the truth in comparing the etched, engraved and moulded designs in the Korean bowls with those of the ivory white Ting ware. Incidentally it may be mentioned here that a white porcelain of Ting type and a bluish white porcelain of *ying ch'ing* type have both been found in Korai tombs; but whether they were, all or some, made in Korea itself or imported from China are questions not yet decided. The finest Korai ware is undoubtedly the blue green celadon made in the best period which may be placed between 1050 and 1170; and it is either plain or delicately decorated with etched or carved designs. Sometimes the glaze is more grass green like the typical Lung-ch'üan celadon or olive green like the so-called northern celadon (*see* above).

Indeed there are specimens which could hardly be distinguished from this latter ware, were it not for the typical Korean finish of the base which is shallow and covered with glaze and almost always scarred with the marks of the spurs or sand on which the piece was supported in the kiln. This rough finish of the base and a tendency to lose shape in the firing are two defects which are apt to mar even the best Korean ware.

It was probably in the last half of the 12th century that a typically Korean method of decorating the celadon ware was first used, namely inlaying the incised designs with black and white clays. Discreetly used this decoration produced a very charming effect; but it was overdone and soon became hackneyed. The easy but mechanical method of stamping the designs instead of drawing them with the stylus was adopted, and a stiff and crowded ornamentation resulted. To this inferior class belongs the so-called "Mishima" ware with its radiating cord patterns which recalled to the Japanese the lines of their Mishima almanac.

Other less usual kinds of decoration on the Korai ware are painting in underglaze red, painting in bold, but often rather crude, designs in brown (rarely in white) in the style of the Chinese Tz'ŭ Chou pottery, and blending variously coloured clays so as to make a marbled body. Black- and brown-glazed wares of the "Honan *temmoku*" class are also found in Korea, but, as with the ivory white and *ying ch'ing* types, their native origin remains to be proved. By the end of the 13th century the Korai pottery had become definitely decadent: the beautiful celadon glaze had turned brown and cement-coloured, and the inlaid and brown-painted wares were coarse and clumsy.

The Korai dynasty was followed by the Yi which lasted from 1392 to 1910. The capital was removed from Song-do to Seoul and the name of the kingdom was changed to Chosen. But the country was impoverished by many calamities and the final blow to its prosperity came with the invasion of the Japanese under Hideyoshi at the end of the 16th century. From this time Korea was virtually closed to the outside world and became a veritable hermit kingdom. We know little of the early Yi pottery except so far as it is reflected in Japanese imitations. From these we would infer that it included a rough kind of red or grey pottery with translucent glaze varying from brown to light grey tinged with pink; coarse *mishima*, and brown-painted wares which the Japanese call *e-gorai* (painted Korean); a creamy buff ware with closely crackled glaze; and grey ware with opaque milk white glaze of thin paint-like appearance which the Japanese call *koma-gai*. For the rest, specimens of the 17th to 19th century wares in our collections comprise porcellanous stoneware with crackled grey or buff glaze, plain or painted with sketchy designs in dull underglaze blue; and white porcelain painted in underglaze blue and red, with occasional relief decoration and open work.

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JAPAN

Japan, like every other country, has its primitive pottery, a rough hand-made material sometimes mat-marked like the primitive Chinese. A more advanced type is found in the dolmen burials which date from the 3rd century B.C. to the 7th A.D. The dolmen-builders were invaders from the mainland, doubtless from Korea, and the dolmen pottery closely resembles the Korean wares of the Silla period. The development of the potter's art in Japan was slow—perhaps it was retarded by the preference for other materials, such as lacquer, for the articles of every day use—and it seems at first only to have moved forward under the stimulus of foreign influences. The first foreign influence was Korean. The next was Chinese, and this must have been felt as early as the 8th century, for the treasure of the Emperor Shomu, preserved at Nara, includes a few specimens of motley glazed pottery of T'ang type. In the 13th century Kato Shirazaemon is said to have gone to China to study the work of the Sung potters, and to have set up kilns in Seto on his return. Reputed specimens of his work are tea jars and tea bowls with thick treacly glazes of black, amber brown, chocolate and yellowish grey colour. This type of pottery took a firm hold in Japan and variations of the Seto glazes were subsequently made in many factories throughout the country. A second and more potent wave of Korean influence flooded Japan after Hideyoshi's campaigns in the 16th century,

from which he brought back a large number of Korean captives. It happened too that about the same time the famous aesthete Senno Rikiu organized the tea ceremony, which has played ever since an important part in Japanese social life. The masters of the tea ceremony decided that pottery was the most fitting material for the tea vessels; and the Japanese potters soon learnt from the Koreans how to meet the demand satisfactorily. Hence the numerous imitations of Korean Yi dynasty wares to which allusion was made in the last section. Indeed many of the best known Japanese potteries, such as those of Karatsu, Satsuma, Shigaraki, Takatori and Hagi, owe most of their importance, and also very often their origin, to Korean teachers. From the 16th century onward Japanese pottery developed rapidly and many new and original types were invented, of which the *raku* ware is one of the most important.

Though the credit for the invention of *raku* ware is given to a Korean family settled in the Kioto district, the ware itself is essentially Japanese. It is a soft, hand-made earthenware, requiring only a slight firing, and covered with a peculiarly waxen, treacly and semi-opaque glaze of various colours of which the black and salmon are the earliest and the yellow, green, cream white and mixed colours later.

Another successful Japanese creation is the antithesis of the *raku* ware. It is a hard reddish brown stoneware unglazed as a rule, except for an accidental smear, and evidently well suited for figure modelling. Its habitat is the province of Bizen, where the industry can be traced back to the 14th century. A fine, hard, buff pottery with closely crackled cream glaze is another Japanese specialty. It is a development of the Korean *koma gai*, or white ware; and it reached its finest expression in Satsuma. Here and at numerous factories in Kyoto it was used as the vehicle for enamelled decoration.

The art of enamelling on porcelain was learnt from China, the story being that Sakaida Kakiemon, an Arita potter, was instructed in it by a Chinese ship's master about the middle of the 17th century. One of the most celebrated Japanese potters, whose art-name is Ninsei, adapted its use to the cream glazed pottery and developed a special style of enamelling in purely Japanese taste. Ogata Kenzan, another of the great Japanese ceramic artists, at the end of the 17th century found a way of using enamelled decoration on the soft *raku* glazes. From this time onwards Chinese influence was discounted in the pottery which displays much originality and a true national style.

Japanese Porcelain.—Meanwhile the manufacture of porcelain had started in Japan. Needless to say the technique was learnt from the Chinese, a potter named Gorodayu go Shonzui visiting Ching-tê Chên itself to study in the 15th century. Shonzui's difficulty on his return to Japan was to find suitable raw material and he was forced to work with imported Chinese clays. Not till the beginning of the 17th century did the discovery of the important deposits of porcelain stone on Izumi Yama, in the Arita district of Hizen, permit the establishment of the Japanese porcelain industry on a firm basis. The Arita district was the chief centre of the manufacture; and it was here, at the seaport Imari, that the Dutch traders obtained the "Old Imari" porcelain with which they flooded Europe. Here too Kakiemon practised his new-found art of enamelling, in a style which is for ever associated with his name. The Kakiemon enamels were soft orange red, grass green and lilac blue, supplemented by pale primrose yellow, turquoise green, gilding and occasionally by underglaze blue; and his decorations are slight and in the best Japanese taste. A few blossoms, a floral medallion, a flowering prunus tree, a banded hedge with birds, quails and millet, a tiger and bamboos, a dragon and sometimes children are motives of the nicely balanced Kakiemon designs which have been imitated wherever porcelain has been made.

The "Old Imari" of the Dutch importers included another highly specialized but less artistic kind of porcelain. It was painted with masses of heavy impure blue supplemented by red and gold and to a less extent by enamel colours. The designs are irregular and confused, asymmetrical panels enclosed by mixed brocade patterns. Over-loaded, but not without decorative value, they appealed strongly to the Dutch taste.

Many factories were started in the Arita district, those of the princely houses of Hirado and Nabeshima being the most noted; and the industry soon spread to other provinces. It was early established in the Kutani district of the province of Kaga and at a little later period at Seto in Owari, Mino, Kioto and many other places. The Kaga potteries in the 19th century popularized a special kind of decoration in red and gold; but on the whole Japanese painted porcelain follows closely on Chinese lines, and the highest ambition seems to have been to make wares which could be mistaken for Ming porcelain. The Koto factory on the shore of Lake Biwa was noted for its enamelled porcelain in the middle of the 19th century; and good imitations of Chinese celadon were made in the Arita district at an early date and at Sanda and Kioto since the end of the 18th century. In the early 19th century remarkably fine porcelain of "egg-shell" thinness was made at Mikawachi, in Seto, Shiba and Mino.

Since the reopening of Japan to the foreigner in 1868 vast quantities of pottery and porcelain have been made for the Western market. These wares, usually overloaded with ornament, do not represent true Japanese taste, which requires that a piece of pottery be made strictly to serve its useful purpose and decorated soberly in a style appropriate to its form and use.

It is not practicable within the compass of this article to describe the work of individual potters, and the mere mention of famous names, such as Banko, Hozan, Dohachi, Eisen, Rokubei and Zengoro Hozen, cannot serve any useful purpose. The potteries are very numerous, being for the most part small family concerns; and as each had its individual mark or seal and a proper pride in using it, the list of Japanese potter's marks is a formidable one, for which the reader must consult works cited below.

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PERSIA AND THE NEAR EAST

The ceramic history of the Near East between late Roman and Islamic times is still obscure. Little Sassanian pottery of any importance has been identified, and the excavations at Constantinople which should tell the Byzantine side of the story have hardly begun. But the continuity of ceramic tradition in these regions is not for a moment in doubt. The most familiar of all the Persian glazes is the blue-green which appears on late Babylonian, Parthian and late Roman wares; while in Egypt there is no real break in the sequence of potters from early dynastic times to the present day, though the chain of evidence is very weak in the period immediately preceding the coming of Islam.

The "Gabri" Types.—What is reputed to be the earliest type of mediaeval Persian pottery has been called "Gabri" because it was believed to have been made by the pre-Islamic, fire-worshipping (Gabri) peoples. It is an earthenware with a reddish body which is usually concealed by a coating of white slip (liquid clay) and covered with a transparent lead glaze. The commonest form of decoration was effected by cutting or scratching a design through the slip coating so as to expose the red ware below; and by varying the naturally yellowish colour of the glaze by washes of green and purplish brown, derived respectively from copper and manganese. This technique is probably of Byzantine derivation, but it has been used since in every civilized country and at all periods. The Gabri ware, though often crude and bucolic, is attractive for its bold designs and warm colouring, and in the best specimens the rendering of animal forms among floral scrolls and of ornamental inscriptions is highly artistic.

In point of date some of it may go back to the early days of Islam (7th century), but the bulk of it may safely be placed between the 10th and 13th centuries. In Egypt the same technique was largely used on the armorial pottery of the 15th century. Gabri ware has been excavated chiefly in northern Persia, at Zendjan, Rhages and Hamadan; and a kindred ware reputed to come from Amul, south of the Caspian, is distinguished by the additional colours, yellow and ochreous red. A rare type

reputed also to be of Amul make has painted designs in white on a background of black slip. A red ware with painting in coloured sups, as well as with incised ornament, has been found in some quantity as far east as Samarkand.

Samarra.—A shining exception to the usual haphazard excavation is the work done by Profs. Sarre and Herzfeld in the ruins of Samarra on the Tigris, a site which was occupied for about 50 years in the 9th century. The finds made here are of the utmost historic importance, and they include a variety of interesting pottery types. One is a thin reddish buff earthenware decorated in low relief with formal designs under a green lead glaze and strongly reminiscent of the lead glazed wares of the late Roman period. Another and more characteristic type is a close-grained, buff pottery with an opaque greyish white glaze which is sometimes painted with a dark cobalt blue, sometimes with lustre pigments of golden brown, green or blood red tones. The blue-painted ware is varied at times with patches of green and manganese brown. The same Samarra body is found with monochrome white, green and yellow glazes, and also with glazes splashed and mottled with green and yellow in the style of the Chinese T'ang wares with or without incised designs. Indeed it is clear that the Samarra potters deliberately set themselves to copy Chinese wares, fragments of which in company with white and celadon porcelain have been found on the site. But the most important of the Samarra fragments are those decorated with lustre.

Lustre painting is perhaps the chief contribution of the Near East to ceramic decoration. When and where it was first used are still debated questions, but one fact at any rate is established by the Samarra finds, namely that the process was fully developed in the 9th century. The lustre is applied in the form of a metallic salt (derived from copper or silver) which is painted on the glazed ware and developed at a low temperature in a special kind of kiln. This process deposits a film of metal on the surface of the ware, in colour golden brown, greenish or red, and when the film is thin enough to allow the light to penetrate it, it glows with beautiful rainbow reflections. The blue-painted and the lustred pottery of the Samarra type have been found at Susa certainly, and, according to report, at Rhages also; and examples of the lustred types have all been found in the waste heaps at Fostat in Egypt.

Rakka Ware.—Extensive pottery remains, including a number of kiln wasters, have been dug up at Rakka, in Syria, a place situated on the Euphrates about 100 m. E. of Aleppo. Rakka is a very ancient site and one which had considerable importance between the 8th and the 14th centuries. It includes ruins of several cities, one of which was the residence for a time of the Caliph Harun Al-Rashid. The pottery found at Rakka is of a type which became general in the Near East after the 10th or 11th century. It has a sandy, white or buff white body, loosely constructed and friable, and it is covered with a clear silicious glaze which became opaque when tinted with certain colours. A bowl of Rakka ware figured in Chatfield Pier's book is said to have a dated inscription of the year 831: it is painted in black under a pale blue glaze. Other Rakka wares are decorated with a characteristic brownish lustre; and some of these may date back to the 10th or 11th century. Others again have designs in bold relief which is lustred, or covered with opaque turquoise or translucent bluish green glaze. But the most characteristic type is painted in black under a pale blue glaze or in blue and black under a clear glaze.

Sometimes the glaze is coloured a fine purplish brown with manganese. The blue and black painted ware is common to Syria and Egypt, whence its name Syro-Egyptian, and the bulk of it was made between the 13th and the 15th centuries.

Kiln sites have also been found at Rakka with remains of another kind of ware which appears to belong to the 11th or 12th century. It is white with engraved designs under a clear glaze which is sometimes coloured with dabs of blue. Probably other colours also were used, for specimens of this type reported to come from Rhages have the same features with the addition of green, yellow and manganese purple.

Rhages Ware.—To return to Persia, the ruins of Rhages have long been a happy hunting ground for pottery seekers, and they have produced wares of great variety and of many periods. There is little doubt that Rhages was an important centre of the ceramic industry, though very few waste pieces have been found to indicate the presence of kilns. The city, once the capital of the Djebal, was laid waste by the Mongols in 1220, and, though not completely abandoned till the 17th century, it never recovered from this disaster. The classic period of Persian pottery is from the 12th to the 14th century; and among the fragments found at Rhages are some of the most beautiful Persian wares. They are mostly made of the sandy white material; and the glaze is usually opaque and of a creamy tone, and much of it is finely painted with golden brown lustre with or without touches of blue. Another beautiful type, specially associated with the name of Rhages, is painted in enamel colours heightened by leaf gilding on a cream white or turquoise blue glaze. The Rhages enamels include blue, turquoise, manganese purple, red, green, mixed colours and white, and, with the exception of the blue, they generally have a mat appearance which gives a subdued splendour to the colour scheme. The designs on this Rhages enamelled ware are pencilled with miniature-like fineness recalling to a great extent the beautiful workmanship in the manuscript illuminations of the early 13th century. Indeed it has been thought that the court miniaturists may have assisted at the work. In some cases, especially with the more formal designs, parts of the pattern are built up in relief and these incrustations are jewelled with enamels and gilding.

Again the red, white and gold are effectively used in tracing formal designs on a fine dark blue glaze or on an opaque turquoise glaze which frequently covers moulded reliefs. Enamel colours too are sometimes used on the unglazed water jugs of porous buff earthenware, which are found all over the Near East and which are often decorated with artistic relief ornament.

The ruins of Sultanabad, in Kazvin, have also given us much fine pottery of the classic period, wares painted in lustre with or without blue, decorated in strong relief under blue, turquoise or green glazes, and painted in blue and brown under a clear glaze. The most characteristic Sultanabad type is a variety of the last mentioned, with animals, birds or human figures set in a background of close foliage, outlined in black and washed in with blue. The central motives are frequently speckled with black dots, and parts of the ornament are slightly raised.

The beauty of these specimens is further enhanced by the warm grey tone of the glazed ware in the remaining spaces. Chinese influence is frequently observable in the drawing of the figures, and pure Chinese motives such as the dragon and phoenix also appear. These features indicate a date in the second half of the 13th century after the Mongol conquest. Excavations at Khar have produced pottery of the best Rhages types, and it is probable that many other sites could be found equally productive, for there is no doubt that pottery centres were widely distributed throughout Persia and that Rhages and Sultanabad are only two of many.

Persian Tiles.—One of the most attractive forms of Persian pottery, the beautiful lustred wall tiles, have been found at Rhages Veramin, Koum, Natinz, Meshed and Kashan, and it is reasonable to suppose that such things were manufactured on the spot. But the wall tiles illustrate almost every phase of Persian ceramic art. Some of the earliest have ornamental inscriptions in strong relief and a coating of monochrome glaze, light blue or green. Next came the splendid lustred tiles, cut into star shapes and decorated with a complete design on each, chiefly consisting of ornamental foliage which sometimes encloses animals, birds and even human figures. An inscribed border usually completes the tile, and many of the inscriptions have the added interest of dates in the 13th and 14th centuries. The designs are sometimes painted direct in the lustre pigment, sometimes reserved in a lustred ground: details are etched with a needle point and parts of the design, especially the borders, are often touched with blue and occasionally with turquoise. It was soon discovered by the craftsmen that a slight relief gives additional play to the lustre, and reliefs were freely used, especially on the larger mihrab tiles. In place of lustre we

also find traceries of red, white and gold on dark blue or turquoise glaze as on the Rhages wares. Another characteristic Persian mural decoration is in a mosaic composed of glazed pottery sawn in intricate patterns and embedded in mortar. There are fine examples of this work on buildings of the 14th century. Later the same general effect was produced by the easier method of painting the design in coloured glazes leaving the outlines dry to represent mortar.

Before leaving the classic period of Persian pottery mention should be made of the fairy-like effects obtained in the sides of bowls and vases by open work designs into which the glaze has been allowed to run, forming transparencies. This beautiful decoration is seen on white wares which may be as old as the 11th century and on the pottery found at Rhages, Sultanabad and Fostat. It reappears at a later date on the so-called Gombroon ware.

Later Persian Wares.—In the post-classical period, from the 15th century onwards, the fashions in Persian pottery underwent considerable change. Few of the older styles survived, and those which did are barely recognizable. The body of the ware is the same sandy white material; but it is more highly vitrified and quite often it is translucent in the thinner parts, a condition only occasionally noticeable in the early wares. It is in fact a kind of soft porcelain. Chinese influence is very strong in the decoration. Celadon greens and other colours are copied as monochromes or painted with traceries of white slip: the painted designs in blue and black, or in blue alone, under a clear glaze, so closely follow the Ming blue and white that they are often mistaken for it. The Persian potters even marked their wares with imitations of Chinese seals. Survivals of the old Persian types include decoration scratched through a black slip under a pale blue glaze, painting in black under a blue glaze, and lustre ware, but in every case the character of the designs has changed. As to the lustre ware it would perhaps be more correct to describe it as a revival, for we have no examples made during the century which preceded the reign of Shah Abbas (1587–1629). On the revived ware the lustre is greenish or reddish brown in colour and its reflections are generally coppery, but sometimes of a beautiful ruby tint. It is applied over a white, or a vivid blue, glaze, rarely over yellow; and the designs are freely drawn trees and plants, among which the cypress occurs frequently, animals and birds and formal patterns, arabesque scrolls, leaf medallions and cable borders. The old device of reserving the design in a ground of lustre does not seem to have been used. Though this ware is generally known as Shah Abbas lustre, the only published specimen with a date was made in the year 1651 (or 1673 according to the reading), and a jug in the British Museum has a metal mount of about 1700. The ware in fact seems to be a 17th century revival but there is no evidence that it continued beyond that period.

The effective use of pierced ornament filled with transparent glaze on the earlier wares has already been noted. After a long interval it reappears on the white translucent ware of the later periods. The incised patterns are of a simple kind and they are supplemented as a rule with a few sprays or arabesques in blue and black. This singularly light and elegant pottery has been called Gombroon ware, because it was believed to have been shipped from the port of Gombroon; but it was probably made in many places, and the material differs in no respect from the contemporary ware made all over Persia. The few known dated examples are of a rather coarse type and belong to the early years of the 19th century; but the ware was largely made in the 18th and some of it may date back to the 17th century.

The late Persian types are no easier to localize than the earlier. Chardin, who travelled in Persia in the 17th century, tells us that faience in Chinese style was produced all over the country, but that the best came from Shiraz, Meshed, Yezd, Zorende and Kerman. There is an interesting product of Yezd in the British Museum, a kettle-shaped ewer of fine white ware well painted in blue in Chinese style and inscribed "The Work of Mahmûd Mi'mar of Yezd. The decorator of it the poor Zari. 1025" (=A.D. 1616). Hannover describes a pottery decorated in blue, green and a red similar to that used on the Turkish wares (*see* below), which he believed to be of Kerman make. Kubatcha in the Caucasus is also credited with the manufacture of a ware painted in similar colours or in a greyish blue under a glaze which tends to crackle. A typical specimen of this ware is a dish with a female bust surrounded by floral ornament, while others have rather coarsely painted designs in the style of Chinese blue and white; but all that can be said with certainty is that pottery of this kind has been found in the neighbourhood of Kubatcha. With even less reason a considerable group of post-classical pottery with black designs under a transparent blue glaze, which is inclined to crackle, have been assigned to Kubatcha; but there is little doubt that this type was made in various parts of Persia and certainly at Damascus. Specimens exist with dates around the year 1500.

The later tile work tends to be pictorial, with hawking figures on horseback and the like in slight relief in a ground of landscape and flowers. One of the best examples of the 17th century tile work is in the Victoria and Albert Museum, a large panel made up of many plaques and representing a princess and court ladies in a garden of flowers and cypress trees.

In the middle of the 18th century overglaze enamel painting in the colours of the Chinese *famille rose* came into use on tiles and on ordinary pottery. But the late 18th century and the 19th century Persian wares are in the main coarse versions of older types.

Mention has already been made of the early lustred pottery, the *graffiato* wares, and the blue and black painted wares of Syrian type found in Egypt, and of the continuity of the potters' art there from early dynastic times to the present day. Most of the early Persian and Syrian types were made in Egypt in the neighbourhood of Cairo; and the finds at Fostat are specially rich in lustre wares of all kinds, in pottery painted in black and blue under a clear glaze, and in monochromes which imitate Chinese porcelain.

Turkish and Damascus Wares.—Little is known of the potteries of Asia Minor in the middle ages, but in the 16th century under Ottoman rule they became famous for a pottery which is unsurpassed for its bold designs and powerful colouring. It is directly descended from Persian wares, but it has decided characteristics of its own which reflect the taste and temperament of the Ottoman peoples. It has the standard Near Eastern body of sandy whitish material, but in all the better specimens this body is dressed with a slip of fine white clay. On this the decoration is painted in black outlines which are filled in with brilliant blue, turquoise, green, and either manganese purple or thick red, under a clear glassy glaze. The colours are laid on with a full brush, and the Turkish designs have a distinctive character. They consist chiefly of sprays of certain flowers such as the narcissus, tulip, carnation, rose, fritillary, etc., naturalistically treated, or of arabesques of feathery leaves; and the dishes have borders of spiral clouds.

The transition from the old Persian types to the full-blown Turkish ware is abrupt; but a link may be found in the pottery of Damascus.

Outside this important city, kiln sites have been found with remains of a pottery of the 14th century Syro-Egyptian type, painted in blue and black under a clear glaze; and there is a vase with lustred decoration on a blue glaze, bearing legend "painted by Yussuf of Damascus" which implies a knowledge of the lustre technique among the Damascenes. Pottery painted in black under a blue glaze has been found in some quantity near Damascus and tiles of the same kind of ware adorn buildings in the city. Some of these have delicate Persian scroll-work suggesting a date not later than the 15th century, while other specimens have the large feathery leaf designs which appear on the Turkish wares. Finally Damascus has been credited with the manufacture of the most refined of the wares of Turkish type, distinguished from the rest by soft colours which include a dull lilac in place of the thick Turkish red, a delicate turquoise blue and sage green, and also by a certain Persian flavour in its arabesque ornaments. It must be admitted, however, that the claims of Damascus to a monopoly of this ware are more than doubtful.

The most outstanding feature of the pure Turkish pottery is a brilliant red colour, made with Armenian bole, which is laid

on in palpable relief. Its manufacture must have been widely spread over the Turkish dominions, for the ware is found effectively decorating the walls of mosques and public buildings from Adrianople to Cairo. Important centres of the manufacture were at Constantinople, Nicaea, Broussa and possibly in the island of Rhodes, though the old tradition that the ware came exclusively from Rhodes has been proved erroneous. The dating of the Turkish ware is established by the tiles on various buildings of which the history has been preserved, by a few specimens with European metal mounts and by still rarer pieces with dated inscriptions. From these sources we learn that the best period was in the 16th century, and that the quality of the ware had deteriorated by the last part of the 17th century, when the designs had become coarse and hackneyed and the ware itself dirty and yellowish. A beautiful mosque lamp of the finest Turkish ware in "Damascus" style in the British Museum bears the date 1549. A ware of such individuality could not fail to affect the pottery of other regions, and its influence can be traced on the Persian pottery of the 17th century, and particularly on the kind which is called Kubatcha.

Kutahia in Anatolia was till quite recent times a busy ceramic centre. From the 17th century onwards a pottery of Turkish type was made here, but painted with small patterns—palmettes, scrolls and flowers, scale and leaf diapers, etc.—in lively colours including blue, turquoise, green, yellow and the Turkish red. It is a crisp ware, thinly potted and sometimes engraved with criss-cross patterns in the paste. Dated specimens of the years 1719 and 1787 are known. A much more artistic ware painted in shades of blue has also been attributed to Kutahia; but this attribution rests on the reading of an inscription of a ewer in the Godman collection (Cat. Pl. LV., No. 35) which is given as follows: "This mass cruet commemorates the servant of God, Abraham of Kutahia, Anno Armen: 959" (=A.D. 1510). The date is interesting, but if the reading is correct it still leaves open the question whether the ewer was made at Kutahia or elsewhere.

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UNITED STATES

It is difficult to write an accurate comprehensive story of pottery and porcelain in the United States. There are several reasons. First, local history is inadequate. In some parts of the country where the potters did not belong to the group considered socially important, it is almost impossible to trace accurately their activities because they were seldom mentioned in newspapers or records. In other sections, the potters were among the leaders so that complete records are available. As a result, it is sometimes incorrectly supposed that certain parts of the country had practically no pioneer potters. The second reason is that until the 20th century, ceramic history centred attention on foreign developments. The third reason is that nowhere is terminology clear-cut, due to the fact that pottery began before there were printed records and has continued to spread and develop in many directions ever since so that each new development has been a gradual merging of one phase of expression into another. Such changes often took place simultaneously even in different parts of the same country. Twentieth century commercial practice added to the confusion of terms. Often manufacturers gave to their ware trade names which erroneously suggested classification within groups popularly considered valuable. Because of looseness in terminology, it was usually impossible to determine unquestionably where one classification ended and another began, or to list characteristics which could remain unchallenged as distinguishing qualities of a given group.

Historically, development of pottery and porcelain in the United States was practically a duplication of the progress of ceramic history of the world except that, due to an accumulated ceramic knowledge and new scientific and industrial processes, ceramic development in the United States took place within about 300 years, while the world development had been going on for many centuries. The history of American pottery and porcelain can be divided into three distinct periods. The first comprised pioneer pottery made by individual potters for utilitarian purposes. By gradual change, ceramics became an important industry supplying quantities of inexpensive ware made by mass production methods, and about the middle of the 19th century the decoration and making of pottery and porcelain began as an art.

Pioneer Pottery.—Pioneer pottery resulted from the use of natural local materials made simply and directly into articles needed in the everyday life of the group wherein the potter lived. As a result, the ware had a ruggedness, directness and simplicity which are usually lost as soon as civilization reaches the point where needs are less demanding.

Potteries were operated by three and four generations of the same family. The principles and problems of the potter's life were similar to those of a carpenter or blacksmith—only materials and equipment were different. Often the potter was part farmer or tradesman. Usually, the red firing clay was baked at a comparatively low temperature so that the ware was porous and easily broken. Glazes were lead or a mixture of lead, flint and clay. Workshops were fitted with a wheel and a kiln. Near by was a clay pit with a paddle turned by a mule or horse for mixing. In most cases, ware was thrown on the wheel but occasionally it was pressed into or over moulds of fired clay or wood. Often pieces were decorated with quaint designs, mottoes or patriotic inscriptions. The drawing was childlike, the craftsmanship varied.

Decoration was done in various ways. In one method, slip (liquid clay) of a different colour was painted on by means of a brush or slip cup. This was called "slip painting." Sometimes a piece was partially or completely covered by slip and later, when the piece was "leather-hard," the design was scratched through the slip. This method was known as "sgraffito." At other times a design was cut or scratched into the clay without the coating of slip. Such objects as churns, crocks, pitchers, plates and toys were made. The colours were terra-cotta, white, dark brown and yellow, with touches of green and blue. Often the ware was distributed by boat, especially throughout the Ohio and Mississippi valleys as far south as New Orleans. At other times it was sold in local stores or peddled from door to door. Some pieces are valuable historically because important events were recorded and dated. Examples of this ware can be found both in museums and in private collections. One of the best displays is in the Pennsylvania museum in Philadelphia.

The term "pioneer" potter refers more to a point of view or a stage of development than to chronology. During the colonization period, pottery enterprises spread. In each case, the simplest use of local clays made into utensils was the most logical beginning.

By the early 17th century, many pioneer potteries were established, though the exact date and location of the first potter is not known. In 1641, John Pride was working in Salem, Massachusetts. There are indications that potteries were in Jamestown, Virginia, at the time of Captain John Smith and it is known that as early as 1650 several potteries had been established in Virginia. It appears that in 1684, a pottery was functioning in Burlington, New Jersey. Dr. Daniel Coxe of London, once governor of New Jersey, caused the pottery to be built. In eastern Pennsylvania, Germans settled as early as 1735, then spread southward and westward. Beginning about 1750, over 115 potteries were recorded in eastern Pennsylvania alone, making colourful slip-painted and sgraffito ware according to the German tradition. All were small. The Bell pottery of Waynesboro boasted six wheels. It was considered large. Peter Craven, the first of the Jugtown potters in North Carolina, is said to have come from Staffordshire, England, about 1750. From that time to the present date Jugtown potters have supplied the needs of that community. The ware is shaped on the wheel and glazed with simple glazes. The first pottery

known west of the Alleghenies was built at Morgantown, West Virginia, by Foulke, about 1784, and continued until 1890. William McFarland went from Kentucky to Losantiville, later called Cincinnati, and many others followed to various parts of Ohio, Indiana, Illinois, Minnesota, Missouri and farther west. The Moravians were established in North Carolina about 1840. They were the same race and religion as the German settlers of Pennsylvania. Their ware was similar. One potter was named Brother Aust. He must have been successful because the authorities of the colonies complained that people came from a radius of 50 to 60mi. to buy. He was ordered to discontinue sales to outsiders "on account of the crowd it draws."

Refinement of Ware.—As communities became more established and there were time and money for more than bare essentials, pottery began to leave the pioneer stage. This took place as a gradual natural growth, affected tremendously by the development of the machine age and greater use of available scientific knowledge. These changes brought about increased refinement of clays, more expert workmanship, higher fire—effecting harder bodies and glazes—mould production, improved machinery and new decorative processes. Thus, generally speaking, one may say that pottery began with pioneer ware—soft, crude and red—and progressed by successive steps through Rockingham ware to a gray stoneware often glazed with salt, and on to white china and porcelain.

During the early part of the 18th century potteries sprang up in many places and great development followed. Two families, headed by John Remmey and William and Peter Crolius, established themselves at "Pot Baker's Hill" or "Potters' Hill," New York city, in 1745. The two families worked and lived as neighbours for several generations. Both families included members influential in public life. Connecticut, the birthplace of the bean-pot, led in quantity production of pottery and earthenware from 1771 to 1850. In 1793, Captain John Norton, who had learned his trade in Litchfield, Connecticut, founded a pottery in Bennington, Vermont. It functioned over a century. The ware of this period was glazed in several ways; one was by throwing salt into the fire so it would volatilize and coat the piece with sodium silicate, thus making what is known as "salt glaze ware." In a second method, a stoneware clay was coated with Albany slip, a low-burning red clay. By firing the coated piece to a high temperature, the slip melted into a beautiful brown glaze.

Beginning of White Ware.—Next came interest in a whiter ware. During the last part of the 17th century and throughout the 18th, England, France and Germany were striving to produce ware equal to porcelains from China. In the Bodleian Library at Oxford an old record indicates that "white Chiney Ware" was made at the pottery established by Dr. Daniel Coxe near Burlington, New Jersey. It may have been the first white ware made in the United States. In 1745, William Cookworthy (*q.v.*), an important potter of England, wrote referring to a "china earth" discovered in Virginia. He said, "I have lately with me the person who hath discovered the china earth. He had samples of the china ware of their making with him, which were, I think, equal to the Asiatic. 'Twas found in the back of Virginia. He has gone for a cargo of it, having bought the whole country from the Indians." Some authorities believe the samples referred to were made in the United States; others think they were made in England from clay imported into England from the United States. In a patent taken out in 1774 by Edward Heylyn and Thomas Frye of the Bow Pottery in England for the making of "china ware" it was stated that the material was "an earth, the product of the Chirokee nation in America, called by the natives 'Unaker'." Samples found at the Wedgewood factory and tested by William Burton proved that "Unaker" was a china clay.

During the 18th century, after Philadelphia had become the social capital of the United States, there was a demand for better ceramic wares to supply the needs of a well-to-do class. With this background, more refined ware began to succeed. In 1765, Josiah Wedgewood was worried because potteries were being established in the American colonies. Referring to the colonial market, he wrote, "We cannot make anything too rich and costly."

For about 100 years, potters tried to make chinaware before they were able to record commercial success. During that time, numerous fortunes were lost. Many of these efforts took place in or near Philadelphia. Alexander Trotter was mentioned in 1808 as a leading manufacturer of Queensware (earthenware). Another Philadelphia potter was Abraham Miller, member of a family of potters, an expert modeller, member of the State senate, and a leading member of the Franklin Institute. In 1824, he exhibited a silver lustre pitcher and a specimen of porcelain. In 1842, he showed decorated plates, vases and ornamental flower pots. By the time he died in 1858, excellent American porcelain was being made, equal in quality to the best produced in England. Around 1850, American potters began to succeed in producing a vitrified earthenware and parian—a hard, unglazed white ware, which required fewer skilled workmen and presented no problems with glaze and colour. Later, a modified parian appeared as a very thinly cast glazed ware. It was called Belleek. Although small amounts of high grade white ware had been made, it was not until about 1825 that porcelain was manufactured in any quantity. About 1820, William E. Tucker, a member of a Quaker family of educators in Philadelphia, undertook to decorate imported white ware by the overglazed process. Soon he became interested in making his own ware for decorating. The beginnings were crude, but several medals were earned. In 1825, he succeeded in making hard-paste porcelain. Eventually, there were financial struggles and changes in partnerships until, in 1832, Joseph Hemphill joined the firm, bringing financial backing and a great capacity for business. Soon Tucker died and Hemphill imported capable workmen from Europe. As a result, the firm experienced a period of producing excellent ware of expert workmanship and a better quality of design.

Moulds for Quantity Production.—In 1859, the demand for cheaper domestic ware had grown sufficiently to enable potters to establish themselves on a sounder financial basis. Mould making was being carried on as a trade by men who made and sold moulds, though exclusive rights were not yet practised. Small potteries often purchased their moulds from a mould maker or a defunct potter. Probably no one person contributed as much practical information toward this change in production as William Bloor. In Trenton, New Jersey, from 1854 to 1859, he was associated with James Taylor and Henry Speeler who established the first pottery factory in Trenton in 1852. In 1856, a medal was awarded the firm by the Franklin Institute of Philadelphia. In 1859, he went to East Liverpool from whence he had come in 1854. There, in 1860, he manufactured on a commercial scale the first white ware to be made in East Liverpool, Ohio, now one of the great pottery centres of the world. The ware was translucent and well vitrified. Most of it was made in moulds and skilfully decorated with designs painted by expert workmen. This success had a great influence on the production of moderately priced white ware. In 1865 he returned to Trenton, which at that time was America's pottery centre and helped establish the firm which later became the Eutreria pottery where a high quality Belleek china and fine ivory porcelain were made.

In 1870, he went back to East Liverpool where he supplied the potteries with materials from mines he had discovered and owned in New England, Maryland and Missouri. Later, he helped establish the Dresden pottery of which firm he was a member when he died in 1877. In the *Journal of the American Ceramic Society* it is stated of Bloor: "Giving information freely to competitors in Trenton and East Liverpool, the transition from yellow ware to white ware was quickly made under Bloor's tutelage. Americans were ready and able to purchase white ware made on Bloor's formulas and by Bloor's methods. Thus the white dinnerware industry of Trenton and East Liverpool was started by Mr. Bloor."

One pioneer in the manufacture of pottery in Trenton, New Jersey, told how he had travelled over the States of New York, Pennsylvania, Delaware and Ohio, searching for the best place to manufacture pottery. He had chosen Trenton because it was between the two great markets—New York and Philadelphia—and because the section was healthy, abounding with fine clay and convenient for the collection of other materials by canal or river.

Referring to development during a few years following 1861, he wrote: "If the business increases at the same ratio, Trenton is destined to be the Staffordshire of America and in 50 years hence but little ware will need to be imported." In 1890, Mrs. Benjamin Harrison wished to buy domestic tableware for the White House but could find nothing suitable. It was not until 1918 that Lenox, Incorporated, Trenton, New Jersey, supplied the White House with the first American-made table service.

Imported Workmen.—Far-sighted manufacturers often brought skilled workmen from France, England and Germany to improve the quality of their ware. About 1835, Joseph Hemphill of Philadelphia imported experts from Sevres who produced pieces more or less copies of Sevres ware. In 1843, Julius Norton, the third generation of potters at Bennington, Vermont, brought over John Harrison, modeller from Copeland; he brought many of the latest moulds and designs being used in England. About the middle of the 19th century, Charles Cartlidge and Company of Green Point, New York, brought Josiah Jones from the Staffordshire pottery in England. He was a designer, modeller and ceramist. Soon after his arrival he imported Elijah Tatler, a decorator of great ability. In 1853, the firm sent ware to the International exhibit in New York. It included tea and dinner sets in bone china, as well as earthenware and statuettes, modelled by Jones. There are good specimens of these in the Metropolitan museum and the Pennsylvania museum.

Handicaps.—From the beginning, unfamiliarity with new materials was a definite handicap to the potter. One who had been a master workman in the old country might find himself bankrupt in the new country before he became accustomed to materials. Since there was little scientific ceramic knowledge he had to discover correct materials and proportions by the trial and error method before his funds were depleted. While the problems of new materials were being overcome, and better ware was being developed, a more sophisticated social life was evolving so that the potter had to deal with a public prejudice against American-made ware. Sometimes the cause of the prejudice was due to the fact that American-made ware was more crude, but often people considered it elegant to use imported ware. The European manufacturers encouraged that feeling. At times there was sabotage among the American workmen, sympathetic with the mother country. At other times the markets were temporarily flooded with ware to be sold at a price the local manufacturer could not meet, so that the potter had to go out of business or move to a section where there was less competition.

Toward the end of the 19th century, there were other handicaps. Both in Europe and the United States, emphasis had been placed upon improved techniques for mass production at the expense of sound design. As a result, many pieces were created primarily as demonstration of technical skill with little thought of good design. Eventually there was a reaction, especially in Europe where simpler and better design began to replace the extravagantly ornate. The designers in the United States still clung to the type of design traditional with the designers, who were usually old countrymen. Conservatism and prejudice against ware made in the United States lasted well into the 20th century.

Ceramics Becomes Scientific.—Up to the end of the 19th century, ceramic information had been guarded and handed on from generation to generation. New discoveries were kept secret and experimentation was carried on by rule of thumb. While working on the minerals from 1884 to 1894, Edward Orton, Jr., discovered a dearth of literature concerning the science of ceramics. Being a public spirited, practical man, he succeeded in getting sufficient support for a law authorizing the establishment of a ceramic department at Ohio State university in Columbus in 1894. It was the first school in the United States for the scientific study of ceramic engineering. Not long after that the New York State College of Ceramics was established at Alfred, New York, with Charles F. Binns as its director. Dr. Binns had had life-long acquaintance with ceramics since his father was a factory superintendent in England and he himself was for some time superintendent in the Royal Porcelain Works at Worcester, England. Soon other States had established similar departments. At these schools scientific methods were developed for compounding efficient bodies and glazes and for solving problems encountered by the potters. The ceramists turned more and more to the fields of chemistry, physics, geology, mineralogy, microscopy and other sciences to discover what those fields might contribute.

Under the leadership of Edward Orton, Jr., the American Ceramic Society was founded in 1898 to co-ordinate ceramic interests and further progress. Its work was carried on by meetings, by collecting, publishing, and distributing available ceramic information and by encouraging research. Thus ceramic knowledge became accumulative so that early in the 20th century a person successfully completing a four-year ceramic course had the opportunity of a better understanding of the science of ceramics than a master under the old system could have had after working a lifetime.

As trained ceramists were gradually absorbed into the potteries, they greatly influenced production—making better-wearing bodies and glazes and developing cheaper factory methods. However, because emphasis was put on science and technique, at the expense of good design in form, colour and decoration, the country was soon producing ware which was of the best technically but the designs were often copies of European patterns or a conglomeration of patterns produced under a variety of conditions. As a result, the ever-developing taste of the American public continued to be prejudiced in favour of imported ware, but this time for a different reason. It was no longer the quality of the ware or workmanship which was responsible for the prejudice but instead lack of beauty and distinction and the absence of that intangible quality which comes from the hand of a skilled creator but is lost by one who copies—regardless of how accurately the work is done.

Pottery and Porcelain as an Art.—About the middle of the 19th century, European women were interested in doing over-glaze decorating. The idea spread to America where it became fashionable for women to go to Europe to study the subject. In 1879, the Cincinnati Pottery Club was formed by a group of women for the purpose of encouraging sound pottery production. They did under- and over-glaze decoration and made porcelain. Much credit is due this pioneer work. In 1891 the National Ceramic Association was founded. Ten thousand women were actively engaged in the United States working at ceramics. Five thousand earned a living doing over-glaze painting. The association was organized in Chicago where there were 1,000 pottery decorators. The object was to advance the art and secure the finest possible exhibition for the World's Fair. In 1892 Mrs. S. S. Frackelton of Milwaukee, Wisconsin, organized the "National League of Mineral Painters." Its aim was to bring into closer relationship the over-glaze painters in order to define lines of study and to aid in the development of a national school of ceramic art. At one time the membership became as high as 500 women. They exhibited in many places and took part in international expositions, often winning recognition for exceptional achievement. Later, Mrs. Frackelton did excellent work with salt glaze in an effort to use a humble material as a medium for artistic expression. She received honours at home and abroad. Many of the decorators became interested in creating the forms they were to decorate. Some of those creating the forms continued to expand until a business or profession was established. As a result of the activity of the Cincinnati Pottery Club, the Rookwood pottery developed. The Pewabic pottery was established by Mrs. Stratton in Detroit. Mr. and Mrs. A. Robineau in Syracuse, New York, turned to porcelain, carved decoration, crystalline and other glazes. Also, they were in charge of a ceramic department at the University of Syracuse. Charles F. Binns in his work at the New York State College of Ceramics lent valuable support to the expression of ceramics as an art. Besides helping to organize the science of ceramics, he made excellent stone ware of the quality of the Chinese. He knew factory methods and was an expert craftsman who often explored the historical background of ceramics. Because of his broad interests and high standards, he was an inspiring teacher in the field of ceramic art. Many excellent ceramic artists were trained by him and valuable research was done under his direction.

It was only natural that the increased interest in the art ex-

pression of ceramics should result in new scientific developments among the artists and improved design for individual and manufactured ware. To study and further these ends, a section of the American Ceramic Society was organized which was known as the Art Division of the American Ceramic Society. Work of the division is carried on through regular meetings, exhibitions and research reports and other articles published in the *Journal of the American Ceramic Society*. The most important regular exhibition is organized annually at the Syracuse Museum of Fine Art as a Robineau Memorial Ceramic Exhibition. It was started in 1932 by Ann Wetherill Olmstead, director of the museum. Because of Miss Olmstead's work, American potters were invited to send an exhibition to museums in the Scandinavian countries, to England, and to many important museums and galleries of the United States. As a result of various efforts the quality and appearance of work done by studio potters improved greatly during the first half of the 20th century and the design of ware for reproduction methods is given increasing attention.

After about 150 years of technical, financial and artistic struggle, it is encouraging to find that in 1940, the best of the United States pottery and porcelain is as good in quality and design as any made. Ceramic artists in many parts of the country work as designers, studio potters and teachers; the number increases steadily and standards constantly improve as the general public learns to understand the beauty of fine ceramics.

Many States have tax-supported ceramic schools. Art schools advocating better designs for industrial use encourage the ceramic department to study mass production possibilities and methods along with the craft of the potter. Pottery work is taken more and more seriously in public schools. The national, State and local governments are sponsoring the making of pottery as an art expression. A U.S. ceramic experiment station is in the Tennessee Valley. (*See* also NORTH AMERICA: *Archaeology.*)

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POTTER'S CLAY: *see* CHINA-CLAY.

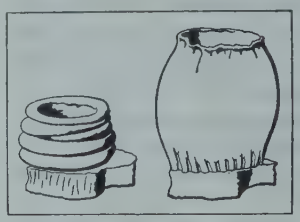
POTTERY, PRIMITIVE. Receptacles of some kind are essential to man, however primitive, and are made of basketry, skins, gourds and other suitable natural objects. But over all these pottery has an advantage, for it can be brought into contact with fire and not be destroyed, and it is therefore valuable for cooking purposes.

Pottery-making is not universal, however; partly because its construction is not easily carried on under certain cultural conditions, *e.g.,* a nomadic life; partly because it depends upon suitable materials being available, though sometimes potters obtain their clay from other districts. It is absent from large regions of America, and in certain islands of the west Pacific has become a lost art. The knowledge of pottery-making was, at one time, believed to mark a stage in the cultural development of mankind, but its presence among such peoples as the Andamanese, Eskimo, Bushmen and Hottentots, and its absence among the advanced Polynesians, make this questionable.

The manufacture of pottery falls into five stages: preparing the *body* or raw material; shaping the pot; drying and firing it; decorating it; and varnishing or in some other way rendering it non-porous. This last is often lacking in the pot-making of primitive peoples, but the other four processes are found in the manufacture of the simplest wares.

As regards the raw material, it seems that the clay is frequently dug and seasoned for a while before using. Clays vary very greatly. Those which are highly plastic and hold the water, though convenient for working, are liable through excessive shrinkage to crack in the drying or firing of the pot and must therefore be *opened* by mixing them with non-plastic materials. Sand is often used to this end, or carbonaceous materials such as chopped grass, cinders, dried cow or donkey dung; frequently old potsherds are ground up for this purpose. In mixing the *body,* the proportion of clay, *opener* and water necessarily varies greatly and is judged empirically by the potter.

Shaping.—The body having been prepared, the next stage is the shaping. There are three main ways of doing this: by hand, with the aid of a few simple implements; by moulding; and by throwing on the potter's wheel. Of these, the first is by far the most common. There are two hand techniques—modelled and coiled. The simplest way in which a pot is modelled is that used by the women of the Baronga in South Africa. Having kneaded the body into a very soft ball, the woman "makes a hole in it, which she enlarges by degrees, hollowing it out and gradually giving it the shape she wishes. . . . It is astonishing to see the beautiful symmetry of these utensils." (H. Junod, *The Life of a South African Tribe.*) If the pot is to be a big one, the initial lump of clay may not be enough and more is added to build up the walls of the vessel. Frequently the pot is modelled in parts, which are then welded together.



FROM DALE & SMITH, "THE ILA SPEAKING PEOPLE OF NORTHERN RHODESIA" (MACMILLAN)

FIG. 1.—STAGES IN PRIMITIVE POTTERY PRODUCTION
Left, rings of clay piled up. Right, walls completed by scraping the clay upwards

In the coiling technique, the raw material is rolled out into a slender rope which is coiled upon itself (fig. 1).

The coils are carefully worked together with the fingers and the unevennesses smoothed away, so that, when the pot is finished, no trace of them is visible except occasionally in faint ridges on the inner surface. The modelled and coiled techniques may be combined; the base of the pot is modelled from a lump and the coils built up on this.

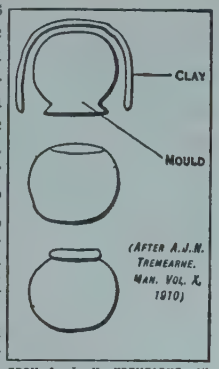
Certain tribes used baskets for moulds. These were subsequently burned in the firing. A similar method is used by shaping the belly of the pot over a ring of vegetable fibre, then adding the neck and base. In these examples a mould is destroyed with every pot made. More advanced is the method by which one mould is made to serve several times. Among the Hausas of Nigeria, a pot is inverted and over this a sheet of clay is spread so as to form a bell-like dome. This is then removed from the mould and the shoulders and neck modelled by hand (fig. 2). A moulded pot may be made in two or more sections, then joined.

Shaping a pot by means of throwing on the wheel is little known among primitive peoples, because primitive potters can make by hand pots which rival those thrown and because it takes years to learn to throw expertly.

Drying and Firing.—When a pot is finally shaped, it is necessary to render the clay hard by firing it. The material of which a vessel is composed contains a certain amount of free water which can be removed by leaving it to dry or be sun-baked for a time; but it also contains a quantity of combined water which is only liberated at a temperature of from 350°–400° C. If only sun-baked, the vessel when filled with water would absorb this and after a short while collapse into a shapeless mass. But when the combined water has been liberated the clay is completely decomposed; it is impossible for it to become malleable again and it will hold water safely. Except, therefore, for certain pots which are destined only to contain grain and other dry goods, all vessels must be fired.

After being shaped the pot is set aside to dry for some hours, usually where there is a free current of air. Except in a few cases, ware is fired but once. Usually the firing is done in the open. The pyre is carefully built and the pots stacked so that the heat may circulate freely. A genuine kiln has only been recorded from the region of the Lower Congo. It seems to be a beehive shaped structure. The more common primitive practice is to bake the ware in a hole in the ground. The "oven" is fairly elaborate, for charcoal is used and openings are therefore cut through the soil to the chamber that bellows may be employed to sustain the

necessary heat. The time taken for firing varies greatly, from about half-an-hour to two days. Pots which have been fired for only a short time are less durable than others. There is great diversity of shapes and an amazing similarity in wares widely separated from each other in time and space. Some elaborate forms have a utilitarian purpose, others a religious significance, while others appear to be the outcome of the artist's desire to create something beautiful. In many cases, the pots are modelled in imitation of natural or manufactured objects, which before the introduction of ceramics served the people as vessels.

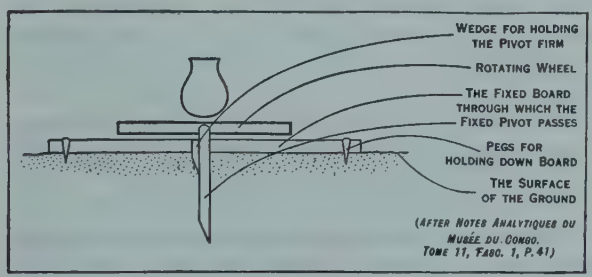


FROM A. J. N. TREMEARNE, IN "MAN"

FIG. 2.—POTTERY MAKING
1. Clay spread over inverted pot, 2. Clay removed from mould and shaped, 3. New pot with roll of clay for modelling mouth

Decoration and Colour.—In most primitive pottery decoration is done by means of incised lines, made with a pointed stick, thumbnail or coil of rope. Sometimes wooden stamps are used or the "beater" with the aid of which the pot is modelled is carved or wrapped about with string and the designs may be but the marks thus left on the surface. Where pots are moulded over baskets, the clay will be decorated by the impress of these. The most usual designs are bands of chevrons or other rectilinear skeuomorphs, though animal and plant, and occasionally human motifs, do occur. To increase the effect, the incisions are often filled with powdered lime or some other substance which shows up against the dark background of the vessel. Less common are ornaments applied to the surface such as knobs, scrolls and figurines. Raised designs are also produced by pressing out the wall of the pot from within. Another method, of restricted distribution, is that of scraping away the surface so as to leave the figures in relief.

The colour of a vessel is to a great extent dependent upon the composition of the body and the method of firing. Of materials present in bodies, iron is usually the only colouring element. This, on being subjected to heat under oxidizing conditions, is changed into a red iron oxide and gives a shade varying from yellow to an orange or red; under reducing conditions producing a colour which ranges from light bluish gray to a deep, sometimes metallic, black. Usually among primitive peoples no effort is

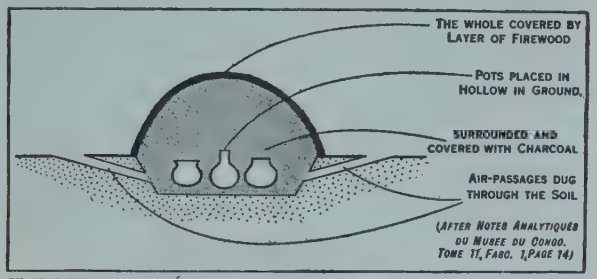

WEDGE FOR HOLDING THE PIVOT FIRM
ROTATING WHEEL
THE FIXED BOARD THROUGH WHICH THE FIXED PIVOT PASSES
PEGS FOR HOLDING DOWN BOARD
THE SURFACE OF THE GROUND
(AFTER NOTES ANALYTIQUES DU MUSÉE DU CONGO. TOME II, FASC. 1, P. 41)

BY COURTESY OF MUSÉE DU CONGO BELGE

FIG. 3.—DIAGRAM OF POTTERY MOULDING MACHINE

made to produce certain shades by regulating the conditions of the firing. A dark colour is often the result of a pot's being smoked; this may be an unintentional incident of the firing, but among the Ashanti it is brought about by setting the vessel, while still red-hot from the furnace, on a heap of dry tinder. This it ignites. Water is then poured on and the pile is left smoking. The smoke permeates the heated clay and deposits on and sometimes through it a mixture of finely divided tar and carbon, rendering it non-porous. Decoration by means of slip is occasionally found, but true painted pottery is extremely rare among primitive peoples.

Varnishing.—Fired pots are nearly always porous. They are therefore frequently varnished and this varnish is often decorative as well as useful. Many different methods are employed to treat the surface with a resin, gum, fat or gelatinous substance. Similar in artistic effect to varnishing but without so great utilitarian value is the practice of polishing or burnishing the ware, but this is only possible where the clay is of a fine body. Though vessels are the most common pottery products of primitive peoples, other things are sometimes made, such as tobacco pipes, drums, toys and figurines.


THE WHOLE COVERED BY LAYER OF FIREWOOD
POTS PLACED IN HOLLOW IN GROUND.
SURROUNDED AND COVERED WITH CHARCOAL
AIR-PASSAGES DUG THROUGH THE SOIL
(AFTER NOTES ANALYTIQUES DU MUSEE DU CONGO. TOME II, FASC. 1, PAGE 14)

BY COURTESY OF THE MUSÉE DU CONGO

FIG. 4.—DIAGRAM SHOWING PROCESS OF BAKING POTTERY

Sociological and Religious Aspect.—Little attention has as yet been paid by ethnologists to the religious and sociological aspects of pot-making. Generally the craft is confined to one sex, usually the female, except where the potter's wheel is used, which is always operated by men. In so far as domestic utensils are naturally matters which concern women it is not strange that they should be the potters, but this does not explain why, in many cases, men are definitely prohibited from potting nor why their very presence during the manufacture is inimical to it. Thus among the Sema Nagas of Assam a man may not even speak to a woman thus engaged nor approach her work. The making of ceramics is often the prerogative of certain families or a certain district and any infringement of this may easily cause trouble. Even where this is not so, certain villages become famous for their wares. Theories of origins are necessarily speculative, but in evolving them it must not be forgotten that clay shaped and burnt does not produce a pot. The body must be properly prepared, the vessel properly dried and fired under suitable conditions. The accidental discovery of pottery, therefore, is not so easy as has sometimes been implied.

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POTTHAST, AUGUST (1824–1898), German historian, was born at Höxter on Aug. 13, 1824, and was educated at Paderborn, Münster and Berlin. He assisted G. H. Pertz, the editor of the *Monumenta Germaniae historica*, and edited the *Regesta pontificum romanorum, 1198–1304* (1874–75). From 1874 to 1894 he was librarian of the German Reichstag. Potthast compiled the monumental and indispensable *Bibliotheca historica medii aevi* (1862; new enlarged ed., 1896), a guide to the sources of European history in the middle ages. The work, in the form

of an index, gives particulars of practically all the historical writers of Europe and their work between 375 and 1500. Potthast died on Feb. 13, 1898.

POTTINGER, SIR HENRY (1789–1856), British administrator, was born in Ireland, Oct. 3, 1789. In 1804 he became attached to the British army in India and during the next 35 years served successively as collector of Ahmadnagar, resident of Cutch and resident of Sind. In 1840 he was appointed envoy and plenipotentiary to China, a war having broken out between Britain and that country over the opium trade. In 1842, the struggle having been successfully terminated, Pottinger was responsible for the drawing up of the treaty of Nanking, the terms of which included the cession of Hong Kong to Britain. He was made governor and commander in chief of Hong Kong in 1843, the first to hold that office under English rule. He held the governorship for a year and subsequently served for a short time as governor of the Cape of Good Hope (1846–47). In Aug. 1847 he was appointed governor of Madras, where he remained until 1854.

Sir Henry died at Malta, March 18, 1856.

POTTO, the name of the West African slow lemurs, *Perodicticus* and *Arctocebus,* popularly miscalled "sloths." The aborted condition of the index finger is their most distinctive feature. The ordinary potto (*P. potto*) is about the size of a squirrel, with large staring eyes and a stump of a tail; its colour is rufous brown. It occurs from the Gold Coast to the mountains of Kenya. The awantibo (*Arctocebus calabarensis*), nearly allied, of Old Calabar, has no tail (*see* PRIMATES).

POTTSTOWN, a borough of Montgomery county, Pennsylvania, U.S.A., on the Schuylkill river, 40 mi. N.W. of Philadelphia; on federal highway 422; served by the Pennsylvania and the Reading railways. Pop. (1950) 22,589; (1940) 20,194. It is the centre for a population of 90,000 and has important manufactures, notably tires, tubes, plastics, fabricated steel, die castings, pipe fittings, automotive and aviation parts. In a natural park 3.5 mi. N. are the "ringing rocks," covering about 150 ac., which give different tones of the musical scale when struck. Pottstown was founded in 1753 by John Potts, and was called Pottsgrove until 1820. It was incorporated as a borough in 1815. In this neighbourhood the first commercially important iron furnace in America was established in 1716.

POTTSVILLE, a city of Pennsylvania, U.S., the county seat of Schuylkill county; on the Schuylkill river, 90 mi. N.W. of Philadelphia. It is served by the Lehigh Valley, the Reading and the Pennsylvania railways. The population in 1950 was 23,640; in 1940 it was 24,530 by the federal census. It has a picturesque location (627 ft. above sea level) at the gap made by the river through Sharp mountain and is in the midst of the southern ("Schuylkill") region of the anthracite coal field. Besides its large coal-mining interests, it has railroad shops and a variety of manufacturing industries, including textiles, aluminum and steel fabrication. The city operates under a commission form of government.

The first white family that settled there was massacred by the Indians in Aug. 1780. Permanent settlement dates from about 1795, and soon after that an iron furnace was set up. In 1804 this furnace was bought by John Potts, founder of the borough. Coal was discovered in 1807.

The town was laid out in 1816, incorporated as a borough in 1828, became the county seat in 1851 and was chartered as a city in 1911.

Pottsville was a centre of the Molly Maguires (*q.v.*) disturbances (1854–77), subject of a book by Allan Pinkerton, the detective, and of *The Valley of Fear* by A. Conan Doyle. Some of the leaders were tried there and convicted in 1876–77.

POUCHED MOUSE: *see* MARSUPIAL MOUSE.

POUGHKEEPSIE, a city of New York, U.S., the county seat of Dutchess county; on the east bank of the Hudson river, midway between New York city and Albany. It is on federal highway 9E, and is served by the New York Central and the New York, New Haven and Hartford railways and river steamers.

The population in 1950 was 41,023; by 1940 federal census 40,478. A cantilever railroad bridge, 6,767 ft. long, with approaches, and 200 ft. above the water, spans the Hudson at this point, and a highway bridge there was completed in 1930. The city is built on terraces rising to 200 ft. above the river. On its eastern boundary is the extensive campus of Vassar college (*q.v.*), and 2 mi. N. of the city is the Hudson River State hospital (1871).

There are several private schools in the city and several charitable institutions, including a hospital (1878) and a home for old men (1881) founded by the Vassar brothers. The manufactures are numerous and widely diversified. The city's assessed valuation for 1950 was $59,559,308. Poughkeepsie was settled by the Dutch about 1687. It was incorporated as a village in 1799 and as a city in 1854.

The New York legislature met there in 1778, 1780, 1781, 1782, 1788 and 1795, and there on July 26, 1788, the state convention ratified the federal constitution.

The name is a modification of an Indian word, meaning the reed-covered lodge by the little water place.

POULENC, FRANCIS (1899–), French composer, was born in Paris on Jan. 7, 1899. His first important work, the *Rapsodie Nègre,* played in Paris in 1917, excited much interest as the work of so young a composer. It was followed by *Le bestiaire* and *Cocardes* (1919) and *Quatre poèmes de Max Jacob* (1921) for solo voice and chamber orchestra. In 1920–21 he wrote the comic opera, *Le gendarme incompris,* for one violin, one violoncello, one double-bass, one clarinet, one trombone and triangle. His works include a ballet, *Les Biches* (1924); a cantata, *Figure humaine* (1943); and the comic opera, *Les Mamelles de Tirésias* (1944).

POULSEN, VALDEMAR (1869–1942), Danish engineer, was born at Copenhagen, Nov. 23, 1869. He became an assistant in the technical section of the Copenhagen telephone establishment and in 1898 invented the telegraphone, an electromagnetic phonograph capable of registering human speech by the alternating magnetization of a wire. Poulsen's device was the forerunner of the modern magnetic sound recorder developed for commercial use by Armour Research foundation of the Illinois Institute of Technology.

In 1900 W. du B. Duddell (*q.v.*) devised his singing "arc" by connecting an inductance and a capacity with an ordinary arc; and in 1903 Poulsen invented a modification of this by means of which he produced continuous oscillations of frequencies used in wireless telegraphy (*q.v.*), thus solving one of the greatest problems in the science of radio technique.

POULTRY AND GAME. The term poultry includes fowls, ducks (domestic), turkeys, guinea fowl and geese; the word game is usually applied to wild duck, partridges, grouse, pheasants, quails, deer (venison) and other edible wild birds and beasts. Rabbits, hare and pigeons are usually classed with game.

Poultry and game may be cooked in a variety of ways: roasted; boiled; grilled; stewed in various forms; boned and made into galantines; baked in pies, puddings, vol-au-vents, pasties, etc.; combined with cereals, jellies and special sauces, or pounded and used for spreading on pastry or bread and butter.

Preparation of Game and Poultry.—Poultry and feathered game should be plucked and then singed to remove any stray hairs or feathers. It is easier to pluck poultry when warm. The neck is cut off at the shoulder, leaving the skin. There are two ways to draw poultry. The English loosen the skin around the vent with the point of a knife, lay the bird on a board, back uppermost, make a small incision in the skin of the neck lengthwise, insert the fingers through the opening and draw out the entrails, being careful to avoid breaking the gall. Americans cut a slit from the vent of about two inches and draw out the entrails from there. The gizzard, from which the inner bag has been removed, heart and liver are saved for giblet gravy or used in the stuffing. The bird is then washed thoroughly inside and out with cold water. Chop off the ends of the claws and fold back the pinions in the form of a triangle; turn the bird over and bend back the legs toward the neck. Either pin in place with a skewer (if a small bird) or use a trussing needle and stitch through the bird under the knee-bones, at the same time securing the flap and pinions. Birds which need larding should then be covered with

bacon fat.

Roasting.—Birds which require stuffing should be filled with a suitable forcemeat (chopped meat, spiced and seasoned) which ought, if possible, to include the pounded liver of the bird. Turkeys and large fowls (capons) are frequently stuffed with veal and ham forcemeat flavoured with lemon peel and nutmeg or with chestnuts; geese and ducks with sage and onions chopped finely and mixed with other forcemeat ingredients, and ducks are occasionally stuffed with prunes and apples. Roast wild duck, widgeon, teal and most small game birds are generally served without stuffing, though pheasants may be stuffed with chestnuts. To keep game birds moist while cooking, a small piece of butter or rump steak is often placed inside the bird. Small birds should be protected with a buttered paper or larding. To roast very small birds, *e.g.*, larks, place them on a skewer.

The best way to roast a haunch of venison is to wrap it in buttered paper and seal this over with a flour and water paste. Ordinary dripping is used for basting poultry and venison, but butter is preferable for basting game birds. About 10–20 minutes before poultry and game have finished cooking remove buttered paper or larding and dredge with flour.

A good gravy with roast poultry or game is essential. Stuffed birds need a thickened gravy. Bread, cranberry, mushroom or chestnut sauce may be served with turkey, and sausages or bacon is a common addition. Roast fowl, pheasant, partridge and grouse are all usually accompanied by rashers of bacon and bread sauce. Water-cress is used as a garnish. Fried breadcrumbs are served with partridge, pheasant and grouse. Red currant jelly should always accompany roast venison and hare. Apple sauce is substituted for bread sauce in serving roast goose.

Poultry is boned and stuffed to form a galantine. Remove the head and feet; then draw the bird. Divide the skin down the back with a sharp knife and turn down the flesh from the ribs, breast and side bones, leaving these as bare as possible. Pull legs and wings carefully out at the sockets, cutting the sinews through with a knife, and turn these inside out with the rest of the outside skin. Free the skeleton and turn the skin outwards again. Stuff the bird to restore its original shape.

Other Methods of Cooking.—All poultry may be boiled in the same way as butcher's meat, *i.e.*, in a well-flavoured stock (*see* COOKERY) and served with different sauces, *e.g.*, boiled chicken and egg sauce. As a general rule, game is not boiled. Both game and poultry are used for making entrées and these may take the form of elaborate stews (brown stews flavoured with special condiments, such as mushrooms, truffles, orange peel, vegetables, etc.); salmi of game; timbales (moulds of cold poultry and game); creams (purées with cream and egg liaison); fricassées; blanquettes; spatchcock of game (split bird grilled and served with melted butter to moisten); jellies (cold game and poultry purées formed into shapes and masked with aspic or white sauce, or both mixed together); minced game and poultry formed into rissoles or croquettes and dipped in batter, rolled in pastry or dipped in egg and breadcrumbs and fried in deep fat.

In the making of soups, game and poultry are also used as foundations, and any game or poultry may be used for making raised pies, ordinary pies, pasties and vol-au-vents. Where sufficient giblets are available these may also be used for pie-making. To prepare giblets, first scald them and remove any outer skins, such as tough skin adhering to gizzards, etc., take out crop and remove gall. Cut into convenient pieces and partially stew before adding to the pie.

Rabbits and Hares.—For roasting, rabbits and hares are first cleaned and then filled with stuffing; after which they are sewn up. Extend the fore-legs straight along the sides and skewer through the body. Bring the hind-legs forward and bend back the head on to the shoulders and fix into place by passing a skewer through the mouth into the body. For stewing, brown the meat in the same way as for meat. Rabbits may also be curried. For jugged hare, skin and clean the hare, joint it and remove the liver; place in an earthenware pot and add a bunch of sweet herbs, onion stuck with cloves, blade of mace, piece of lemon rind, celery seed or stalk of fresh celery, carrot and a few button mushrooms. Cover with stock. Cook slowly until the flesh is tender. Strain off the gravy and thicken with flour, pounded liver and some of the blood of the hare. Stir in one tablespoon of red currant jelly, one tablespoon of Worcester sauce and a dessertspoon of mushroom ketchup. A wineglass of port wine is frequently added to this dish. Serve with fried or poached forcemeat balls and red currant jelly.

POULTRY AND POULTRY FARMING. In practically all countries poultry farming for the purpose of producing meat and eggs for table use is carried on to some extent. In fact, few other agricultural enterprises are so widespread, and in Eire, China, Canada, Denmark, England, Australia and the United States and some other countries, the poultry industry is one of the leading branches of agriculture. Within each country the egg and chicken business is by far the most important branch of the poultry industry.

In most countries turkey production is carried on to a limited extent only, although in the United States it is a relatively important enterprise. The raising of ducks for eggs is an industry of moderate importance in England, the Netherlands and Belgium and for meat production primarily in the United States. Geese are raised exclusively for meat, goose production being of limited importance in practically all countries except Germany and in one or two other European countries. The raising of guinea fowl for meat production is of relatively little importance in any country.

In all countries most flock owners of chickens are primarily interested in egg production because more income is obtained from egg production than from chicken-meat production. In certain sections of some countries, especially France, England and the United States, however, producers receive practically all of their poultry receipts from market poultry. It is true, of course, that on farms where egg production is the primary consideration most of the males raised each year are sold as broilers, fryers or roasters.

Domestic breeds of chickens descended from the jungle fowl of India. The numerous modern breeds of chickens known throughout the world may be conveniently classified into the following five classes, on the basis of their origin: English, Asiatic, American, Mediterranean and Continental European. The breeds belonging to the Mediterranean class are for the most part somewhat smaller in body size and more active than the breeds belonging to the other classes. Also, Mediterranean breeds lay white-shelled eggs, become broody relatively seldom, and have white ear lobes whereas most of the breeds belonging to other classes lay brown-shelled eggs, are likely to become quite broody, and have red ear lobes. The Mediterranean breeds are not as well suited for meat production as most of the other breeds. The Asiatic and some of the Continental European breeds have feathered shanks whereas other breeds have nonfeathered shanks.

Principal Breeds and Varieties.—Although there are more than 100 breeds and varieties of chickens, the number kept primarily for meat or egg production or both is very limited, several breeds and numerous varieties having been developed because of some unique structural character, such as an odd shape of comb or the presence of a crest on the top of the head, or because of the beauty of the plumage pattern. All birds belonging to the same breed have the same shape. Varieties within a breed differ with respect to colour of plumage. There are numerous Bantam breeds, kept by some poultrymen as novelties. Only the more popular breeds and varieties of outstanding economic importance can be discussed here.

Australorp.—This breed originated in Australia and was developed primarily as an egg producer, although its medium size makes it a good meat bird. The comb is single, the skin white and the plumage black. It is kept to some extent in the United States but is more popular in Australia.

Dorking.—The Dorking is an English breed and of the three varieties, the White, the Coloured, and the Silver Gray, only the last named variety has assumed importance in England. Dorkings have long, broad, deep and low-set bodies and five toes, most other breeds having four toes. The Silver Gray Dorking has a single comb and white skin, is an excellent meat bird and is used

to a considerable extent in England for crossing with some of the Game breeds.

Leghorn.—Of the 12 different varieties of Leghorns, only the Single-Comb White is kept extensively in any country. The Leghorns belong to the Mediterranean class. White Leghorns have been bred to a high level of egg production in England, Canada, Australia and the United States and for years have occupied a very prominent place on commercial poultry plants devoted to market egg production. Its white-shelled egg and yellow skin enhance its popularity, although Leghorns do not make as good table birds as most of the larger sized breeds. For market egg production, exclusively, and for economy of production the Single-Comb White Leghorn is pre-eminent.

New Hampshire.—The New Hampshire is an American breed, with single comb and yellow skin, popular in the United States and Canada as an egg and meat producer. In both sexes the plumage over most of the body is chestnut red, and there is some black in wing and tail feathers; in the male the hackle and saddle feathers are reddish bay. Well bred New Hampshires grow fast and mature early and for that reason have been used extensively for the production of broilers and fryers. For this same purpose New Hampshire females are crossed with Barred Plymouth Rock males with good results.

Orpington.—This is a single-combed English breed of which there are four varieties: Buff, Black, White and Blue. The Buff and White varieties have enjoyed more popularity in England than the other varieties. The Orpington is an egg producer of moderate ability as compared with the Leghorn and the more popular American breeds. The white skin is largely responsible for the raising of the Buff variety in the middlewestern section of the United States, where a dressed carcass with a light-coloured finish is sometimes desired.

Plymouth Rock.—Among seven different varieties of this American breed, only the Barred and the White varieties have assumed a place of economic importance, although the Buff variety is kept to some extent. The comb is single and the skin is yellow. In the Barred variety the black and white bars should be of equal width in males, and the white bars should be one-half as wide as the black bars in females. In both sexes the end of each feather is black. In the United States Barred Plymouth Rock males are crossed extensively with New Hampshire females to produce chicks for commercial broiler and fryer raisers because some markets prefer a barred bird, barring being dominant to the New Hampshire plumage colour. After about 1935, White Plymouth Rocks increased in popularity, especially in the U.S. middlewest. The Plymouth Rock is a bird of good size, with good fleshing properties, and when properly bred lays well.

Rhode Island Red.—The Rhode Island Red is another American breed, the single comb variety being much more popular in England, Canada and the United States than the rose-comb variety. The skin is yellow. The plumage should be rich dark red over all parts of the body, there being black in the tail and parts of the wing feathers. The Single-Comb Rhode Island Red has been bred extensively for egg production and in the United States especially, and some strains lay as well as some of the best strains of Single-Comb White Leghorns. The Red is also a good meat producer.

Sussex.—This English breed contains the Light, Speckled and Red varieties, the Light variety being by far the most popular in England although but few of any Sussex varieties are kept in other countries. The comb is single and the skin is white. In plumage colouration the Light Sussex is similar to the Light Brahma. Sussex fowl have long been noted for the excellence of their flesh and are kept extensively in England for the production of roasters. After about 1925, English poultry breeders made considerable improvement in the laying qualities of the Light Sussex.

Wyandotte.—Among several varieties of this American breed, the White Wyandotte is the only variety bred extensively in England, the United States, or other countries. Wyandottes have rose combs and yellow skins. Like several other American varieties, they are a good general-purpose fowl, suitable for both meat and egg production. In England, egg production has been developed to a higher level among White Wyandottes than in other countries. In the United States White Wyandotte has largely been supplanted in popularity by the other previously mentioned American varieties.

Other Breeds and Varieties.—Of hundreds of other breeds and varieties of chickens kept in various countries, only a few can be mentioned. The Ancona is a Mediterranean breed with mottled plumage. The Dark Cornish is of English origin and has a very broad, compact body, ideal as a roaster type but a poor layer; it is sometimes used for crossing with other breeds. The Faverolle is a French breed with feathered shanks; in England the Salmon Faverolle is crossed extensively with the Light Sussex for roaster production. Old English and Modern Game breeds make excellent roasters but are poor layers and are kept largely by fanciers. The Jersey White Giant is the largest of the American breeds, developed primarily as a meat breed and is not noted for egg production. The Light Brahma has always been the most popular representative of the Asiatic breeds but is kept to a limited extent only. The Black Minorca is the largest of the Mediterranean breeds but has never been kept to any great extent in any country. The Black Sumatra is a native of Sumatra and is a fancier's breed exclusively.

Breeding for Meat and Egg Production.—Success in raising chickens for meat and egg production is largely a matter of good stock plus good management. Good stock can be secured only from carefully selected, well bred parents that are properly mated.

Meat Production Standards.—For profitable meat production, chickens must grow at a rapid rate and make good gains in body weight for the feed they consume. Usually the fewer pounds of feed consumed per pound of gain in body weight, the greater the profit in meat production. The characteristics which birds raised for meat production should possess include: (1) good health and vigour; (2) fast wing feathering at hatching time and fast tail feathering at 10 days of age; (3) well feathered over the back by 8 weeks of age; (4) rapid growth to marketing time; (5) well proportioned body, with good length and width and fair depth in proportion to shank length, body depth being uniform from front to rear; (6) good fleshing on breast and thighs. The selection of breeding stock on the basis of these six characteristics implies that the poultry breeder must carry on a definite selection program from hatching time to the time of mating.

Commercial poultrymen interested in poultry meat production exclusively frequently resort to crossbreeding with beneficial results, since crossbreeding tends to stimulate growth during the first 10 or 12 weeks, and mortality is usually less than among purebred chickens. However, the actual results secured from crossbreeding depend largely on the breeding quality of the parental breeds crossed. In England, and to a lesser extent in some other English-speaking countries, new breeds have been developed by crossbreeding for the purpose of enabling the sexes to be separated at hatching time according to differences in the colour of the down. This makes it possible for meat producers to purchase male chicks only and market egg producers to purchase female chicks only.

Egg Production Standards.—In addition to the six characteristics for meat production given previously, a pullet, to lay well, should possess the following four outstanding characteristics: (7) early sexual maturity; White Leghorns should commence to lay at about 150 days of age and Light Sussex, New Hampshires, Plymouth Rocks, Rhode Island Reds and other general-purpose birds at about 170 days of age; (8) pullets of all varieties should lay at a rate of at least 50% production, or a minimum of 15 eggs per month; (9) there should be little or no broodiness; White Leghorns usually do not exhibit much broodiness, but general-purpose varieties must be bred for non-broodiness or there will be numerous interruptions in laying; (10) pullets of all varieties should continue to lay for a period of approximately 10 months from the time they start to lay.

In order to develop a strain of birds noted for a high level of egg production, the poultry breeder must adopt a rigid program

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EUROPEAN AND AMERICAN BREEDS OF POULTRY

1. White Leghorn cock
2. White Leghorn hen
3. Rhode Island Red cockerel
4. Rhode Island Red pullet
5. Ancona cockerel
6. Ancona hen
7. Speckled Sussex cock
8. Speckled Sussex hen
9. Jersey White Giant pullet
10. Jersey White Giant cockerel
11. Buff Orpington cock
12. Buff Orpington hen
13. White Wyandotte cock
14. White Wyandotte pullet
15. Australorps, cock and hen
16. New Hampshire Red pullet

POULTRY AND POULTRY FARMING

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EUROPEAN AND AMERICAN BREEDS OF POULTRY

1. White Plymouth Rock cock
2. White Plymouth Rock hen
3. Light Brahma cock
4. Light Brahma hen
5. Barred Plymouth Rock cockerel
6. Barred Plymouth Rock pullet
7. Dark Cornish cockerel
8. Dark Cornish pullet
9, 10. Cross-bred pullets of Barred Plymouth Rock male and Rhode Island Red female cross
11. Minorca cockerel
12. Black Minorca pullet
13. Old English Black and Red game cock
14. Modern game cock
15. Sumatra game cock
16. Old English game cock

of selecting his breeding stock from year to year. The program of selection should be based on minimum standards for early sexual maturity, rate of laying, non-broodiness and persistence of production. Selecting birds with good pedigrees for future breeding purposes is an additional help in developing a good laying strain. The best help of all in selecting females for breeding purposes is to select them from among the families of full sisters that are outstanding in laying performance. Males for future breeding purposes should also be selected from the outstanding families but too close inbreeding should be avoided.

Additional Standards of a Good Strain.—In addition to the 10 desirable characteristics previously mentioned, a good strain of chickens should also possess the following essential characteristics: (11) good egg size, eggs attaining approximately standard weight (2 oz. each) within about 60 days from the time a pullet commences laying; (12) eggs of good interior quality; (13) hatchability of at least 75% of all eggs incubated; (14) low mortality among growing chickens and laying stock; the strain should possess the ability to resist disease to a marked degree; (15) long productive life.

Renewing the Flock.—Whether chickens are raised for meat production or pullets are kept for egg production, the entire flock or part of it has to be renewed every year. Commercial producers of broilers and fryers renew their flocks several times a year, depending upon the number of lots produced annually. Market egg producers should plan each year to replace about two-thirds of the layers with a fresh lot of pullets because birds usually lay about 20% fewer eggs in their second than in their first laying year.

In practically all English-speaking countries it is possible for the great majority of poultry producers to secure from hatcheries the chicks necessary to renew their flocks. Hatching chicks in incubators rather than under broody hens makes it possible to secure larger numbers earlier in the season, which is a distinct advantage. Some farmers still hatch their own chicks in oil-heated incubators of limited capacity. The egg capacity of incubators used by a commercial hatchery operator may run up to several thousand eggs, these incubators being heated for the most part by gas, coal or electricity.

Hatchery operators may be divided roughly into two groups: (1) those who produce their hatching eggs with their own breeding flocks and (2) those who secure their hatching eggs from flocks owned by others. The hatchery operator who produces his own hatching eggs naturally has complete control over his flock and is thus in a position to do a great deal toward improving the quality of chicks hatched for customers. The most progressive hatchery operators who secure their hatching eggs from various flock owners adopt a system of close supervision concerning the management of the flocks and see to it that the females are carefully selected and are mated to males with as good breeding as possible.

Since many of the chickens raised in different countries each year are secured as chicks from hatcheries, it is quite apparent that they occupy a very important place in the poultry industry. The quality of chicks produced by hatcheries determines very largely the results secured by those who purchase the chicks for meat or egg production.

Rearing Chickens.—If a few chickens only are to be raised, they may be brooded with hens, but if a few hundred or more are to be raised, they should be brooded artificially. Moreover, brooding chicks artificially makes it possible to raise a larger number at one time than with natural brooding so that a larger number of pullets of the same age may be placed in the laying house in the fall of the year.

There are several different types of brooders for artificial brooding, varying according to size, design and the kind of fuel used to supply heat. Brooders differ in size from those accommodating about 50 chicks to those accommodating several thousand chicks.

Most makes of brooders are portable and can be moved from place to place. Many of the portable brooders are equipped with canopies or hovers for conserving the heat to a limited area near its source. There are colony brooders for lots of about 60 to a few hundred chickens, continuous brooders for brooding chickens by the thousands, and battery brooders for brooding in strict confinement. The kind of fuel used to supply heat in colony brooders may be kerosene, coal, wood, distillate oil, gas, or electricity. Continuous brooders are heated by burning coal, gas, or distillate oil. Battery brooders are usually heated electrically.

When only a few chickens are to be raised, some kind of lamp brooder is often justified, because the initial expense is relatively low. On the other hand, if a few hundred or more chickens are to be raised, one of the other types of brooders would undoubtedly be justified.

Most poultrymen use electric or wood-burning or coal-burning portable brooders. Best results are usually secured when not more than 250 chickens are brooded together.

For the first few days, the temperature under the hover of the brooder should be about 95° F. at about 2 in. above the floor. The temperature should be lowered about 5° each week depending upon the time of the year and the outside temperature. The temperature of the brooder house should be about 70° F. The most critical period in brooding is the first two weeks; thus the most careful attention should be given the brooder during this time. Drafts in the brooder house should be avoided and the litter should be kept dry to prevent the spread of disease. When the chickens are well feathered, they require little heat. They should be given access to a grass or other succulent green range when a few days old. Plenty of waterers and hopper feed space should be provided, larger sized waterers and dry mash hoppers being provided as the chickens grow.

A 10 ft. x 12 ft. or a 12 ft. x 12 ft. colony brooder house is large enough for brooding 250 chickens up to about eight weeks, when the sexes should be separated. The pullets may be moved to range shelters to be reared on range, and the cockerels may be kept until they attain broiler, fryer or roaster stage.

Feeding Problems.—Several different kinds of nutrients are required for growth and for egg production. Water, carbohydrates, fats, proteins, minerals and vitamins are all necessary. Ample supplies of carbohydrates and fats are supplied by the cereal grains and their by-products, since these ingredients constitute such a large part of the diet. Particular attention must be given to the selection of protein, mineral and vitamin supplements used to balance the diet.

White Leghorn chickens reared on range, both sexes in approximately equal numbers, should weigh about 2 lb. each at 12 weeks of age and would have consumed about 7.5 lb. of feed per bird; at 24 weeks they should average about 4.25 lb. each and would have consumed about 24 lb. of feed per bird. Chickens belonging to the general purpose breeds, both sexes in approximately equal numbers, should weigh about 2.75 lb. each at 12 weeks and would have consumed about 8.75 lb. of feed per bird; at 24 weeks they should average about 6 lb. per bird and would have consumed about 30 lb. of feed per bird.

Among laying birds of the same size, those that lay well consume more feed than those that lay poorly, but egg production is more efficient. For instance, a 4-lb. 100-egg bird consumes on the average about 71 lb. of feed in a year, whereas a 4-lb. 200-egg bird consumes about 85 lb. of feed in a year. Nevertheless, the 200-egg bird is much more efficient, because she consumes about 5 lb. of feed for every dozen eggs produced, whereas the 100-egg bird consumes about 8.5 lb. of feed per dozen eggs produced.

Laying birds averaging 4 lb. and laying at the rate of 30% consume about 8 lb. of feed per dozen eggs produced, whereas the same birds laying at the rate of 70% consume about 4.5 lb. of feed per dozen eggs produced. Laying birds averaging 6 lb. and laying at the rate of 30% consume about 10 lb. of feed per dozen eggs produced, whereas the same birds laying at the rate of 70% consume about 5 lb. of feed per dozen eggs produced.

Housing the Laying Stock.—The purpose of housing is to give the layers protection and keep them comfortable so that they will be efficient egg producers. In extremely hot weather the layers are very likely to suffer considerably if they cannot

secure relief in a cool house. The chicken has no sweat glands to assist in keeping the body cool. In extremely cold weather, chickens not only suffer from the cold in a poorly built house but use too much of the energy contained in their feed to conserve body heat instead of to produce eggs. The primary objective in housing laying stock, therefore, is to protect the birds against excessively high and low temperatures and especially against sudden changes in temperature. In addition, the proper housing of the layers makes it possible to manage them more efficiently.

The location of the laying house should be such as to provide for the proper circulation of air within the house and at the same time avoid unnecessary exposure to the wind. A southern, well-sheltered slope which offers good air and water drainage is usually the most desirable. The size of the house needed varies according to the size of the flock. For flocks of 15, 25 and 50 birds, houses should have about 70, 100 and 180 sq.ft. floor space, respectively. A flock of 125 birds should have about 400 sq.ft. floor space. A flock of several hundred or a few thousand birds should be divided into units of about 125 or 250 birds per unit, several units being housed in one long continuous house.

It costs less, on the average, to build a square house than a long narrow one, which is likely to be drafty. Houses for small flocks should be at least 10 ft. deep, and houses for large flocks should be at least 16 ft. or better still, 20 or 24 ft. deep. Large flocks may be kept in houses that are two, three or four stories high. A multistoried house reduces the labour required to manage a large flock, as compared with a single-storied house. A multistoried house simplifies ventilating problems to some extent and makes it possible to maintain more uniform temperatures in summer and winter.

A concrete floor is more durable and much more sanitary than a board floor. Insulating the walls and roof, especially the latter, helps greatly to keep the house cool in summer and warm in winter. The proper ventilation of the house is necessary in order to remove excessive moisture and provide fresh air but, at the same time, drafts should be avoided. Sunlight in the laying house is desirable not only because it brightens up the house but also because it tends to keep the house dry and is a good germicide, being effective in destroying disease organisms.

Moreover, sunlight is a good source of vitamin D. A good absorbent litter helps to keep the floor dry. How frequently the litter should be removed depends largely on the number of birds in the house, weather conditions, and the extent to which the house is properly ventilated.

Marketing Eggs.—Nearly all eggs at the time they are laid are of superior quality. They represent the kind of eggs that most consumers would like to purchase the year round. The proper steps to preserve fresh-laid egg quality are far more important than most producers realize. The proper preparation of eggs for market and marketing them to best advantage are just as important, in many respects, as producing them efficiently.

Since the germ of a fertile egg begins to develop at about 69° F., eggs for market should be kept at a temperature lower than 68° F., a temperature of 55° F. being desirable. All producers of market eggs should keep the males away from the females except during the breeding season.

Unless eggs are gathered frequently and cooled promptly in warm weather, they commence to deteriorate. In fact, the higher the temperature and the drier the air of the room in which eggs are held, the more rapid the deterioration. Some of the most striking changes that take place in eggs subjected to high temperatures and dry atmosphere are: (1) water evaporates through the porous shell, (2) the thick white tends to break down into thin white, (3) the yolk membrane becomes weaker, and (4) the yolk becomes more flaccid.

The excessive heating of eggs, whether from being exposed to the sun's rays or held for a long time in a warm room, results in a complete breakdown of the thick white, giving the entire white a watery appearance.

Clean litter and clean nests, one for every five hens, are essential for the production of clean eggs. The eggs should be gathered in wire baskets three or four times daily in warm weather and stored in a room in which the temperature is about 55° F. and the relative humidity about 75%.

Flock owners who only have a few layers often sell all of their surplus eggs direct to consumers. This is especially true of flock owners in villages or those living in areas adjacent to towns and cities. In the case of farm and commercial flock owners the eggs may pass through any one of several different marketing channels before reaching the consumer. Selling market eggs on a graded basis is in the best interests of producers, dealers and consumers. Eggs are graded according to size, shell cleanliness, size of air cell, and the quality of the yolk and white.

The method of packing eggs in different countries varies. In several European countries, for instance, long wooden boxes are used for packing eggs in straw whereas in Canada and the United States different kinds of containers are used, including cartons holding ½ doz. or 1 doz., fibre or cardboard boxes holding 15 or 30 doz., or wooden egg cases holding 30 doz. From the surplus producing areas in a country, eggs are shipped by express to consumers or retailers in consuming centres or they are shipped in refrigerated cars or trucks to wholesalers who sell them to retailers.

Co-operative egg marketing methods have been developed extensively in various English-speaking countries, especially Australia and the United States as well as in such countries as Eire and Denmark.

Prior to World War II some countries, including China, Denmark, Australia, New Zealand, South Africa and Eire, exported considerable quantities of eggs annually to Great Britain, which is primarily an importing country. (*See* also EGGS.)

Marketing Chickens.—Chickens are sold alive at various ages, ranging from those about 8 weeks old, weighing about 1 lb. each, to those that are several years old. They are all called "chickens" when one wishes to distinguish them from turkeys, guineas, ducks and geese. From the market standpoint, however, the term "chicken" is usually used to distinguish growing birds, except stags and capons, from cocks and hens, the latter usually being referred to as "fowl." Stags are older than chickens, have more prominent spurs, and the flesh is not so tender. Capons are male birds that were castrated while young, the flesh being relatively tender even when the birds are almost fully grown.

While the marketing of live chickens is an important industry in many countries, the proportion of dressed poultry marketed by live-poultry buyers increased considerably after about 1930. In all countries the great bulk of market poultry is sold to consumers either in the dressed, drawn or cut-up form. A dressed bird is one that has been killed and plucked. A drawn bird is a dressed bird from which the head, feet and entrails have been removed. A cut-up chicken is a drawn bird that has been cut up into parts suitable for frying.

Feed should be withheld from birds for about 15 hours before they are killed and plucked. The different methods of plucking chickens include dry plucking, hard-scald plucking, semiscald plucking, wax plucking, and machine plucking. Dry plucking must be done the moment the bird is killed, while the body is still warm. The hard-scald method involves immersing the bird for a few seconds, except the head and feet, in water kept at a temperature of 180° to 190° F. If the water is too hot or the birds remain in the water too long, the skin will have a scalded appearance. For semiscalding, the temperature of the water should be approximately 127° F. for broilers, 128° F. for fowl, and the birds should be kept in the water for 30 to 35 sec. Wax plucking is a somewhat involved process in which a special kind of melted wax is used to facilitate the removal of feathers, pinfeathers and hair. Plucking machines are used to some extent, especially in England and the United States. Some of the machines are equipped with a revolving disc or cylinder for dry plucking and others are equipped with a revolving cylinder to which rubber "fingers" are attached for plucking by the semiscald method.

After the birds have been plucked, the heads, feet and vents are

cleaned thoroughly in order to give the dressed carcasses an attractive appearance. After the birds are dressed, they should be cooled thoroughly by immersing them in cold water for about an hour, or they may be held for about a day in a room for dry cooling at a temperature of 32° to 34° F. If the dressed birds are to be packed in boxes or other containers for shipment to market, the heads are wrapped in parchment or kraft paper waxed on one side.

In some countries, especially the United States, dressed birds are drawn in poultry-packing plants and after being inspected and cleaned are prepared so that they are ready to be placed in the consumer's oven for roasting. Such poultry is called quick-frozen full-drawn, the carcasses being frozen immediately after being drawn at temperatures which range as low as −20° F.

The practice of selling fresh-killed chickens cut in pieces suitable for frying has gained considerable impetus in Canada and the United States. Buying cut-up chicken is popular with many housewives, because practically no labour is necessary in preparing the poultry for the frying pan.

Great Britain is the principal importer of dressed poultry. Prior to World War II most of its imported supplies were obtained from Eire, France, Austria and Latvia.

Raising Ducks for Meat and Eggs.—Duck raising is practised on a limited scale in practically all countries, for the most part as a small farm enterprise; but in such countries as England and the Netherlands they are kept extensively for egg production, and in the United States a considerable number of commercial plants have been developed for meat production exclusively. The Runner duck, formerly called the Indian Runner, and the Khaki-Campbell are especially adapted for egg production, whereas the larger sized Pekin breed is a meat producer of exceptional merit. Some strains of Runners and Khaki-Campbells will lay better than many strains of chickens. Pekin ducks grown commercially for meat are marketed from about 8 to 12 weeks of age, when they weigh from about 4½ to 7 lb. each. In England the Aylesbury is the kind kept for meat production. The Muscovy duck, of South American origin, is kept on farms for meat production to some extent because it does not "quack."

Goose Raising.—Goose raising is a farm enterprise of limited proportions in practically all countries, although in Germany, Austria, parts of France, and certain sections of other countries, goose raising on a commercial basis is carried on extensively. The Toulouse, predominantly gray in colour, and the Embden, a white breed, are the two outstanding meat-producing breeds. On some commercial plants, market geese are fattened by a special process, the forced-feeding of noodles sometimes being practised, resulting in a considerable enlargement of the livers.

Some goose raisers make a practice of plucking feathers from the live birds, usually just before the birds moult, up to one pound of feathers being obtained from a bird.

Guinea Raising.—Guineas are raised as a sideline on a few farms in various countries. In some cities there is a relatively good market for them, and they are often used as a substitute for game birds, such as quail, grouse, pheasant and partridge.

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(M. A. J.)

POUND, SIR (ALFRED) DUDLEY (PICKMAN ROGERS) (1877–1943), first sea lord and admiral of the British fleet during World War II, was born Aug. 29, 1877, on the Isle of Wight. He was educated in grammar schools in Surrey and Greenwich until 1891, when he entered the navy. In 1913–14, Pound attended the Naval War college, and in 1914 was raised to the rank of captain and appointed naval assistant to Lord John Fisher, then first sea lord. He commanded H.M.S. "Colossus" during the battle of Jutland and for his part in the engagement was mentioned in dispatches. From 1922–25 he served in the admiralty as director of the plans division and in 1925 entered two years' service as chief of staff to the Mediterranean fleet's commander in chief, Admiral Sir Roger Keyes. In 1926 he was promoted to rear admiral and from 1927–29 was assistant chief of the naval staff. From 1929–31 he commanded a battle cruiser squadron. In 1932, having reached the rank of vice admiral, he was made second sea lord and chief of naval personnel at the admiralty, and in 1935 he was made admiral and temporary chief of staff of the Mediterranean fleet. From 1936–39 he was commander in chief of that fleet. On May 17, 1939, he was advanced to first sea lord and chief of the naval staff and in July 1939 was made admiral of the fleet. He resigned Oct. 4, 1943, because of ill health and died the following Oct. 21.

POUND, EZRA LOOMIS (1885–), U.S. poet, was born in Hailey, Idaho, Oct. 30, 1885. He was educated at the University of Pennsylvania and at Hamilton college, Clinton, N.Y. He taught until 1907, when he left the United States to travel in Europe; and except for two brief return visits to the United States, he remained in Europe thereafter, living successively in London, Paris and Italy. Although Pound had written a number of works by 1912, his first important publication, *Ripostes*, was printed in that year. This volume contained five imagist poems by T. E. Hulme and its appearance was regarded as the beginning of the imagist movement. Pound gave further impetus to the movement in 1914 with *Des Imagistes*. From 1917–19 he was London editor of the *Little Review*.

In 1924 he settled in Italy, where, in 1941, he began to make profascist broadcasts from Rome. Indicted in 1943 for treason, he was arrested near Genoa by U.S. troops in May 1945. He was brought to the U.S., reindicted and later ruled insane and mentally unfit for trial. In Feb. 1949 he won the Bollingen prize from the Library of Congress for his *Pisan Cantos* (1948).

POUND, ROSCOE (1870–), U.S. jurist and educator, was born at Lincoln, Neb., Oct. 27, 1870. He graduated at the University of Nebraska, Lincoln, Neb., and studied law in the Harvard law school, 1889–90. On his admission to the bar in 1890, he commenced practice in Lincoln, Neb. He was commissioner of appeals of the supreme court of Nebraska, 1901–03.

He was assistant professor of law at the University of Nebraska, 1899–1903, and dean of the law faculty, 1903–07; was professor of law at Northwestern university, 1907–09, and at the University of Chicago, 1909–10. In 1910 he accepted the Story professorship of law at the Harvard law school, becoming Carter professor of jurisprudence there in 1913 and dean from 1916 to 1936. In June 1947 he retired from the Harvard law school faculty.

Pound has written *Phytogeography of Nebraska*, with F. E. Clements (1898); *The Spirit of the Common Law* (1921); *Criminal Justice in the American City* (1922); *Introduction to the Philosophy of Law* (1922); *Interpretations of Legal History* (1923); *Law and Morals* (1924); *Readings on the History and System of the Common Law*, 3rd ed. (1927); *Criminal Justice* (1930); *History and System of the Common Law* (1939); *Organization of Courts* (1940); *Appellate Procedure in Civil Cases* (1941); *Social Growth through Law* (1942); and *The Task of the Law* (1944).

POUND (1) An enclosure in which cattle or other animals are retained until redeemed by the owners, or when taken in distraint until replevied, such retention being in the nature of a pledge or security to compel satisfaction for debt or damage done. Animals may be seized or impounded when (*a*) distrained for rent; (*b*) damage *feasant*, *i.e.*, doing harm on the land of the person seizing; (*c*) straying; (*d*) taken under legal process. The pound-keeper is obliged to receive everything offered to his custody and is not answerable if the thing offered be illegally impounded. Where cattle are impounded the impounder must supply sufficient food and water (Cruelty to Animals Acts, 1849 and 1854); any person, moreover, is authorized to enter a place where animals are impounded without food and water more than 12 hours and supply them; and the cost of such food is to be paid by the owner of the animal before it is removed. Pounds are almost obsolete. (*See* DISTRESS.)

POUND (2)—(*a*) a measure of weight; (*b*) an English money

of account. (*See* POUND STERLING.)

(*a*) The English standard unit of weight is the *avoirdupois* pound of 7,000 grains. The earliest weight in the English system was the Saxon pound, subsequently known as the tower pound, from the old mint pound kept in the Tower of London. The tower pound weighed 5,400 grains and this weight of silver was coined into 240 pence or 20 shillings, hence pound in sense (*b*) (a pound weight of silver). The pound troy, probably introduced from France, was in use as early as 1415 and was adopted as the legal standard for gold and silver in 1527. The act which abolished the tower pound (18 Hen. VIII: the "pounde Troye which exceedeth the pounde Tower in weight iii quarters of the oz.") substituted a pound of 5,760 grains, at which the pound troy still remains. There was in use together with the pound troy, the merchant's pound, weighing 6,750 grains, which was established about 1270 for all commodities except gold, silver and medicines, but it was generally superseded by the pound avoirdupois about 1330. There was also in use for a short time another merchant's pound, introduced from France and Germany; this pound weighed 7,200 grains. The pound avoirdupois has remained in use continuously since the 14th century, although it may have varied slightly at different periods—the Elizabethan standard was probably 7,200 grains. The standard pound troy, placed together with the standard yard in the custody of the clerk of the house of commons by a resolution of the house of June 2, 1758, was destroyed at the burning of the houses of parliament in 1834. In 1838 a commission was appointed to consider the restoration of the standards, and in consequence of their report in 1841 the pound avoirdupois of 7,000 grains was substituted for the pound troy as the standard. A new standard pound avoirdupois was made under the direction of a committee appointed in 1834 (which reported in 1854), by comparison with authenticated copies of the original standard (see *Phil. Trans.* 1856). This standard pound was legalized by an act of 1855 (18 & 19 Vict. c. 72). The standard avoirdupois pound is made of platinum, in the form of a cylinder nearly 1.35 in. high and 1.15 in. in diameter, and is marked "P.S. 1844. 1 lb.," P.S. meaning parliamentary standard. It is preserved at the standards office, in the custody of the board of trade. Whereas the British standard pound was determined by independent legislative action, the U.S. avoirdupois pound was derived from the international kilogram. By a law of 1866 and an executive order of 1893, the U.S. pound was established on the basis of 2.204621 pounds per kilogram.

See the *Reports of the Standards Commission* (6 parts, 1868–73).

POUND STERLING. From about the year 775 silver coins known as "sterlings" or pennies were issued in the Saxon kingdoms, 240 of them being minted from silver of the weight of the pound then in use for weighing the precious metals, which was probably about equal to the later troy pound. Hence large payments came to be reckoned in "pounds of sterlings," a phrase later shortened to "pounds sterling." After the Norman conquest of Britain the pound was divided for accounting purposes into 20 shillings and in mediaeval Latin documents the words *libra, solidus* and *denarius* were used to denote the pound, the shilling and the penny, which gave rise to the use of the symbols *£., s., d.* (*see* SHILLING; STERLING). Silver pennies were the only coins used until the 13th century, and the pound as the unit of account was based upon a silver standard until the 18th century, when the growth of wealth and trade brought large quantities of gold into the country and effected a gradual change from the silver standard to the gold standard on a basis fixed by Sir Isaac Newton as master of the mint in 1717. Gold of 22 carats was rated in money at £3 17*s.* 10½*d.* per oz. troy.

The addition of paper money to the circulation added great flexibility to the quantity of money and made the regulation of its value much more difficult. The heavy issues of paper to finance the war with Napoleon caused the abandonment of the gold standard in 1797 and the pound remained a paper standard until 1819 when the gold standard was restored without any change in the standard weight. During the 19th century, failure to regulate satisfactorily the paper currency and the banking system nearly caused an abandonment of the gold standard on at least three occasions, but it was nevertheless maintained without a break until World War I. Then once again a disturbance of normal international trade and a large creation of paper currency caused a severance of the link with gold. The British government regulated the value of sterling in some degree by introducing control of the supply and prices of essential commodities and by exercising full control of the exchange with the dollar, "pegging" the rate at 4.76 to the pound. When these controls were abandoned in 1919 there was a heavy fall of value but by 1925 the value had recovered sufficiently to permit the convertibility of paper money into gold to be for the second time restored at Newton's old 1717 rate.

1931 Abandonment of the Gold Standard.—By this time the emergence of the United States as a great creditor nation was causing a very large part of the world's total stock of gold to flow to that country, and this in turn set up a steady rise in the value of gold in terms of goods. All countries on the gold standard in consequence suffered from falling prices, trade depression and an increase in the burden of debt. By 1931 the steady drain upon Great Britain's gold reserves was such that overseas financial houses holding balances in London grew nervous and began to withdraw those balances upon a large scale. In September this movement had become so rapid that it was evident that the whole of the gold reserve would soon be drained away if paper money continued to be convertible into gold. The government, therefore, with the concurrence of parliament, released the Bank of England from its obligation to exchange notes for gold and the pound again became a paper standard.

From 1931 until the outbreak of war in 1939 the value of the pound was regulated by various financial measures adopted by the government. The budget was kept strictly balanced. An embargo was placed upon the lending of money overseas, and an exchange equalization fund was set up and used to buy and sell pounds for foreign currencies to the extent necessary to limit short-term fluctuations of value, thereby curbing the activities of speculators. The measures were fairly successful, although the period was not inflationary and other countries had also imposed exchange controls.

Immediately prior to the outbreak of World War I, the pound sterling circulated in two main forms, namely, gold sovereigns and Bank of England notes. When war broke out in 1939, the British government immediately realized that more comprehensive measures to safeguard the value of the pound would be necessary. Full control was taken of all foreign exchange transactions, the dollar rate being fixed at 4.03. Rigid control of the supplies and prices of most essential commodities was introduced, coupled with high taxation and heavy borrowing designed to leave consumers very little income to spend upon goods whose prices were free.

In Sept. 1949 the exchange rate of the pound was cut to $2.80 U.S. British import prices, measured in sterling, increased by nearly 20% after devaluation and then levelled off in the second quarter of 1950. It had been estimated that the direct effect of devaluation would be to increase prices of British imports by a little more than 15% while there would be a further rise because of indirect effects, which were substantial. By Nov. 1950 the index of the average value of total imports had increased to 143 (1947=100). During the first 15 months after devaluation British export prices also increased steadily but much more slowly, domestic costs being relatively stable. As a result first of devaluation and then of boom conditions in the U.S. and elsewhere, there was a worsening in the terms of trade, amounting to about 13% between Aug. 1949 and May 1950 and to a further 6% in the second half of 1950. The United Kingdom retail price index in Aug. 1949 stood at 179½ (1938=100). In the eight months following devaluation, the cost of living increased not more than 2½%. By Nov. 1950 it was at a level 4% above that before devaluation. (*See* also MONEY.)

(A. E. F.; X.)

POURTALES, COUNT FRIEDRICH VON (1853–1928), German diplomatist, was born at Oberhofen, Switzerland, on Oct. 24, 1853. After a brief period of service in the army, he entered the German foreign office in 1880. He was for the seven years immediately preceding World War I, German ambassador at St. Petersburg. He published in 1927, *Meine*

letzte Verhandlungen in St. Petersburg Ende Juli 1914, in which he relates his last effort to dissuade the tsar from mobilization in July 1914. He died at Bad-Nauheim on May 4, 1928.

POUSSIN, NICOLAS (1594–1665), French painter, was born at Les Andelys (Eure) in June 1594. He learned painting under Quentin Varin, a local painter, till he went to Paris, where he entered the studio of Ferdinand Elle, a Fleming, and then of the Lorrainer L'Allemand. He improved himself by studying prints after Raphael and Giulio Romano; and in 1624 he proceeded to Rome, where he stayed for six years, and married Anna Maria Dughet, a Frenchwoman. His intimacy with Du Quesnoy, afterwards celebrated under the name of Il Fiammingo, may have led Poussin to the careful study of antique reliefs, many of which he modelled. He also attended the academy of Domenichino, whom he considered the first master in Rome. Among his first patrons were Cardinal Barberini, for whom was painted the "Death of Germanicus" (Barberini palace); Cardinal Omodei, for whom he produced in 1630, the "Triumphs of Flora" (Louvre); Cardinal de Richelieu, who commissioned a Bacchanal (Louvre); Vicenzo Giustiniani, for whom was executed the "Massacre of the Innocents," now in the museum at Chantilly; Cassiano dal Pozzo, who became the owner of the first series of the "Seven Sacraments" (Belvoir castle); and Fiéart de Chanteloup, with whom in 1640 Poussin, at the call of Sublet de Noyers, returned to France. Louis XIII. conferred on him the title of "first painter in ordinary," and in two years at Paris he produced several pictures for the royal chapels (the "Last Supper," painted for Versailles, now in the Louvre) and eight cartoons for the Gobelins, the series of the "Labours of Hercules" for the Louvre, the "Triumph of Truth" for Cardinal Richelieu (Louvre), and much minor work. In 1643, disgusted by the intrigues of Simon Vouët, Feuquières and the architect Lemercier, Poussin withdrew to Rome. There, in 1648, he finished for De Chanteloup the second series of the "Seven Sacraments" (Bridgewater gallery), and also his noble landscape with Diogenes throwing away his Scoop (Louvre); in 1649 he painted the "Vision of St. Paul" (Louvre) for the comic poet Scarron, and in 1651 the "Holy Family" (Louvre) for the duke of Créqui.

The finest collection of Poussin's paintings, as well as of his drawings, is possessed by the Louvre; but, besides the pictures in the National Gallery and at Dulwich, England possesses several of his most considerable works. The "Triumph of Pan" is at Basildon (Berkshire). Other important works are in the collection of Sir Herbert Cook, Richmond; the duke of Bedford, the earl of Carlisle, the earl of Yarborough, the duke of Devonshire, Burdett Coutts and at Longford castle. The Prado, Madrid, the Dresden museum, the Eremitage at Leningrad, possess a number of representative pieces by this prolific master. The prints that have been engraved after his principal pictures amount to upwards of 200.

Nicolas Poussin was an eclectic, selecting and combining what he admired in the classic art of the past. He not only emulated Titian's glowing colour and the rhythm of Raphael's design; he also borrowed figures out of pictures by these masters (from Titian's "Bacchanal" and Raphael's "Stanze" for instance) and introduced them into his canvases. Yet he was no mere copyist. His conceptions are essentially French, and his characters might be staged in one of Corneille's dramas. His art is reasoned and intellectual. The Greek law of unity in space and time is realized. His statuesque figures are ranged parallel to the picture plane as in antique reliefs. The landscape background is similarly arranged; and he applied the principles of figure composition to his landscapes. His influence on French painting was great and lasting. It was felt in the work of successive generations—of David, Ingres, Delacroix, Chassériau, Puvis de Chavannes and Corot, down to modern times. He stands for the classical tradition, for the balance and harmony in things, for the rhythmic movement of line, for decorative arrangement in composition after which modern artists since Cézanne have been striving, in reaction to impressionism. Poussin's immediate follower was Gaspard Dughet, his brother-in-law and pupil, who through this double bond of relationship shared the name of Poussin.

Gaspard Poussin (1613–1675) devoted himself to landscape painting and rendered admirably the severer beauties of the Roman Campagna. He worked for three years in the studio of his brother-in-law and then came under the influence of Claude Lorrain. He worked mainly at Rome, thence making excursions to Milan, Perugia, Castiglione, Florence and Naples. A noteworthy series of works representing various sites near Rome is to be seen in the Colonna palace; other important works are in the Doria and Borghese palaces; but one of his finest easel-pictures, the "Sacrifice of Abraham," formerly the property of the Colonna, is now in the National Gallery, London. The frescoes executed by Gaspard Poussin in S. Martino di Monti are in a bad state of preservation. Gaspard died at Rome on May 27, 1675.

See G. P. Bellori, *Le Vite de Pittori, scultori ed architetti moderni* (1672); Sandrart, *Acad. nob. art. pict.; Lettres de Nicolas Poussin* (1824); Félibien, *Entretiens* (1666–88); P. Desjardins, *Poussin* (1903); W. Friedländer, *Nicolas Poussin* (Munich, 1914).

POUT or **BIB** (*Gadus luscus*), a small fish of the Mediterranean and the Atlantic coast of Europe, differing from its relative, the cod, in the deeper body, larger eye, etc. It is coffee-coloured, with broad, dark transverse bands.

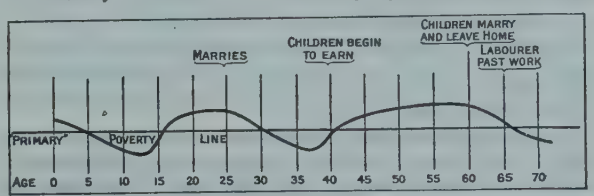
POVERTY LINE. The words "poverty line" have only come into use in comparatively recent years, and probably, to the general public, they merely represent a vague social cleavage between people living in varying degrees of security and comfort and people who are constantly exposed to actual privation. To the social student, however, the term has gradually acquired both greater content and greater precision.

It was first made familiar by Charles Booth, in his monumental *Life and Labour of the People,* commenced in 1886. In analysing the population of London, he divided it into eight classes, four of which he defined as poor, the other four as "above the line of poverty." "My 'poor,'" he wrote, "may be described as living under a struggle to obtain the necessaries of life and make both ends meet, while the 'very poor' live in a state of chronic want. It may be their own fault that this is so: that is another question; my first business is simply with the numbers who, from whatever cause, do live under conditions of poverty or destitution."

Booth found 30% of the population of London living under such conditions, or "below the line of poverty."

Illuminating, however, as were Booth's researches, they left the actual basis of the poverty line indefinite. In 1899 Seebohm Rowntree made a somewhat similar investigation into poverty in York, a city with a population at that time of about 76,000. The comparative smallness of the area covered enabled him to undertake a closer analysis of the poverty problem and to distinguish between "primary" and "secondary" poverty.

By the former he implied poverty due solely to lack of sufficient income to maintain a family of normal size in a state of physical efficiency, even though all the resources available were economically administered. "Secondary" poverty, on the other


CHILDREN MARRY AND LEAVE HOME
CHILDREN BEGIN TO EARN
MARRIES
LABOURER PAST WORK
PRIMARY POVERTY LINE
AGE 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
DIAGRAM SHOWING AGES AT WHICH THE POVERTY LINE VARIES

hand, was due to the expenditure of some part of the income on objects other than the maintenance of physical efficiency.

Requirements of Physical Efficiency.—In order to fix his primary poverty line it was necessary to calculate the bare minimum requirements of physical efficiency and the cost of satisfying these. The procedure was as follows:

The requirements of physical efficiency were classified under three headings: (1) Food, (2) House rent including rates, (3) Household sundries, such as clothing, light, fuel, etc. With regard to food, certain standards, in terms of calories per day, were established, in the light of the latest scientific evidence available,

for adult males, adult females, and children of varying ages. The standard adopted for the adult male was 3,500 calories per day, this being the amount required for men doing moderate work. Due proportions of this were fixed for women, adolescents and children. In this way the food required by any given family could be expressed in the terms of a common unit, namely, the calories consumed "per man per day." The dietary selected by Rowntree to provide the necessary calories was based upon the cheapest rations falling within the Local Government board order for workhouses, and included no alcohol, no tobacco and no meat, with the exception of a little bacon, being less generous than the average dietary required for workhouse purposes. It was then priced according to the cheapest rate ruling in York at that time, and the following figures were adopted as representing the necessary minimum expenditure for food, viz., 3s. each per week for adults, and 2s.3d. each per week for children.

With regard to rent, the actual sums then paid were taken as the necessary minimum. As regards household sundries, the sum allowed for a family of father, mother and three children for clothing, fuel and all other sundries was 4s. 11d. per week—a figure arrived at after detailed investigation. Allowing 4s. for rent, these figures totalled up to £1 1s. 8d. a week for a family of five. With the prices ruling on Feb. 1, 1928, this figure becomes £2 1s. 11d., made up as follows:—food £1 3s. 11d.; clothing, fuel, and all other sundries 10s. 8d.; rent 6s., and compulsory insurance 1s. 4d. No allowance was made for so much as a tram ride or a postage stamp during the year, or for any expenditure whatever upon moral, mental, or social development, and even the sick club and the funeral club were excluded. The aim was simply to ascertain the lowest cost at which bare physical efficiency could be achieved, if the housewife were a woman of considerable experience, commonsense, and strength of will.

Having fixed the primary poverty line, the next step was to ascertain what proportion of the population of York were living in primary and secondary poverty respectively.

York's Ten Per Cent of Primary Poverty, 1899.—In order to do this trained investigators visited every working class house in York, and gathered together with other facts, information which enabled a reasonably accurate estimate to be made of the income of each family. In the course of the visits note was taken of every family which was evidently living in poverty as judged by the housing conditions and the signs of malnutrition. The number of those living in secondary poverty was ascertained by subtracting from the total population found to be living in poverty those whose incomes placed them below the primary poverty line. It was found that 10% of the total population of the city or 15½% of the working-class population were living in primary poverty, and 18% of the total population or 28% of the working-class population were in secondary poverty. It may be noted that when the two groups of "primary" and secondary poverty are taken together we have figures, namely, 43% of the working classes and 28% of the total population of York, which are readily comparable with the results obtained by Booth.

Rowntree, in analysing the immediate causes of primary poverty, showed that more than one half of it was due solely to the death of the wage earner, 22% to largeness of family, and the rest to miscellaneous causes.

The causes of secondary poverty do not lend themselves to similar classification, but Rowntree stated them as drink, betting, ignorant or careless housekeeping, and other improvident expenditure, and put drink as the predominant factor.

It may be added that subsequent investigators, such as Prof. A. L. Bowley and Miss Hogg, have practically ignored the existence of secondary poverty, concentrating rather on the endeavour to estimate the number of those who in any given area are compulsorily below the poverty line or are living in primary poverty.

Later Enquiries.—The enquiries of Booth and Rowntree were followed by other investigations of particular areas. In 1912 and 1913 investigations were made by Prof. A. L. Bowley and Prof. A. R. Burnett-Hurst into conditions in certain typical provincial towns, namely, Reading, Northampton and Warrington, and the mining area of Stanley. These were supplemented a little later by a similar enquiry into conditions in Bolton, and the results of these researches were published in *Livelihood and Poverty* in 1915. The lines followed were similar to those of Rowntree, save that the method of taking samples of each town was adopted, in place of the investigation of every household. The results were measured by Rowntree's "poverty line" and also by the authors' "new standard," based upon that of Rowntree, with certain minor variations—the general effect of which was to make the standard somewhat higher for an adult and somewhat lower for a child. The net difference per family between the two standards, however, was comparatively slight. With prices ruling on Feb. 1, 1928, Bowley's standard amounted to £2 1s. 2d., made up as follows:—food £1 2s. 6d.; clothing, fuel and sundries 9s. 4d.; rent 8s. 0d., and compulsory insurance 1s. 4d. This compares with Rowntree's £2 1s. 11d.

The conclusion reached by those adopting the new standard, assuming full time wages to be earned in every case, was that in these five towns 11% of working-class families were below the primary poverty line. It should be noted that this figure makes no allowance for loss of earnings due to unemployment, and therefore it cannot properly be compared with Rowntree's figures, which were based upon the actual average income over the year. The fundamental principle, however, that of a poverty line determined by the requirements of bare physical efficiency, remains precisely the same.

Investigation of 1924.—In 1924 a similar investigation was made in the same towns with a view to discovering whether poverty had diminished in the intervening period. The results of this appear in *Has Poverty Diminished?* by Prof. Bowley and Miss Margaret H. Hogg. Taking the "New Standard" as the basis of comparison, and allowing for the increase in the cost of living, the investigation showed that the proportion of the working-class population below the primary poverty line had fallen from 11% in 1912–14 to 3·6% in 1923–4, assuming full time wages to be earned in every case, or to 6·5%, assuming that the actual incomes of the families observed during the week of the investigation were equal to their average weekly incomes throughout the year. The latter basis is the more appropriate for purposes of comparison with Rowntree's figures.

Although not claiming exact accuracy, such figures afford strong evidence that the volume of poverty in Britain has continued to diminish throughout the first quarter of the 20th century. Probably the proportion of the population living below the primary poverty line in 1925 was less than half the proportion in 1900. At the same time the gravity of the position should not be underestimated. Taking 6·5% of the working-class population as representing 4% of the total population, we had in 1924 in the British Isles practically 2,000,000 persons living below the standard necessary for the maintenance of mere physical efficiency. Moreover, the number of different individuals who at one time or other fall below the poverty line is much greater than those who fall below it at a given moment.

From the national standpoint it is serious that in any given family the period of greatest want occurs before any of the children begin to earn. At that time those living near the poverty line are liable to fall below it, and the stress is most severe upon the younger children, and women who are bearing children. According to Bowley and Hogg, even in our improved post-war conditions, more than one child in six lives below the poverty line at some period, while a smaller proportion of children live below it for many years together.

Nevertheless, there has certainly been a striking reduction in the proportion of primary poverty. One of the outstanding characteristics of post-war conditions is the rise in the real wages of the lowest paid labour. Between 1913 and 1924 the wages of unskilled labour approximately doubled, whilst the cost of living was only 70% higher. A second characteristic is the reduction in the average size of the family. The census figures of 1921 showed the average number of children under 14 years of age per "family" to be 1·12 against 1·29 in 1911. Thus, the effect of increased wages in reducing poverty appears to be twice as great as the

reduction in the size of families.

All the above figures refer to Great Britain only. There are no comparable figures for other countries—though undoubtedly the proportion of people below the poverty line is less in the British Dominions and in the United States than in Great Britain. It may possibly be less in Holland, Denmark and Switzerland; but, in the absence of figures, this is only guess-work. It is almost certainly greater in the other European countries, while in Japan, China and India it is enormously greater, even after making full allowance for differences in climate and national customs. To raise the standard of living in the East is perhaps the most urgent material task confronting civilisation.

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POVINDAH, a class of warrior nomadic traders in Afghanistan, who belong chiefly to the Ghilzais. Their name, which designates their occupation, is derived from the same root as the Pushtu word for "to graze." They are almost wholly engaged in the carrying trade between India and Afghanistan and Central Asia.

See Census of India 1921, Vol. I. 1924, p. 96.

POWELL, FREDERICK YORK (1850–1904), English historian and scholar, was born in Bloomsbury, London, on Jan. 14, 1850. Much of his childhood was spent in France and Spain. He was educated at Rugby, and at Christ Church, Oxford, was called to the bar at the Middle Temple in 1874, and married in the same year. He became law-lecturer and tutor of Christ Church, fellow of Oriel college, delegate of the Clarendon Press, and in 1894 he was made regius professor of modern history in succession to J. A. Froude. He assisted Professor Gudbrandr Vigfússon in his *Icelandic Prose Reader* (1897), *Corpus poeticum boreale* (1887), *Origines islandicae* (1905), and in the editing of the Grimm Centenary papers (1886). He took a keen interest in the development of modern French poetry, and Verlaine Mallarmé and Verhaeren all lectured at Oxford under his auspices. He was also a connoisseur in Japanese art. York Powell befriended refugees after the Commune, counting among his friends Jules Vallès the author of *Les Réfractaires;* and he was also a friend of Stepniak. He died at Oxford on May 8, 1904.

See the *Life,* with letters and selections, by Oliver Elton (1906).

POWELL, JOHN WESLEY (1834–1902), American geologist and ethnologist, was born at Mount Morris, N.Y., March 24, 1834. His parents were of English birth, but had moved to America in 1830, and he was educated at Illinois and Oberlin colleges. He began his geological work with a series of field trips including a trip throughout the length of the Mississippi in a rowboat, the length of the Ohio, and of the Illinois. When the Civil War broke out he entered the Union Army as a private, and at the battle of Shiloh he lost his right arm but continued in active service, reaching the rank of major of volunteers. In 1865 he was appointed professor of geology and curator of the museum in the Illinois Wesleyan university at Bloomington, and afterwards at the Normal university.

In 1867 he commenced a series of expeditions to the Rocky Mountains and the canyons of the Green and Colorado rivers, during the course of which (1869) he made a daring boat-journey of three months through the Grand Canyon; he also made a special study of the Indians and their languages for the Smithsonian Institution, in which he founded and directed a bureau of ethnology. His able work led to the establishment under the U.S. Government of the geographical and geological survey of the Rocky Mountain region with which he was occupied from 1870 to 1879. This survey was incorporated with the United States geological and geographical survey in 1879, when Powell became director of the bureau of ethnology. In 1881, Powell was appointed director also of the geological survey, a post which he occupied until 1894. He died in Haven, Me., on Sept. 23, 1902.

His principal publications were: *Exploration of the Colorado River of the West and its Tributaries* (1875), *Report on the Geology of the Eastern Portion of the Uinta Mountains* (1876), *Report on the Lands of the Arid Region of the United States* (1879), *Introduction to the Study of Indian Languages* (1880), *Canyons of the Colorado* (1895), *Truth and Error* (1898).

See F. S. Dellenbaugh, *Romance of the Colorado River* (New York, 1903), and *Canyon Voyage: Second Powell Expedition* (New York, 1908); Wm. H. Brewer, "Obituary of John Wesley Powell," *Silliman's Journal,* series 4, vol. 14 (1902), pp. 377–383.

POWELL, VAVASOR (1617–1670), Welsh Nonconformist, was born in Radnorshire and educated at Jesus College, Oxford. About 1639 he became an itinerant preacher, and for preaching in various parts of Wales he was twice arrested in 1640. During the Civil War he preached in and around London. In 1646 he returned to Wales, and with a salary granted by parliament resumed his itinerant preaching. In 1650 parliament appointed a commission "for the better propagation and preaching of the gospel in Wales," and Powell acted as one of the principal advisers of this body. In 1653 he returned to London, and having denounced Cromwell for accepting the office of Lord Protector he was imprisoned. At the Restoration in 1660 he was arrested for preaching, and after a short period of freedom he was again seized, and he remained in prison for seven years. He was set free in 1667, but in 1668 he was again a prisoner, and he died in custody on Oct. 27, 1670.

See *The Life and Death of Mr. Vavasor Powell* (1671), attributed to Edward Bagshaw the younger; *Vavasoris Examen et Purgamen* (1654), by E. Allen and others; D. Neal, *History of the Puritans* (1822); and T. Rees, *History of Protestant Nonconformity in Wales* (1861).

POWER, (WILLIAM GRATTAN) TYRONE (1797–1841), Irish actor, was born near Kilmacthomas, County Waterford, on Nov. 2, 1797. At the age of 14 he joined a company of strolling players, eventually getting small parts in the London theatres.

On the sudden death of Charles Connor on Oct. 7, 1826, he was given his parts and was immediately recognized as the leading Irish character actor of his generation, becoming a popular favourite in London, Dublin and the United States.

He was on board the steamer "President" when it sunk in March 1841, leaving no survivors. Power wrote several Irish plays, including the farces *Born to Good Luck, or the Irishman's Fortune; O'Flannigan and the Fairies;* and *Paddy Carey, the Boy of Clogheen.* He published three novels, *The Lost Heir* (1830), *The Gipsy of the Abruzzo* (1831) and *The King's Secret* (1831), and also wrote *Impressions of America,* 2 vol. (1836).

He had married when he was 20 years of age and left a widow and seven children, the oldest of whom, Sir William Tyrone Power, became commissary-general of the British army and was knighted in 1865.

POWER. The word "power," as used by the engineer, indicates energy under human control and available for doing mechanical work.

The principal sources of power are the muscular energy of men and animals; the kinetic energy of the winds and of streams; the potential energy of water at high levels, of the tides and of waves; the heat of the earth and of the sun; and heat derived from the combustion of fuels. Of these sources of power the winds, waves and solar heat suffer the disadvantage of being essentially intermittent and therefore requiring some method of storage of power if the demand for power is continuous. From the point of view of the size and cost of the power plant, when large amounts of power are required, windmills, wave motors and solar engines are not adaptable to large-scale power generation; tidal power, while it may be developed in certain places for large power, usually entails excessive first cost; volcanic power or natural steam was used in Italy and experimented with in California; hydraulic turbines and heat engines alone permit the construction of compact plants of practically unlimited capacity and of moderate first cost. The commonly accepted unit of power is the horse-power, which was defined by James Watt (1736–1819) in 1783 as the equivalent of 33,000 ft.lb. of work per minute. This is about ten times as much work as can be done per minute by a labourer working eight hours per day.

The use of domesticated animals was the first enlargement of the power of man and the beginning of his civilization. The use of the wind for sailing vessels was an early development but its use in operating windmills dates from about the 12th century. Water wheels were known in Greek times and are described by Vitruvius, but their capacity was very small. To the end of the 18th century the largest water wheels for industrial use did not exceed 10 h.p. The earliest operative heat engine is the cannon, used first at the end of the 13th century. The social consequences of its invention were momentous; it had a great part in the destruction of the feudal system. It represented a greater concentration of power than had been possible previously. Its indirect influence in stimulating the development of the art of cutting metals is of prime importance in the history of the heat engine.

The special incentive which gave birth to the steam engine was the desire to remove water from mines (particularly the tin mines of Cornwall). In 1698 Capt. Thomas Savery's engine was patented and a number of his engines were built. They were found to be extravagant in their use of coal. Four years later the first steam engine using a cylinder and piston was devised by Thomas Newcomen.

It was while repairing a model of this engine that James Watt made the improvements that resulted in the modern steam engine. In 1782 Watt patented a double-acting rotative engine which, for the first time, made steam power available for driving all kinds of mechanism. The result of this invention was the factory system and the industrial revolution. It became possible also to apply steam power to navigation and to railroads.

The next important advance in power generation was the invention by Benôit Fourneyron of the hydraulic (reaction) turbine in 1827, for utilizing the energy of water available under high heads. Impulse water-turbines of the Pelton type, adapted to use the highest heads, were developed in California about 1860. Hydraulic turbines reached a high degree of perfection, giving efficiencies in excess of 90%.

The thermal efficiency of a heat engine is a function of the maximum and minimum temperatures of the working substance and also of the cycle of operations. The cycle of maximum efficiency for given temperature limits is the Carnot cycle. Combustion, which is the source of heat in heat engines, either may occur outside the engine (external combustion) or may occur inside the engine (internal combustion). In external-combustion engines the working substance is distinct from the products of combustion and heat travels to it by conduction through containing walls such as boiler heating-surface. The maximum temperature of the working substance is then limited by the strength of the containing walls at high temperature. With internal combustion the products of combustion are used as the working substance and there is no maximum temperature limit since the containing walls, piston and valves can be water-cooled. The theoretical thermal efficiency of the steam turbine is about 36%, of the diesel engine about 50%. The brake thermal efficiencies actually realized are considerably lower. The internal-combustion engine is compact, of light weight, instantly available for use, has low labour cost and no stand-by losses. Its principal disadvantage is that it uses a fuel more costly than coal except in diesel engines utilizing the cheapest grades of oil.

The first practical internal-combustion engine was that of E. Lenoir (1860). Two years later Beau de Rochas showed that for good efficiency it is necessary to compress the explosive mixture before igniting it; and in 1876 this idea was effectively realized in a successful explosion engine by N. A. Otto. The Otto cycle is the standard cycle in automobile, aeroplane and many stationary and marine engines. The fuel used by Lenoir and Otto was coal gas but in 1883 Gottlieb Daimler substituted volatile liquid hydrocarbon fuel (gasolene or petrol) and thereby made the engine available for automotive purposes. The use of less volatile hydrocarbon fuels (kerosene, fuel oil, etc.) was first successfully developed by Hornsby in the Hornsby-Ackroyd engine of 1894. A year later Rudolf Diesel built his first engine, in which the air is brought up to the temperature of ignition of the fuel by the work of compression alone and fuel is injected in a finely atomized state after the compression is completed. It is possible to burn in it any fuel that can be atomized by high-pressure air injection, by spraying under very high pressure through small openings, or by other means. It offers the combination of the cheapest fuel and the highest efficiency of utilization. The diesel engine was slow in development at first because of many practical difficulties, especially from heat stresses. It came into wide use, however, in ships, railway locomotives and motor buses.

The principal uses for power up to about 1890 were for driving shafting, pumps, compressors and hoists, for locomotives and for marine propulsion. With the improvements that had recently been made in the use of electricity the power station appeared. Electricity is a means for transmission of power and the only means which is economical for long distances and for complicated systems. The earlier power transmission systems by rope drives, compressed air and water under pressure, were too costly and cumbersome to survive. The maximum size of the electrical units installed increased rapidly from about 150 kw. in 1886 to 5,000 kw. in 1900.

The larger the engine the lower is its rotation speed. Large reciprocating engines are complex, heavy and costly, adapted only to special conditions.

In 1884 Sir Charles Parsons had taken out a patent for a reaction steam turbine and in 1891 made it into a condensing unit and began to supply it to electric-power stations. In 1889 Carl Gustav de Laval introduced the first practical impulse steam turbine. These turbines and those developed from them operate at high speeds of rotation, occupy little space, require no flywheels, are exceedingly simple, and have high steam efficiencies.

In order to obtain high thermal efficiency it is desirable not only that the maximum temperature of the working substance should be high but also that the amount of thermal energy available at high temperature should be considerable. This condition exists with a saturated vapour because the abstraction of latent heat results in change of state without change in temperature. For this reason pressures of 1,400 lb. per square inch are used in a few plants, corresponding to a saturation temperature of nearly 600° F. At the critical pressure the temperature is only a little more than 700° F., so that the limit of possible efficiency with steam is nearly reached; higher efficiencies with external-combustion engines can be obtained by the use of a combination of two working substances or the so-called binary-fluid system. A large-scale installation of a mercury-water system has yielded a brake thermal efficiency of about 35%, which is much more than is possible with any steam plant and practically the same as for a good diesel engine. Development of an internal-combustion turbine was held up by lack of a metal which could maintain adequate strength at high temperatures.

The history of the development of power shows a constant striving for greater economy, greater compactness of the units and greater capacity of each unit. (For atomic power, *see* ATOMIC ENERGY.)

See DIESEL ENGINES; ELECTRIC GENERATOR; ELECTRICAL POWER IN AGRICULTURE; ELECTRICAL POWER GENERATION; ELECTRICAL POWER; NATIONAL AND REGIONAL SCHEMES; ELECTRICAL POWER TRANSMISSION; HYDRAULIC POWER TRANSMISSION; HYDRAULICS; INTERNAL COMBUSTION ENGINES; MOTOR, ELECTRIC; MOTOR CAR; POWER TRANSMISSION: *Mechanical; Variable Gears;* TURBINE: STEAM; TURBINE: WATER; WINDMILLS AND WIND POWER.

(L. S. MA.; X.)

POWER ALCOHOL: *see* ALCOHOL IN INDUSTRY.

POWER AMPLIFIER. In radio work the ratio of the alternating-current power produced in the output circuit to the alternating-current power supplied to the input circuit is known as the power amplification. A power amplifier is an amplifier which is capable of producing relatively large power in an output circuit. (*See* AMPLIFICATION.)

POWER OF ATTORNEY or LETTER OF ATTORNEY is a written authority, usually, though not necessarily, under hand and seal, empowering the person named therein to do some act or acts on behalf of the principal, which otherwise could only be done by the principal himself. It is either general or special. A general power of attorney authorizes the agent to act for his principal in

all matters, or in all matters of a particular nature, or generally in respect of a particular business. A special power of attorney authorizes the agent to represent his principal only in regard to some particular specified act. A power of attorney expires with death of the principal, and is revocable at his will, even by a verbal notice, unless it has been given for a valuable consideration to secure some interest of the donee. The law relating to powers of attorney is a branch of the law of agency. Powers of attorney are used freely in the United States where their form and usage follow that of England. (*See* PRINCIPAL AND AGENT.)

POWERS, HIRAM (1805–1873), American sculptor, the son of a farmer, was born at Woodstock, Vt., on June 29, 1805. In 1819 his father removed to Ohio, where the son attended school for about a year. After leaving school he found employment in a reading-room in the chief hotel of the town; but, being, in his own words, "forced at last to leave that place as his clothes and shoes were fast leaving him," he became a clerk in a general store in Cincinnati and afterwards a mechanic in a clock and organ factory. In 1826 he began to frequent the studio of Eckstein, and at once conceived a strong passion for sculpture. His proficiency in modelling secured him the situation of general assistant and artist of the Western museum in Cincinnati, where his ingenious representation of scenes in Dante's *Inferno* met with extraordinary success. At the end of 1834 he went to Washington, where his remarkable gifts soon awakened attention. In 1837 he settled in Florence, Italy, where he remained till his death. While he found it profitable to devote the greater part of his time to busts, his best efforts were bestowed on ideal work. In 1839 his statue of "Eve" excited the admiration of Thorwaldsen, and in 1843 he produced his celebrated "Greek Slave," which at once gave him a place among the leading sculptors of his time. Among the best known of his other ideal statues are the "Fisher Boy," "Il Penseroso," "Proserpine," "California," "America" (modelled for the Crystal Palace, Sydenham), and the "Last of his Tribe." He died on June 27, 1873.

POWER TRANSMISSION. The appliances connected with installations for the utilization of natural sources of energy may be classified into three groups:—(1) Prime movers, by means of which the natural form of energy is transformed into mechanical energy. To this group belong all such appliances as water turbines, steam turbines, steam engines and boilers, gas producers, gas engines, oil engines, etc. (2) Machinery of any kind which is driven by energy made available by the prime mover. To this group belong all machine tools, textile machinery, pumping machinery, cranes—in fact every kind of machine which requires any considerable quantity of energy to drive it. (3) The appliances by means of which the energy made available by the prime mover is transmitted to the machine designed to utilize it. The term *power* is used to denote the rate at which energy is transmitted. The unit of power in common use is the horse power, and one horse power means a rate of transmission of 550 foot-pounds per second.

In many cases the prime mover is combined with the machine in such a way that the transmitting mechanism is not distinctly differentiated from either the prime mover or the machine, as in the case of the locomotive engine.

In other cases the energy made available by the prime mover is distributed to a number of separate machines at a distance from the prime mover, as in the case of an engineer's workshop. In this case the transmitting mechanism by means of which the energy is distributed to the several machines has a distinct individuality.

In other cases prime movers are located in places where the natural source of energy is abundant (namely, near waterfalls, or in the neighbourhood of coal fields), and the energy made available is transmitted in bulk to factories, etc., at relatively great distances.

In this case the method and mechanism of distribution become of paramount importance, since the distance between the prime mover and the places where the energy is to be utilized by machines is limited only by the efficiency of the mechanism of distribution.

Prime movers are considered in the articles DIESEL ENGINE; HYDRAULIC MACHINERY; INTERNAL COMBUSTION ENGINES; MOTOR, ELECTRIC; STEAM; STEAM ENGINE; and TURBINE. Machines are treated in various special articles.

For the methods and mechanisms of distribution or transmission reference should also be made to ELECTRICAL POWER TRANSMISSION; HYDRAULIC POWER TRANSMISSION; and to ELECTRIC POWER: NATIONAL AND REGIONAL SCHEMES; ELECTRICITY SUPPLY: TECHNICAL ASPECTS; and ELECTRIFICATION OF INDUSTRY. (X.)

POWER TRANSMISSION, MECHANICAL

Mechanical transmission of power is effected generally by means of belts or ropes, by shafts or by wheel gearing and chains. Each individual method may be used separately or in combination. The problems involved in the design and arrangement of the mechanisms for the mechanical distribution of power are conveniently approached by the consideration of the way in which the mechanical energy made available by an engine is distributed to the several machines in the factory.

By a belt on the fly-wheel of the prime mover the power is transmitted to the line shaft, and pulleys suitably placed along the line shaft by means of other belts transmit power, first, to small countershafts carrying fast and loose pulleys and striking gear for starting or stopping each engine at will, and then to the driving pulleys (*q.v.*) of the several machines.

Quantitative Estimation of the Power Transmitted.—In dealing with the matter quantitatively the engine crank-shaft may be taken as the starting point of the transmission, and the first motion-shaft of the machine as the end of the transmission so far as that particular machine is concerned.

Let T be the mean torque or turning effort in ft.lb. which the engine exerts continuously on the crank shaft when it is making N revolutions per second. It is more convenient to express the revolutions per second in terms of the angular velocity ω, that is, in radians per second. The relation between these quantities is $\omega = 2\pi N$. Then the rate at which work is done by the engine crank shaft is $T\omega$ foot-pounds per second, equivalent to $T\omega/550$ horse power. This is now distributed to the several machines in varying proportions. Assuming for the sake of simplicity that the whole of the power is absorbed by one machine, let T_1 be the torque on the first motion-shaft of the machine, and let ω_1 be its angular velocity, then the rate at which the machine is absorbing energy is $T_1\omega_1$ foot-pounds per second. A certain quantity of energy is absorbed by the transmitting mechanism itself for the purpose of overcoming frictional and other resistances, otherwise the rate of absorption of energy by the machine would exactly equal the rate at which it was produced by the prime mover assuming steady conditions of working. Actually therefore $T_1\omega_1$ would be less than $T\omega$ so that

$$T_1\omega_1 = \eta T\omega,$$

where η is called the efficiency of the transmission. Considering now the general problem of a multiple machine transmission, if T_1, ω_1, T_2, ω_2, T_3, ω_3, $\cdots$ are the several torques and angular velocities of the respective first motion shafts of the machines,

$$(T_1\omega_1 + T_2\omega_2 + T_3\omega_3 + \cdots) = \eta T\omega \qquad (2)$$

expresses the relations which must exist at any instant of steady motion. This is not quite a complete statement of the actual conditions because some of the provided energy is always in course of being stored and unstored from instant to instant as kinetic energy in the moving parts of the mechanism. Here, η is the over-all efficiency of the distributing mechanism. We now consider the separate parts of the transmitting mechanism.

Belts.—Let a pulley A (fig. 1) drive a pulley B by means of a leather belt, and let the direction of motion be as indicated by the arrows on the pulleys. When the pulleys are revolving uniformly, A transmitting power to B, one side of the belt will be tight and the other side will be slack, but both sides will be in a state of tension. Let t and u be the respective tensions in pounds on the tight and slack side; then the torque exerted by the belt on the

pulley B is $(t-u)r$, where r is the radius of the pulley in feet, and the rate at which the belt does work on the pulley is $(t-u)r\omega$ foot-pounds per second. If the horse power required to drive the machine be represented by h.p., then

$$(t-u)r\omega = 550 \text{ h.p.}, \qquad (3)$$

assuming the efficiency of the transmission to be unity. This equation contains two unknown tensions, and before either can

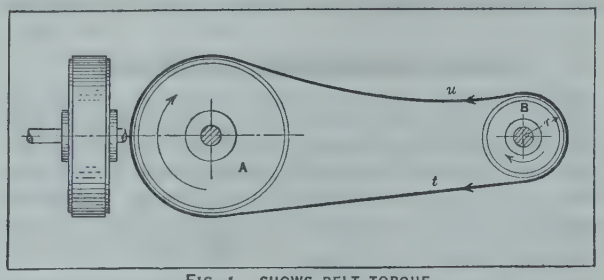


FIG. 1.—SHOWS BELT TORQUE

be found another condition is necessary. This is supplied by the relation between the tensions, the arc of contact θ, in radians (fig. 2), the coefficient of friction μ between the belt and the pulley, the mass of the belt and the speed of the belt. Consider an element of the belt (fig. 2) subtending an angle $d\theta$ at the centre of the pulley, and let t be the tension on one side of the element and $(t+dt)$ the tension of the other side. The tension tending to cause the element to slide bodily round the surface of the pulley is dt. The normal pressure between the element and the face of the pulley due to the tensions is $t\,d\theta$, but this is diminished by the force necessary to constrain the element to move in the circular path determined by the curvature of the pulley. If W is the weight of the belt per foot, the constraining force required for this purpose is $Wv^2d\theta/g$, where v is the linear velocity of the belt in feet per second. Hence the frictional resistance of the element to sliding is $(t-Wv^2/g)\mu d\theta$, and this must be equal to the difference of tensions dt when the element is on the point of slipping, so that $(t-Wv^2/g)\mu d\theta = dt$. The solution of this equation is

$$\frac{t-Wv^2/g}{u-Wv^2/g} = e^{\mu\theta}, \qquad (4)$$

where t is now the maximum tension and u the minimum tension, and e is the base of the Napierian system of logarithms, 2·718. Equations (3) and (4) supply the condition from which the power transmitted by a given belt at a given speed can be found. For ordinary work the term involving v may be neglected, so that (4) becomes

$$t/u = e^{\mu\theta}. \qquad (5)$$

Equations (3) and (5) are ordinarily used for the preliminary design of a belt to calculate t, the maximum tension in the belt necessary to transmit a stated horse power at a stated speed, and then the cross section is proportioned so that the stress per square inch shall not exceed a certain safe limit determined from practice.

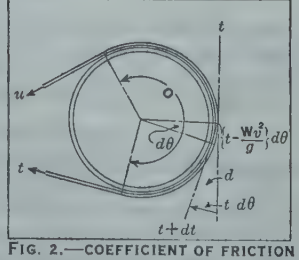


FIG. 2.—COEFFICIENT OF FRICTION

To facilitate the calculations in connection with equation (5), tables are constructed giving the ratio t/u for various values of μ and θ. (*See* W. C. Unwin, *Machine Design*, 12th ed., p. 377.) The ratio should be calculated for the smaller pulley. If the belt is arranged as in fig. 1, that is, with the slack side uppermost, the drop of the belt tends to increase θ and hence the ratio t/u for both pulleys.

Example of Preliminary Design of a Belt.—The following example illustrates the use of the equations for the design of a belt in the ordinary way. Find the width of a belt to transmit 20 h.p. from the flywheel of an engine to a shaft which runs at 180 revolutions per minute (equal to 18·84 radians per second), the pulley on the shaft being 3 ft. diameter. Assume the engine flywheel to be of such diameter and at such a distance from the driven pulley that the arc of contact is 120°, equal to 2·094 radians, and further assume that the coefficient of friction $\mu = 0{\cdot}3$. Then from equation (5) $t/u = e^{2.094\times0.3} = 2{\cdot}718^{\,0.6282}$; that is $\log_e t/u = 0{\cdot}6282$, from which $t/u = 1{\cdot}87$, and $u = t/1{\cdot}87$. Using this in (3) we have $t(1-1/1{\cdot}87)\ 1{\cdot}5\times18{\cdot}84 = 550\times20$, from which $t = 838$ lb. Allowing a working strength of 300 lb. per square inch, the area required is 2·8 sq.in., so that if the belt is $\frac{1}{4}$ in. thick its width would be 11·2 in., or if $\frac{3}{16}$ in. thick, 15 in. approximately.

The effect of the force constraining the circular motion in diminishing the horse power transmitted may now be ascertained by calculating the horse power which a belt of the size found will actually transmit when the maximum tension t is 838 lb. A belt of the area found above would weigh about 1·4 lb. per foot. The velocity of the belt, $v = \omega r = 18{\cdot}84\times1{\cdot}5 = 28{\cdot}26$ ft. per second. The term Wv^2/g therefore has the numerical value 34·7. Hence equation (2) becomes $(t-34{\cdot}7)/(u-34{\cdot}7) = 1{\cdot}87$, from which, inserting the value 838 for t, $u = 464{\cdot}5$ lb. Using this value of u in equation (1)

$$\text{H.P.} = \frac{(838-464{\cdot}5)\times18{\cdot}84\times1{\cdot}5}{550} = 19{\cdot}15.$$

Thus with the comparatively low belt speed of 28 ft. per second the horse power is only diminished by about 5%. As the velocity increases the transmitted horse power increases, but the loss from this cause rapidly increases, and there will be one speed for every belt at which the horse power transmitted is a maximum. An increase of speed above this results in a diminution of transmitted horse power.

Belt Velocity for Maximum Horse Power.—If the weight of a belt per foot is given, the speed at which the maximum horse power is transmitted for an assigned value of the maximum tension t can be calculated from equations (3) and (4) as follows:—

Let t be the given maximum tension with which a belt weighing W lb. per foot may be worked. Then solving equation (4) for u, subtracting t from each side, and changing the signs all through: $t-u = (t-Wv^2/g)\ (1-e^{-\mu\theta})$. And the rate of working U, in foot-pounds per second, is

$$U = (t-u)v = (tv - Wv^3/g)(1-e^{-\mu\theta}).$$

Differentiating U with regard to v, equating to zero, and solving for v, we have $v = \sqrt{(tg/3W)}$. Utilizing the data of the previous example to illustrate this matter, $t = 838$ lb., $W = 1{\cdot}4$ lb. per foot, and consequently, from the above expression, $v = 80$ ft. per second approximately. A lower speed than this should be adopted, however, because the above investigation does not include the loss incurred by the continual bending of the belt round the circumference of the pulley. The loss from this cause increases with the velocity of the belt, and operates to make the velocity for maximum horse power considerably lower than that given above.

Flexibility.—When a belt or rope is working power is absorbed in its continual bending round the pulleys, the amount depending upon the flexibility of the belt and the speed. If C is the couple required to bend the belt to the radius of the pulley, the rate at which work is done is $C\omega$ foot-pounds per second. The value for C for a given belt varies approximately inversely as the radius of the pulley, so that the loss of power from this cause will vary inversely as the radius of the pulley and directly as the speed of revolution. Hence thin flexible belts are to be preferred to thick stiff ones. Besides the loss of power in transmission due to this cause, the bending causes a stress in the belt which is to be added to the direct stress due to the tensions in the belt in order to find the maximum stress. In ordinary leather belts the bending stress is usually negligible; in ropes, however, especially wire rope, it assumes paramount importance, since it tends to overstrain the outermost strands and if these give way the life of the rope is soon determined.

Rope Driving.—About 1856 James Combe, of Belfast, introduced the practice of transmitting power by means of ropes run-

ning in grooves turned circumferentially in the rim of the pulley (fig. 3). The ropes may be led off in groups to the different floors of the factory to pulleys keyed to the distributing shafting. A groove was adopted having an angle of about 45°, and this is the angle still used in the practice of Messrs. Combe, Barbour and Combe, of Belfast. A section of the rim of a rope driving wheel showing the shape of the groove for a rope of $1\frac{3}{4}$ in. diameter is

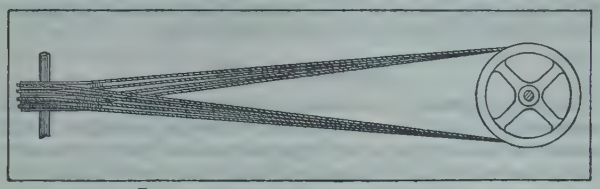


FIG. 3.—GROUP SYSTEM OF ROPE DRIVE

shown in fig. 4, and a rope driving pulley designed for six $1\frac{3}{4}$ in. ropes is shown in fig. 5. A rope is less flexible than a belt, and therefore care must be taken not to arrange rope drives with pulleys having too small a diameter relatively to the diameter of the rope. The principles of §§ 3, 4, 5 and 6, apply equally to ropes, but with the practical modification that the working stress in the rope is a much smaller fraction of the ultimate strength than in the case of belting and the ratio of the tensions is much greater. The following table, based upon the experience of Messrs. Combe, presents the practical possibilities in a convenient form:—

Diameter of rope	Smallest diameter of pulley, which should be used with the rope	H.P. per rope for smallest pulley at 100 rev. per minute
In.	In.	
$\frac{3}{4}$	14	$\frac{5}{8}$
1	21	1
$1\frac{5}{8}$	42	8
$2\frac{1}{8}$	66	16

The speed originally adopted for the rope was 55 ft. per second. This speed has been exceeded, but, as indicated above, for any particular case there is one speed at which the maximum horse power is transmitted, and this speed is chosen with due regard to the effect of centrifugal tension and the loss due to the continual bending of the rope round the pulley Instead of using one rope for each groove, a single continuous rope may be used, driving from one common pulley several shafts at different speeds. For further information *see* Abram Combe, *Proc. Inst. Mech. Eng.* (July 1896). Experiments to compare the efficiencies of rope and belt driving were carried out at Lille in 1894 by the *Société Industrielle du Nord de la France*, for an account of which *see* D. S. Capper, *Proc. Inst. Mech. Eng.* (October 1896). Cotton ropes are used extensively for transmitting power in factories, and though more expensive than Manila ropes, are more durable when worked under suitable conditions.

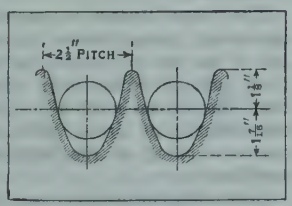


FIG. 4.—SECTION OF RIM FOR ROPE PULLEY DRIVE

Shafts.—When a shaft transmits power from a prime mover to a machine, every section of it sustains a turning couple or torque T, and if ω is the angular velocity of rotation in radians per second, the rate of transmission is $T\omega$ foot-pounds per second, and the relation between the horse power, torque and angular velocity is

$$T\omega = 550 \text{ H.P.} \qquad (6)$$

The problem involved in the design of a shaft is so to proportion the size that the stress produced by the torque shall not exceed a certain limit, or that the relative angular displacement of two sections at right angles to the axis of the shaft at a given distance apart shall not exceed a certain angle, the particular features of the problem determining which condition shall operate in fixing the size. At a section of a solid round shaft where the diameter is D inches, the torque T inch-pounds, and the maximum shearing stress f pounds per square inch, the relation between the quantities is given by

$$T = \pi D^3 f/16, \qquad (7)$$

and the relation between the torque T, the diameter D, the relative angular displacement θ of two sections L inches apart by

$$T = C\theta\pi D^4/32L, \qquad (8)$$

where C is the modulus of rigidity for the material of the shaft. Observe that θ is here measured in radians. The ordinary problems of shaft transmission by solid round shafts subject to a uniform torque only can be solved by means of these equations.

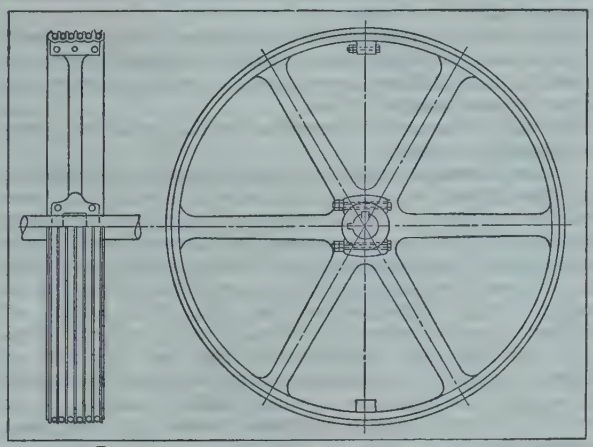


FIG. 5.—DESIGN OF PULLEY FOR SIX ROPE DRIVE

Calculate the horse power which a shaft 4 in. diameter can transmit, revolving 120 times per minute (12·56 radians per second), when the maximum shearing stress f is limited to 11,000 lb. per square inch. From equation (7) the maximum torque which may be applied to the shaft is $T = 138{,}400$ inch-pounds. From (6) H.P. $= \frac{138{,}400 \times 12{\cdot}56}{12 \times 550} = 264$. The example may be continued to find how much the shaft will twist in a length of 10 ft. Substituting the value of the torque in inch-pounds in equation (8), and taking 11,500,000 for the value of C,

$$\theta = \frac{138{,}400 \times 120 \times 32}{11{,}500{,}000 \times 3{\cdot}14 \times 256} = 0{\cdot}057 \text{ radians},$$

and this is equivalent to 3·3°.

In the case of hollow round shafts where D is the external diameter and d the internal diameter equation (7) becomes

$$T = \pi f(D^4 - d^4)/16D, \qquad (9)$$

and equation (8) becomes

$$T = C\theta\pi(D^4 - d^4)/32L. \qquad (10)$$

The assumption tacitly made hitherto that the torque T remains constant is rarely true in practice; it usually varies from instant to instant, often in a periodic manner, and an appropriate value of f must be taken to suit any particular case. Again it rarely happens that a shaft sustains a torque only. There is usually a bending moment associated with it. For a discussion of the proper values of f, to suit cases where the stress is variable, and the way a bending moment of known amount may be combined with a known torque, *see* MATERIALS, STRENGTH OF. It is sufficient to state here that if M is the bending moment in inch-pounds, and T the torque in inch-pounds, the magnitude of the greatest direct stress in the shaft due to the effect of the torque and bending moment acting together is the same as would be produced by the application of a torque of

$$M + \sqrt{(T^2 + M^2)} \text{ inch-pounds} \qquad (11)$$

It will be readily understood that in designing a shaft for the distribution of power to a factory, where power is taken off at

different places along the shaft, the diameter of the shaft near the engine must be proportioned to transmit the total power transmitted whilst the more remote parts of the shaft are made smaller, since the power transmitted there is smaller.

Gearing. Pitch Chains.—Gearing is used to transmit power from one shaft to another. The shafts may be parallel; or inclined to one another, so that if produced they would meet in a point; or inclined to one another so that if produced they would not meet in a point.

In the first case the gear wheels are called spur wheels, sometimes cog wheels; in the second case bevel wheels, or, if the angle between the shafts is 90°, mitre wheels; and in the third case they are called skew bevels.

In all cases the teeth should be so shaped that the velocity ratio between the shafts remains constant, although in very rare cases gearing is designed to work with a variable velocity ratio as part of some special machines.

The size of the teeth is determined by the torque the gearing is required to transmit.

Gearing is noisy at high speeds unless special care is taken in the manufacture to secure exact uniformity in pitch. Great impetus was given to the development of improved methods of manufacture by the need of gearing the high speed marine steam turbine to the low speed propeller. The first turbine geared ship the "Vespasian" was described in a paper by Sir Charles Parsons entitled "On the application of the marine steam turbine and mechanical gearing to merchant ships." *Proc. Inst. Naval Architects,* Vol. LII. 1910. The motor car gear box, back axle and differential gear call for silent gearing and the demand has brought the manufacture of gearing to a high pitch of accuracy. In the best class of work the gears are ground to exact pitch and shape after hardening.

Pitch chains are closely allied to gearing; examples are offered by many automobile engines, *e.g.,* the pitch chain often found driving the large shaft, etc. Pitch chains are used to a limited extent as a substitute for belts, and the teeth of the chains and the teeth of the wheels with which they work are shaped on the same principles as those governing the design of the teeth of wheels.

If a pair of wheels is required to transmit a certain maximum horse power, the angular velocity of the shaft being ω, the pressure P which the teeth must be designed to sustain at the pitch circle is 550 H.P./ωR, where R is the radius of the pitch circle of the wheel, whose angular velocity is ω.

In the case of transmission either by belts, ropes, shafts or gearing, the operating principle is that the rate of working is constant, assuming that the efficiency of the transmission is unity, and that the product $T\omega$ is therefore constant, whether the shafts are connected by ropes or gearing. Considering therefore two shafts, $T_1\omega_1 = T_2\omega_2$; that is $\omega_1/\omega_2 = T_2/T_1$; *i.e.,* the angular velocity ratio is inversely as the torque ratio. Hence the higher the speed at which a shaft runs, the smaller the torque for the transmission of a given horse power, and the smaller the tension on the belts or ropes for the transmission of a given horse power.

Long Distance Transmission of Power.—C. F. Hirn originated the transmission of power by means of wire ropes at Colmar in Alsace in 1850. Such a telodynamic transmission consists of a series of wire ropes running on wheels or pulleys supported on piers at spans varying from 300 to 500 ft. between the prime mover and the place where the power is utilized. The slack of the ropes is supported in some cases on guide pulleys distributed between the main piers. In this way 300 h.p. was transmitted over a distance of 6,500 ft. at Freiberg by means of a series of wire ropes running at 62 ft. per second on pulleys 177 in. diameter. The individual ropes of the series, each transmitting 300 h.p., were each 1·08 in. diameter and contained 10 strands of 9 wires per strand, the wires being each 0·072 in. diameter. Similar installations existed at Schaffhausen, Oberursal, Bellegarde, Tortona and Zürich. For particulars of these transmissions with full details *see* W. C. Unwin's Howard Lectures on the "Development and Transmission of Power from Central Stations" (*Journ. Soc. Arts,* 1893, published in book form 1894). The system of telodynamic transmission would no doubt have developed to a much greater extent than it has done but for the advent of electrical transmission, which made practicable the transmission of power to distances beyond the possibilities of any mechanical system.

See W. J. M. Rankine, *Treatise on Machinery and Millwork;* and W. C. Unwin, *Elements of Machine Design;* and for telodynamic transmission *see* F. Reuleaux, *Die Konstrukteur. See* also, Daniel Adamson, "Spur Gearing," *Proc. Inst. Mech. Eng.* (1916 Jan.–May); R. J. McLeod, "Turbine Reduction Gearing and its Production," *Proc. Inst. Mech. Eng.* (1924 Vol. 2); H. F. L. Orcutt, "Characteristics and uses of Ground Gears," *Proc. Inst. Mech. Eng.* (1925 Vol. 2). (W. E. D.)

UNITED STATES

Mechanical power transmission is bound by many assumptions and conditions, and the selection and successful operation of the various methods employed are largely dependent upon: (1) source and kind of power; (2) character of equipment to be driven; (3) horse-power, speeds and ratios; (4) supports and foundations; (5) bearings—their construction, type and spacing; (6) lubrication; (7) shafting—size, quality and material; (8) belting—type, width, thickness and method of joining; (9) manner of loading and unloading the power to be transmitted; (10) mechanical and atmospheric conditions involved; (11) relation of distribution to prime mover; (12) alignment; (13) available space; (14) maintenance facilities.

Modern Methods.—Recent years have brought efficient and economical small-powered prime movers and improvements in mechanical power mechanisms. These developments have segregated the transmitting of mechanical power into certain groups which, when employed in proper relation to other essential operating factors, make for economy, efficiency and low maintenance. Modern mechanical transmission systems can be classified as follows: (1) direct motor coupled connection; (2) direct motor belt connection; (3) direct motor chain connection; (4) belt and line shaft group system; (5) gear reduction unit system; (6) open gear connection system; (7) multiple fabric or manila rope systems; (8) the variable speed connection unit; (9) the combination of one or more of the above systems.

Direct motor coupled connections afford compactness and are most extensively employed for the driving of modern machine tools (*q.v.*). The connection medium between motor and the power-receiving shaft should be a flexible coupling.

Direct motor belt connections employ a belt as the connection between the motor and power-receiving shaft of the mechanism and are extensively employed for various apparatus and machine tool driving. With this method any ratio up to 6 to 1 is practicable from the motor to machine.

Direct motor chain connections employ chain of various types as the connection between the motor and power-receiving shaft of the mechanism. It is successfully operated on machine tools and line shaft drives. Ratios up to 7 to 1 on short centres are practicable.

The group system is extensively used in modern industrial operations. Group driving is most practicable from 5 to 50 h.p. and if the line is operating at the normal speeds of 150 to 300 r.p.m., one belted or chain reduction is sufficient from motor to line. The driven machine can be belted from the line through countershafts or direct. With this system, the size of the prime mover is based on the aggregate of the running loads of the machines driven.

Gear reduction unit systems. The electric motor has the inherent characteristic of operating at high speed. In many industrial operations the power-receiving shaft of apparatus or machine to be driven must run at slow speed. Ratios of 50 to 1 and 100 to 1 are frequent from prime mover to apparatus, therefore the use of the modern gear reduction unit. Ratios such as these if attempted by the belting and shafting method would require a large amount of transmission equipment. Spur gear reducers are manufactured with ratios up to 500 to 1 and reduce in a straight line. The worm gear reducer has reached a high state of perfection. The single unit can be employed on drives requiring speed reductions of 100 to 1.

The open gear connection system is employed where extremely close centres and moderate ratios are desired such as on small

machine tools and large apparatus. Composition or non-metallic gears are used on the prime mover shaft to eliminate the noise of high speed metallic gears meshing together. Large apparatus at slow speeds are frequently direct geared to the motor and where a greater ratio is necessary than is practicable with one reduction, a back geared motor is employed. This type of motor combines one geared reduction integral with itself.

The multiple fabric rope system is of recent development. The ropes are of "V" shaped endless construction and operate on "V" grooved wheels. Ratios up to 7 to 1 and extremely short centres are possible. It is applicable for direct driving of almost any class of machine or apparatus where adjustment between driver and driven is possible. There are now in use two systems of *manila rope driving:* the American or continuous method and the English or multiple method. The American system employs but one continuous rope winding over all of the grooves with the rope on the slack side forming a loop over an idler sheave and a travelling tightener which automatically regulates the tension of all the wraps of the rope. The English system employs separate and independent endless ropes in each groove of the wheels. The American system will transmit power for great distances and in any direction. The English system is most adaptable for direct high power driving.

Variable speed connection units are used to meet the requirements of numerous industrial operations. Variations in applied speed are absolutely necessary, and the control of this speed change must be smooth or without shock. In modern practice this is accomplished by variable speed motors or by mechanical speed change devices. It frequently happens that it is necessary to employ a *combination of methods* of driving because of limited space. The compactness of modern methods is then an advantage.

Mechanical Consideration.—Consideration affecting power methods are space, speed, ratios and method of control. Mechanical driving requires *space,* the amount being dependent on the method employed. If ratios are low and ample centres are available the "group" system of belt driving should be employed. If space is limited and ratios are high, the close coupled installations such as chain, worm or spur gear reducers, multiple rope and direct gear connections should be used. Space governs moderate *speed ratios,* but available area does not warrant the use of shafting and belting when ratios of 25, 30, 50 and 100 to 1 are necessary. For these ratios gear reduction units should be used.

The method of control is an important factor since it is frequently necessary to change speeds or shut down the machine during operation and then start under load. Unless a slip ring motor is employed, direct connection by any rigid means should not be used. Shafting should be employed for this service equipped with belting or chains controlled by either clutch or shifters.

Plant Considerations.—Plant considerations affecting power methods are power sources and costs. In industry where power is either purchased or generated, the *power source* has no effect on the problem, but in plants where natural power has been harnessed by cumbersome methods and modernizing is desired, the problem is somewhat difficult. Here power is distributed by long lines of shafting and numerous wide belts. If the plant is large, the friction load is high and maintenance excessive. By the installation of gear reduction units and short centre devices much shafting and belting can be removed. *First cost* of mechanical transmission equipment should not be considered to such an extent that the cheapest method is the best. In many instances high initial expenditures are economical. In large industrial operations, *maintenance costs* are of necessity high, but when good quality transmission equipment is installed it should be given care and attention. Careless joining, wrong type and size of belting and injurious dressings are all causes of high maintenance. Inattention to lubrication, poor adjustments, careless installing and overloading cause the maintenance bills to rise on transmission appliances such as bearings, clutches, pulleys and shafting.

Belting.—Power belting is the medium of delivering a given amount of power at a given point at the least cost per unit of time, which should result in the transmission of power at the lowest cost per horse power per year over the longest period of useful service. If the belting fails, the mechanism stops. If the belting slips, the mechanism slows down. It is necessary that the user have some knowledge of the attributes and characteristics of the various power belting materials and the correct atmospheric and mechanical conditions. (*See* BELTING.) The open belted short centre driving installation is not efficient. Its faults have led to the development of modern methods for driving at close centres by flexible shock absorbing non-metallic mediums.

The Automatic idler system is a development of the ordinary tightener pulley. Its chief function is to increase the arc of contact on the driving pulley. The fulcrum or idler pulley is applied to the belt so as to equal the belt tension and to increase the arc of contact both permanently and automatically and in accordance with the load transmitted. The permanent increase is attained by the proper location of the idler fulcrum. The automatic increase is accomplished by wrapping every possible inch of belting around the smaller of the two pulleys. The elongation or stretch of the belt due to its elasticity is in synchronism with the variations in the power transmitted; when the power is maximum, the arc and the grip of the belt on the pulley is also maximum.

The multiple "V" shaped rubber and fabric rope drive is an adaptation of the English multiple endless rope-driving method with the exception that it employs "V" shaped ropes made of rubber and fabric composition operating on multiple "V" grooved wheels. It is an excellent transmitter of power at close range. The greater the load tension, the greater the adhesion to the grooves of the wedge-shaped belting sheaves, therefore, slip is almost entirely eliminated. This method of driving is successful on short centre work, with centre distances up to 12 feet. It has a range in power capacity from ½ h.p. to 2,000 h.p., depending on the number and size of "V" ropes employed.

High Ratio Short Centre Device.—There are occasions for ratios from 15 to 1 to 30 to 1. Solving such reductions by shafting and belting may be out of the question. Worm gear or spur gear reduction units may be too rigid. To meet such requirements a new device has been recently developed, which gives a compact, flexible, short-centre and high-ratio drive. It is composed of a gear, pinion, pulley, spindle and fulcrum arm. The pulley and pinion are keyed to the spindle which is supported by the fulcrum arm centred on the shaft to be driven. The gear is keyed on the shaft to be driven and meshes with the pinion on the spindle. Thus, in the rotation of the spindle by the aid of a belt drive to the spindle pulley, the pinion tends to make an epicyclic movement around the gear wheel with which it meshes, but such movement is restrained when the belt has been tensioned and the continued rotation of the pinion will rotate the gear wheel and operate the apparatus or lineshaft. The degree of tension on the driving belt depends upon the inertia to be overcome in starting the load and in the continued running, so that the belt always retains the correct tension for the power requirements. The chief feature of this method of driving is the absolute automatic load tension on the ordinary open driving belt without the aid of spring or weight controlled idler pulleys. The belt is always in correct tension because the load controls it.

Power Shafting Bearings.—There are various types of bearings manufactured for industrial power transmitting. They are designed to support shafting and the factors which determine the selection of any given design are: (1) diameter and speed of shaft; (2) power transmitted and kind of load; (3) supporting structure; (4) lubrication; (5) space limitations; (6) operating conditions. Bearings are made of iron or steel, bushed or lined with brass, bronze and various anti-friction metals. (*See* BEARINGS.) When bearings are lined with babbitt metal, as is common practice, the shaft beds itself down and distributes its weight uniformly over the entire bearing surface. Industrial bearings are subjected to "moderate" or "excessive" pressures. Moderate pressures exist in industrial head, line, jack and counter shaft operations if the correct number of bearings are employed for the load demand. Standard bearings for this class of work have ample bearing surface for the pressures involved. Excessive pressures on bearings are due to extreme weight, pull or thrust conditions. Excessive dead load causes extreme weight. Excessive pull is due to

high belt or rope tension. Excessive thrust is due to abnormal duty or to faulty mechanical adjustments.

Solid babbitted bearings of babbitted cast iron should be used on slow speed shafting under $4\frac{7}{16}$ in. diameter. Lubrication is by grease cup or plain oiling. *The split flat box* type of babbitted cast iron, furnished with a cap, is employed where moderate powers and speeds are involved, but not on shafting over $3\frac{15}{16}$ in. diameter. Grease or oil is used as a lubricant.

The self-oiling rigid pillow block type of babbitted cast iron is designed to feed the oil to the shaft, by the ring, chain, collar or capillary method. This type should be lubricated by the ring, chain or collar method up to 110 r.p.m. Above this speed the capillary system should be used.

The angle self-oiling rigid pillow block type is similar to the self-oiling rigid pillow block except that the split is at an angle of approximately 45°. This bearing should be employed when a severe power pull is directly on the cap.

The ball and socket self-oiling pillow block type is of cast iron construction, is equipped with ring or capillary oiling features, accommodates itself to shaft movement and possesses vertical adjustment. It is made in sizes from $1\frac{7}{16}$ in. to $4\frac{15}{16}$ in. diameter. It is employed for shafting supported from concrete piers or timbers and particularly on line shafting supported from walls of buildings.

The adjustable drop hanger is designed to support line shafting. It can also be used for head, jack or counter shafting. It is constructed of cast iron and equipped with a self-oiling bearing. The ball and socket type has vertical adjustment through threaded plungers and side adjustment through slotted holes in the base. The 4-point suspension type can be adjusted both vertically and horizontally but the bearing is held more rigidly than that of the ball and socket type. These types of hangers are manufactured for shafting $\frac{15}{16}$ in. to 6 in. diameter.

The adjustable ball and socket post hanger type is of cast iron and is equipped with a self-oiling bearing. It is designed for head and line shafting that must be supported from columns. It has vertical adjustment and the bearing can arrange itself to the shaft movement. It is made for shafting $\frac{15}{16}$ in. to 6 in. diameter. (*See* BEARINGS.)

Transmission by chain has progressed to the extent that there is a type of chain for most any service. The general advantages of chain driving are: (1) very high efficiency; (2) relatively high speeds available; (3) reversability; (4) unaffected by heat, cold or moisture; (5) wide power transmitting range; (6) a positive velocity ratio; (7) utility on short or long centres; (8) security from slippage.

Detachable malleable iron chain is composed of individual malleable iron links so designed as to allow ease of assembly. It finds application in practically every form of industry where the speeds and ratios are held within 400 r.p.m. and under, and the ratio held to not more than 5 to 1.

Steel Roller Chains.—While malleable iron chains have given satisfactory service for the transmission of power in their field, a demand for chains which will operate at higher speeds and carry heavier loads was responsible for the development of a more accurate steel chain. These chains range from a rugged low speed class to machine finished high speed chains.

Light steel roller chain is an accurately pitched chain of light construction, three times the tensile strength of the malleable iron type and operates on the same cast tooth sprockets. It is constructed with medium carbon hot rolled steel side bars. The pins and bushings are of hardened steel and the rollers are of either malleable iron or hardened steel. It is applicable where the speeds and ratios are held within 700 r.p.m. and under, and the ratio held to not more than 5 to 1.

Finished steel roller chain is intended for general power transmission purposes and operates on accurately cut sprocket wheels. This chain is manufactured in a number of pitches ranging from $\frac{1}{2}$ to 4 inches. It is constructed with special rolled steel, heat-treated side bars. The pins are made from alloy steel hardened and the bushings are steel, case hardened. The rollers are high carbon steel, heat treated and can either be made curled or solid. It can be had either riveted or detachable and is made in single or multiple widths. It is possible to operate this chain at 1,000 f.p.m. and with ratios up to 10 to 1, but it is more desirable from an economical and long life standpoint to limit its operating speed to approximately 700 r.p.m. and its ratio to 7 to 1.

The silent chain is manufactured for any reasonable power capacity, and is designed for high speeds. It is therefore employed in connection with motor applications. The silent chain is an assembly of specially designed links which operate on cut tooth sprockets, generally termed pinion and gear. The silent chain drive is applicable in all channels of industrial operations. It is particularly adaptable for direct chain connection between motor and machine or motor and line, head or counter shafting. The most desirable speed for this type of chain is 1,200 to 1,500 r.p.m. and ratios of 15 to 1 have proven successful. (*See* CHAIN MANUFACTURE.)

Gear Reduction Units.—Motor speeds of 500 to 1,800 revolutions per minute are too high for industrial purposes, therefore, some mechanical reduction medium must be interposed between the motor and driven machine. The modern speed reduction gear unit has made possible the elimination of a multiplicity of chains, gears, shafting and belting for ratios such as 15 to 1 and higher. It utilizes four general types of gearing, namely, the worm, the spur, the herringbone and the bevel. Reduction units using these various types are available in suitable sizes and ratios for almost any power and speed reduction required. Each type has inherent limitations, therefore, care should be exercised based on a knowledge of the units in question before a selection is made for a particular requirement. One of the most important factors in the successful operation of a speed reduction gear whether it be the worm, spur, herringbone or bevel type, is the connection to the motor and the connection to the shaft of the driven machine or apparatus. The flexible type of coupling is imperative at these points, because it is not mechanically possible to line two shafts perfectly, each supported on its own bearings, so that both will revolve about the same axis.

The efficiency of a modern *worm gear speed reducer* is entirely dependent in many cases on the helix angle of the thread of the worm. The greater the helix angle (up to about 42°) the greater the efficiency; and the smaller the angle, the greater the power loss. The worm of a modern reducer is usually integral with an alloy steel shaft with threads hardened and ground. This combination is rigidly supported on ball or roller bearings, the rear bearing being of the double row maximum type, capable of carrying the full thrust load of the worm in either direction as well as one half the radial load. The other half of the radial load is taken by the forward bearing. The worm gear usually consists of a chilled cast bronze rim shrunk on and pinned to a high grade cast iron centre. The housing of the reducer is cast iron, compact and sealed tight so that the oil in which the gearing operates can be perfectly maintained.

Ratios of 60 or 70 to 1 are common, but beyond this the efficiency drops rapidly. To obtain higher reductions and still retain the right angle feature of the worm drive, two methods may be employed. One is to provide an auxiliary shaft supported independently, on which is mounted a pinion which in turn meshes with another gear. Another more recent method is to employ a reduction unit specially designed with suitable bearings to permit the mounting of the pinion directly on the slow speed shaft. For special applications and ratios up to 10,000 to 1, the double reduction worm gear unit may be employed. Modern worm gear reduction units can be operated at worm speeds up to 4,000 r.p.m. and are therefore, suitable for direct connection to steam turbines.

The spur gear reduction unit has been evolved to cope with ratios as high as 500 to 1 and reduces in a straight line. The spur gear reducer can be classified into two distinct types, the planetary and the non-planetary. The planetary type is capable of giving the largest speed reduction because it consists of spur gears or idlers radially disposed about a central pinion and in turn mesh with a stationary internal gear. The planetary reducer with single reduction is satisfactory for ratios between 4 and 8 to 1, but should not be considered for ratios of less than 3 to 1. High ratios such as

100, 200, 400 and 500 to 1 are obtainable in the planetary type by the reductions being doubled or tripled and coupled in series in the same cast iron housing. The non-planetary type of spur gear reducer has the advantage of giving comparatively low reductions and keeping the rotational speeds at minimum. Ratios as low as 1 to 1 and as high as 300 to 1 are practical with the non-planetary system. This type consists usually of spur gears radially disposed about a central pinion. Each of the spur gears is keyed directly to pinions which in turn mesh with a central gear mounted upon the slow speed shaft.

The herringbone gear speed reducer does not possess the right angle feature of a worm drive nor the "shafts in line" feature of the spur gear reduction unit. It reduces in parallel. The single reduction type is manufactured up to a ratio of 8 to 1. In ratios over this the reduction is obtained in two steps. There are two distinct types of the double herringbone reduction unit. One type consists of two sets of herringbone gears arranged in series. In the other type, the first set of gears is split, one set being cut right and the other left hand. They are mounted far enough apart to allow the insertion of the final drive pinion between the helical gears. This form of construction equalizes the loads of all bearings as well as making a more compact drive. These two types are manufactured in ratios up to 60 to 1.

Variable Speed Mechanisms.—Methods both electrical and mechanical have been devised for varying applied speed to apparatus. For many operations of this character, the variable speed motor is ideal, but generally, this type of motor possesses a certain definite range of speed alterations, and therefore is not suitable for close speed adjustment. Fine adjustment is possible with modern mechanical speed transformers. These devices operate in connection with constant speed motors and are most efficient. There are certain phases of industrial operations where speeds must be gradually increased or decreased, otherwise destruction of the product results. For operations such as this, the mechanical speed transformer is imperative. (W. STA.)

VARIABLE GEARS

This article is concerned with variable transmission of power, and not merely variable speed transmission, otherwise it would have to include the consideration of a multitude of appliances such as speed indicators, integrators and many kinds of calculating machines.

Power transmission gears may be divided into two classes (1) that in which there is a step by step change and (2) that in which the change is gradually effected and an infinite range of velocity ratio is possible.

Step by step variable gears are familiar to all who have passed through an engineer's workshop, in which lathes, drilling machines and other tools are operated by stepped belt pulleys or trains of wheels of different size, these devices being used to effect variable transmission. A familiar example on the roads is the motor-car, in which with very rare exceptions the change of speed is effected by means of a gear box containing a number of different sized pairs of tooth wheels, arranged so that a change of speed can be effected at will by operating a gear lever. On the other hand infinitely variable transmission is less familiar and until comparatively recent times had no particular application except for very light powers. The increasing employment of infinitely variable transmission is due to the fact that the electric motor, steam turbine, and most of all the internal-combustion engine (*q.v.*) have for many purposes superseded the steam engine. One feature of the greatest value in the steam engine is its flexibility; the inferiority in this direction of other kinds of motive power being very marked. For this reason there have been attempts in recent years to find either by frictional, electric, hydraulic or other mechanical means some practicable and effective form of infinitely variable transmission.

Before proceeding to describe various types of variable transmission it must be understood that it is quite possible to vary the speed of transmission by a slipping clutch and claims are often put forward for such a clutch as effecting infinitely variable transmission. This, however, is not correct, being only a case of variation in speed by a direct loss of energy and not true variable transmission. The true test of variable transmission is as to whether it fulfils, at any rate approximately, what is called the Law of Work that "what is lost in force is gained in speed" and vice versa. Thus, for instance, apart from the unavoidable loss of efficiency due to friction, either a train of wheels or a combination of belt pulleys obey the law of work and overcome a greater resistance by a corresponding reduction of speed. On the other hand, if a lesser resistance is to be overcome the rate of operation can be proportionately increased by suitable alteration of the train of wheels employed.

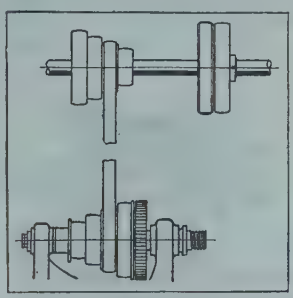


FIG. 1.—DIAGRAM SHOWING STEP PULLEY SYSTEM OF BELT DRIVE FOR AN ORDINARY LATHE

Classification of Methods.—In order to understand the different types of variable transmission they may be classified under the following heads; Frictional, Mechanical, Pneumatic, Electric, and Hydraulic.

Frictional.—Fig. 1 shows the step pulley system, the lower series operating in the headstock of the lathe, and the upper deriving motion from the driving shaft. As the belt is shifted from right to left off and on the different pulleys the speed of the lathe can be increased; or when from left to right the opposite effect is obtained. Corresponding to step by step movement, fig. 2 shows an infinitely variable transmission by pulleys which forms part of the cotton spinning device of Houldsworth invented just a century ago. Here the variation of speed between the driving and driven pulleys is obtained by shifting the belt to and fro along drums of nearly conical form. A modern form of variable transmission was in 1910 and later applied successfully to motor bicycles. Each pulley has a groove of "V" shape, the driving and driven pulleys being both capable of expansion and contraction. This expansion or contraction is effected by shifting in one direction or another the conical movable side of the pulley. The closer the sides come together the greater will be the effective diameter of the pulley. Powerful springs ensure that the driving belt shall be gripped on both pulleys, an idle wheel running between two pulleys accurately to secure the correct location of the conical surface.

A development is now taking place of this type of variable transmission for larger powers. In a useful form variation of the distance apart of the conical sides of a driving and driven pulley is effected when much power has to be transmitted by a hand wheel that operates a combination of worm and worm wheel so as to turn to other worms and thereby move levers, which respectively operate the movable cheeks of the conical pulleys either inwards or outwards. In all probability the oldest type of infinitely variable gear is that in which a friction roller is moved edgeways to and fro on the disk or circular flat plate. If, as in a certain type of motor-car the speed of the driven disk is least when the roller is nearest the edge, the greatest driving force is then obtained. On the other hand, when the roller has approached towards the centre of the disk p the greatest speed is obtained with corresponding reduction of driving force. The power transmitted with this gear is however comparatively small as it depends entirely on frictional contact of the surfaces and the wear of the frictional surfaces is considerable.

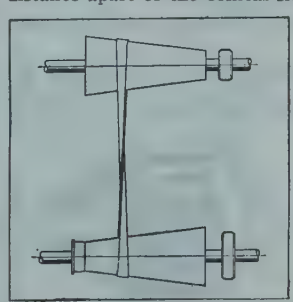


FIG. 2.—DIAGRAM OF A VARIABLE TRANSMISSION BY PULLEYS

Mechanical.—Variable transmission of mechanical kind can be said to be practically confined to the employment of trains of toothed wheels. The most familiar case of mechanical gearing is

that of a lathe headstock, in which by coupling up the largest step pulley to the spur wheel to the spindle of the headstock a direct drive is obtained from the speed pulleys. If this coupling is released and by means of a handle shown in the figure the back axle is approached to the main spindle so as to bring into engagement the two pairs of tooth wheels, the driving now takes place through the pinion driven by the step cone pulley through the axle shaft, and back to the lay spindle. Increase of driving force with corresponding reduction of speed is thus obtained which in the present example is nine times as great as by the direct drive.

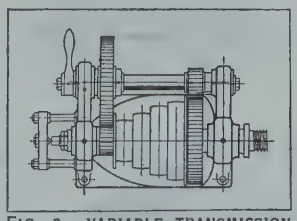


FIG. 3.—VARIABLE TRANSMISSION AS USED IN A LATHE HEADSTOCK

In a standard type of motor car change speed gear box, the engagement of different ratios of spur wheels and pinions is obtained by sliding the teeth sideways into mesh with each other. This is called the "clash" engagement. In another type of gear box no such sideway sliding takes place, the teeth of the respective wheels being always in mesh with each other. Change of gear in this case is effected by sliding the different jaw clutches into engagement with each other.

Pneumatic.—Many attempts have been made to introduce pneumatic variable transmission since 1900 by Dunlop, Lenz, Lebach and others. The best account of these pneumatic devices as applied on a large scale to locomotives was given in *La Revue Générale des Chemins de Fer,* May 1923, by Brillé. Up to the present these devices, though extremely interesting and ingenious, have not proved efficient in practice.

Electrical.—Various inventors have suggested continuously variable electric change speed gear. As already explained a mere reduction of effort by interposed resistance is not a true variable transmission, and all the most important examples of real variable electric transmission as on electric railways, is of essentially a step by step nature. Locomotive systems such as Crochat's mine locomotive, the loco-tractor of Moyse, those of Westinghouse, of Sultzer Diesel and Dewa are on the same fundamental principle as the Tilling-Stevens electric transmission, namely, production of electrical current by a dynamo from an internal-combustion engine and the operation by an electric motor of some form of gearing to turn the wheels.

Hydraulic.—The last form of transmission, and in its development the most recent, is hydraulic transmission. A beautiful device by Hastie was described as long ago as 1881. By means of two springs the stroke of the crank can be altered, when the crank pin slides in a groove.

When the effort is great the springs are compressed and the stroke is increased correspondingly, enabling a constant hydraulic pressure to overcome a variable resistance. This resistance may vary within wide limits, with the corresponding economy in the matter of the fluid employed. In the foregoing case the working fluid was water supplied by a high-pressure hydraulic main on the principle first introduced by Armstrong. Modern hydraulic variable gear in which oil is the working fluid has been brought into extensive operation chiefly to enable electrical power to overcome very variable resistance without causing a rise in the ampères transmitted. The principle of operation is exactly identical with the generation of electrical current by a dynamo, which current is transformed into mechanical effort by an electrical motor. In the case of hydraulic transmission, however, a variable stroke pump is employed to produce a flow of incompressible fluid, generally oil, which operates in a hydraulic motor. Thus it is only necessary to effect a change in the stroke of the pump when any required hydraulic pressure can be obtained with the great advantage of not unduly increasing the driving effort on the pump.

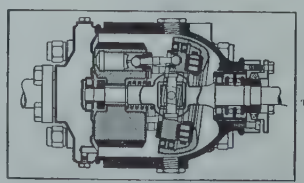


FIG. 4.—SECTION OF ONE ELEMENT OF THE JANNEY-WILLIAMS HYDRAULIC VARIABLE GEAR

Hydraulic variable gear has been employed for a great variety of purposes such as cranes, lifts, winches, tipping wagons, rail cars, gun mountings, planing and broaching machines, swing bridges, etc. The chief types of these gears may be distinguished as parallel and radial. Fig. 4 shows a section of the Janney-Williams gear (either pump or motor) which is an example of the former type, and it will be seen that the variation in effort is attained by varying the angle of what is known as a swash plate, with the result of altering the stroke of the pistons. As the stroke is reduced the working pressure can be increased; thus when the stroke is very small a very great pressure can be produced and consequently great resistance can be overcome. The necessary valve action is obtained by causing the opening at the inner end of the cylinders to pass in succession the supply and exhaust ports.

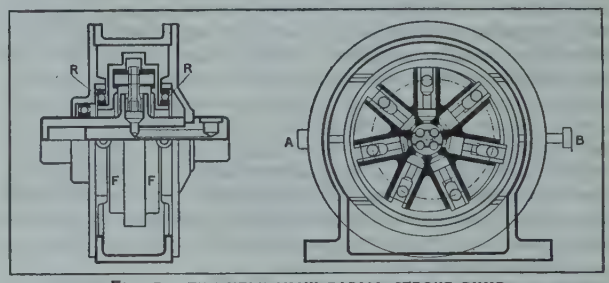


FIG. 5.—THE HELE-SHAW RADIAL STROKE PUMP

In the operation of the one radial type pump, the cylinder body revolves about a fixed axis which forms a cylindrical valve. As the cylindrical body revolves, the working fluid is alternately admitted from and exhausted into the two ports respectively. The fluid comes in under no pressure from the port and is driven out under any required pressure from the port along the shaft. In order to obtain any required variation of pressure the frame to which the connecting rod ends are attached is made to pivot about the fixed centre by a rod attached to the upper end of the frame. In the middle position there is obviously no stroke, and when the neutral position is passed the direction of flow is reversed.

Two views of another type of radial stroke pump are shown in fig. 5 (Hele-Shaw Pump), the left-hand view being in half section, the lower portion of which shows *ff* a revolving case called the "floating ring." The sectional portion in the view shows that this floating ring is carried on ball races *r* and *r*, their object being to reduce the frictional wear of the rollers or slippers by allowing the floating ring to rotate freely with the cylinder body, in which the pistons are carried. If the floating ring is moved bodily along guides on the line *a-b* (shown in the other view) the stroke of the pistons and the fluid pressure can be varied as required, just as in the previous example.

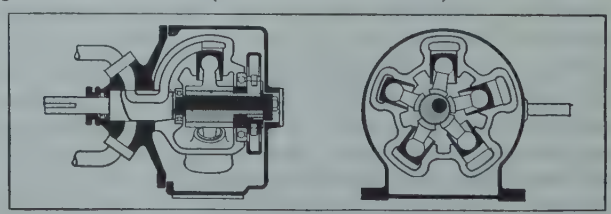
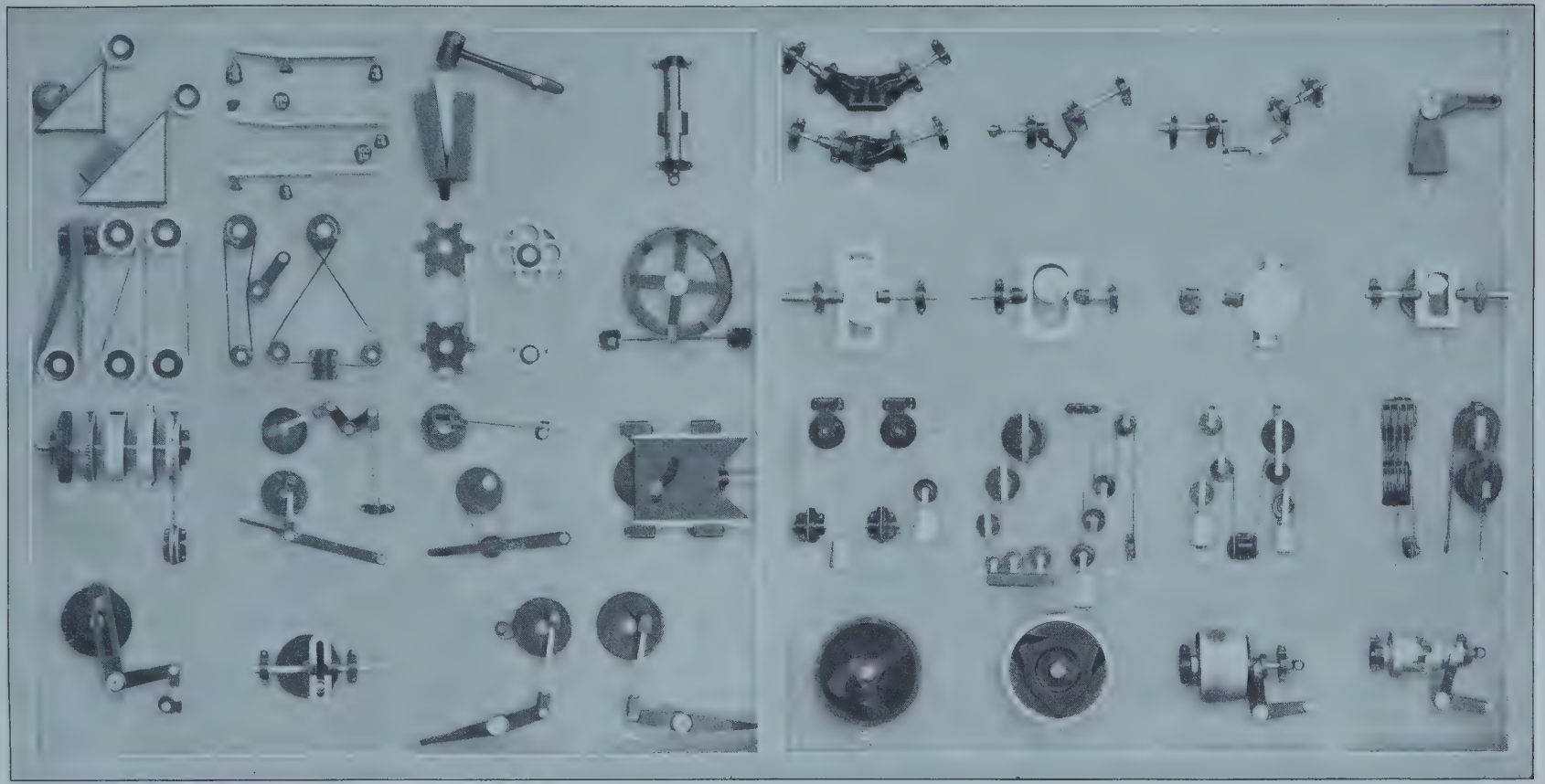


FIG. 6.—THE HELE-SHAW BEACHAM PUMP

An improvement in the foregoing pump has been devised, the Hele-Shaw Beacham pump, in which a central valve is employed, a radical change being effected by what is known in mechanical science as "inversion." Instead of pistons operating outwardly and obtaining their stroke from contact with an eccentric enclosing the whole cylinder body, the pistons are operated from a fixed crank, the cylinder body surrounding the crank and the pistons working inwardly. The variable stroke is obtained by altering the throw of the crank, which is otherwise fixed. The crank is in the form of a live ring mounted with roller bearings on a compound eccentric.

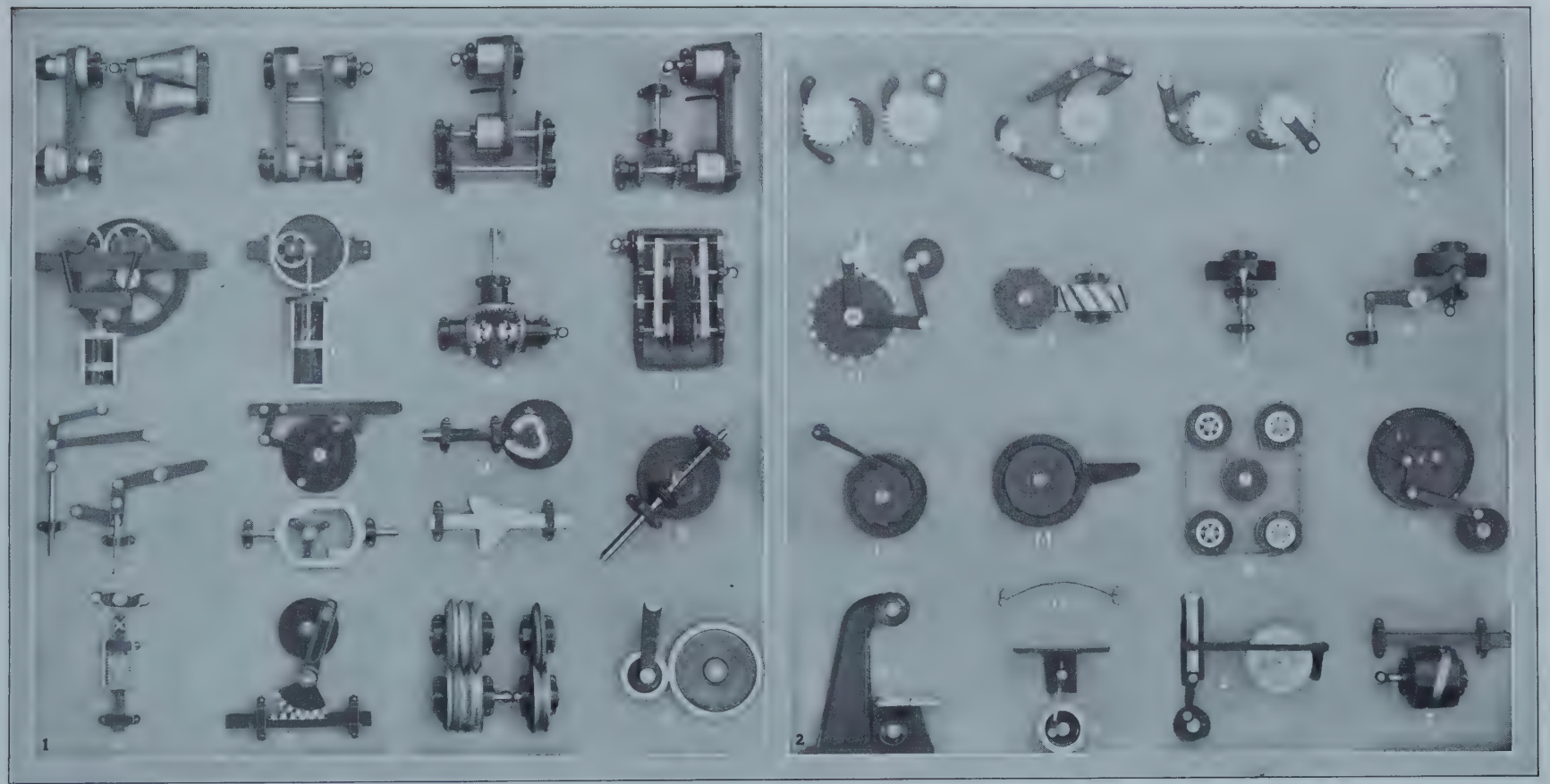


BY COURTESY OF THE MUSEUMS OF THE PEACEFUL ARTS, NEW YORK

FUNDAMENTAL PRINCIPLES OF MECHANICS

1. A. Incline plane showing little friction by rolling weight. B. Incline plane showing friction by sliding weight. C. Three types of levers showing various positions of fulcrum in weight balancing. D. Principle of the wedge. E. Principle of the screw. An inclined-threaded plane roped around a cylinder. F. Pulleys at right angle belt drive. G. Reverse belt drive. H. Straight belt drive. I. Use of idler pulley; adding friction to belt drive to control speed. J. Principle of drum pulley. This principle is used in hand steering apparatus of vessels. K. L. Two types of sprocket chain drives. (L) commonly used in bicycle. M. Rope drive, the drum is connected to water wheel to transmit mechanical power from water wheel to motors. N. Five types of pulleys used in rope drive. From left to right: Common V type; notched V type; common flat pulley; chain pulley; warped grooved pulley. O. Belt crank drive. P. Treadle drive. Q. Slotted connecting rod. R. Bell treadle drive. S. Slotted cross head drive used to convert reciprocating motion to rotary motion. T. Slotted bell crank. U. Slotted yoke drive. V. Off-centre treadle drive employing spring. W. Off-centre treadle drive. 2. A. Double universal joint producing uniform rotation. B. Single universal joint producing non-uniform rotation. C. Out of line joint employing a single rod. D. Out of line joint with rods employing a sliding coupling. E. Out of line drive for parallel shaft. F. Scotch yoke. G. H. I. Three eccentric drives. (G) using circular cam shaft to change reciprocating motion to rotary motion, (H) circular belt cam commonly used in steam engine pumps, (I) using heart cam to change rotating motion to a quick reciprocating motion, sometimes used to control valves. J. Simple pulley having no mechanical advantage, ratio 1–1. K. Double pulley having a mechanical advantage whose ratio is 2–1. L. Complicated system of pulleys having a mechanical advantage, ratio 26–1. M. A system of pulleys whose mechanical advantage is a ratio of 8–1. N. A set of pulleys, ratio 4–1. O. A set of pulleys, ratio 3–1. P. Common type of hoisting pulleys giving a mechanical advantage of 7–1. Q. Similar type of pulleys whose mechanical advantage is 6–1. R. One type of centrifugal clutch employing three weights influenced by centrifugal force. S. Another type of centrifugal clutch employing three wedges. T. Cone clutch formerly used in automobiles. U. Tooth clutch used in modern machinery

POWER TRANSMISSION



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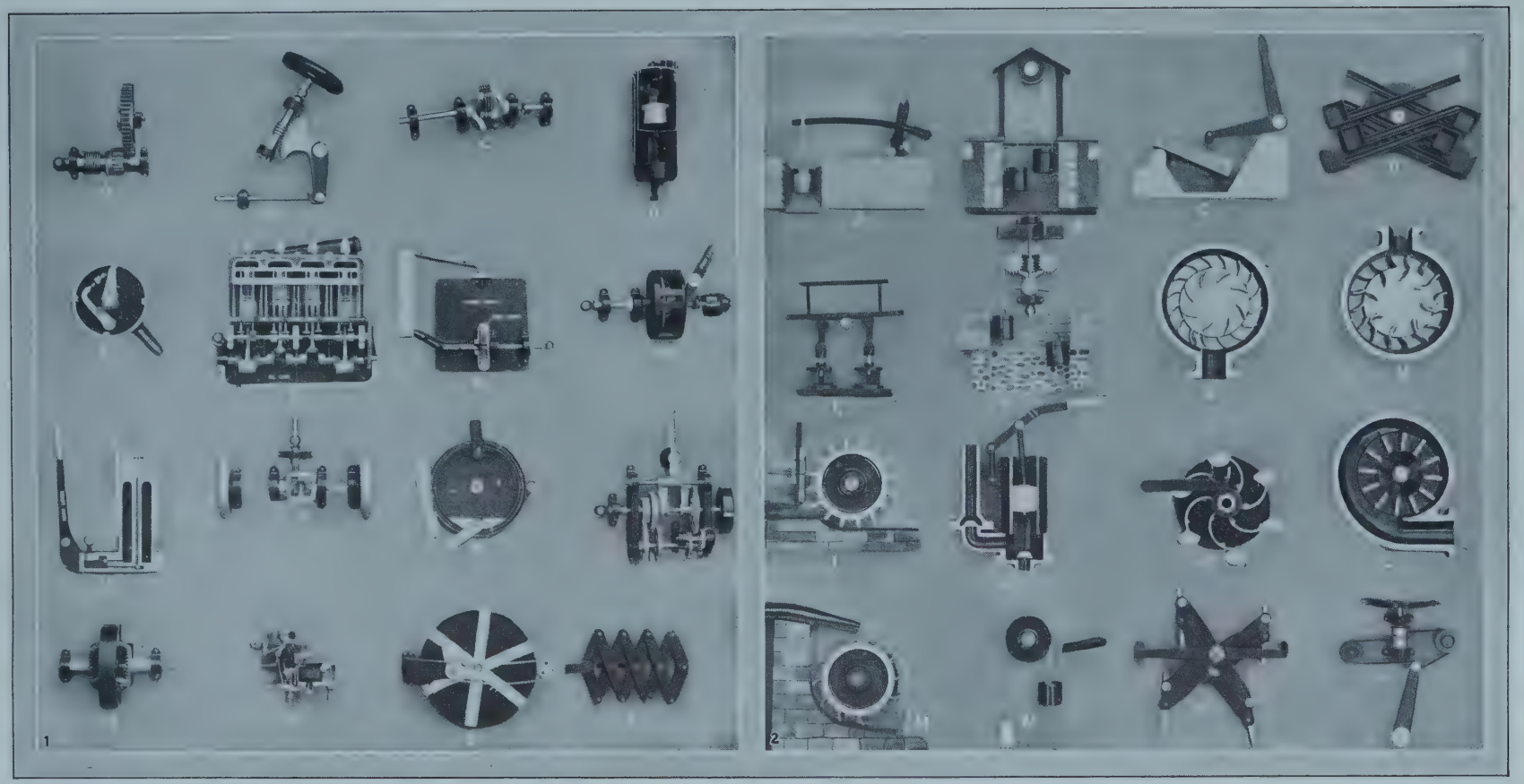
1. PULLEYS, CAM MOTIONS AND DRIVES

A–B. Variable speed pulleys: (A) step pulleys used for changing speed, *e.g.*, on lathes and drill presses; (B) cone pulleys used for great variety of speeds. C. Two speed countershaft employing two belts. D. Two speed countershaft with idler employing gear drives. E. Reversing device using belt shift. F. Straight line drive employing two crank shafts geared to flywheel, used in early steam engines. G. Straight line drive by internal gearing used in early steam engines. H. Reversing device using tooth clutch. I. Reeves variable speed device used for machines where a critical change of speed is necessary as in baking bread. J–K. Two types of straight line motions commonly used in indicators. L–M. Devices to turn rotary motion into reciprocating rectilinear motion: (L) rectilinear motion and stop produced by bell crank; (M) rectilinear motion using star wheel with yoke. N–O. Irregular cam motions: (N) positive motion heart cam; (O) clover-leaf cam giving positive rectilinear motion. P. Variable speed and reversing drive used in early automobiles. Q. Ratchet lift. R. Whitworth's quick return motion principle. S. Triple and single friction drives. T. Eccentric friction drive

2. PRINCIPLE OF RATCHET PAWLS AND SAWS

A. Pawls of various forms used on ratchet wheels to prevent backward motion. B. Intermittent circular motion from constant rotary motion. C. Pawl giving intermittent circular motion from reciprocating circular motion. D. Double pawl ratchet wheel, with lever, used in non-concentric shaft. E. Double pawl ratchet using claw movement. F. Intermittent circular motion from reciprocating circular motion used on concentric shafts. G. Geneva movement giving intermittent circular motion from constant circular motion used on the motion picture machine. H. Intermittent circular motion employing bell crank. I. Intermittent rotary motion from a shaft at right angles. J. Vibrating toothed wheel giving quick return rectilinear motion. K. Wave motion given to bell crank from constant circular motion. L. Double pawl ratchet in different form as (E.) M. Ratchet head with spring pawls. N. Ball and roller bearings for reducing friction. O. Intermittent circular motion from pendulum motion of a lever by friction pawls. P. Band saw for scroll sawing. Q–R. Jig saw for scroll sawing. This has a reciprocating motion: (Q) jig saw; (R) source of power. S. Vertical and circular gang saws, for multiple work. T. Drum cam giving reciprocating motion



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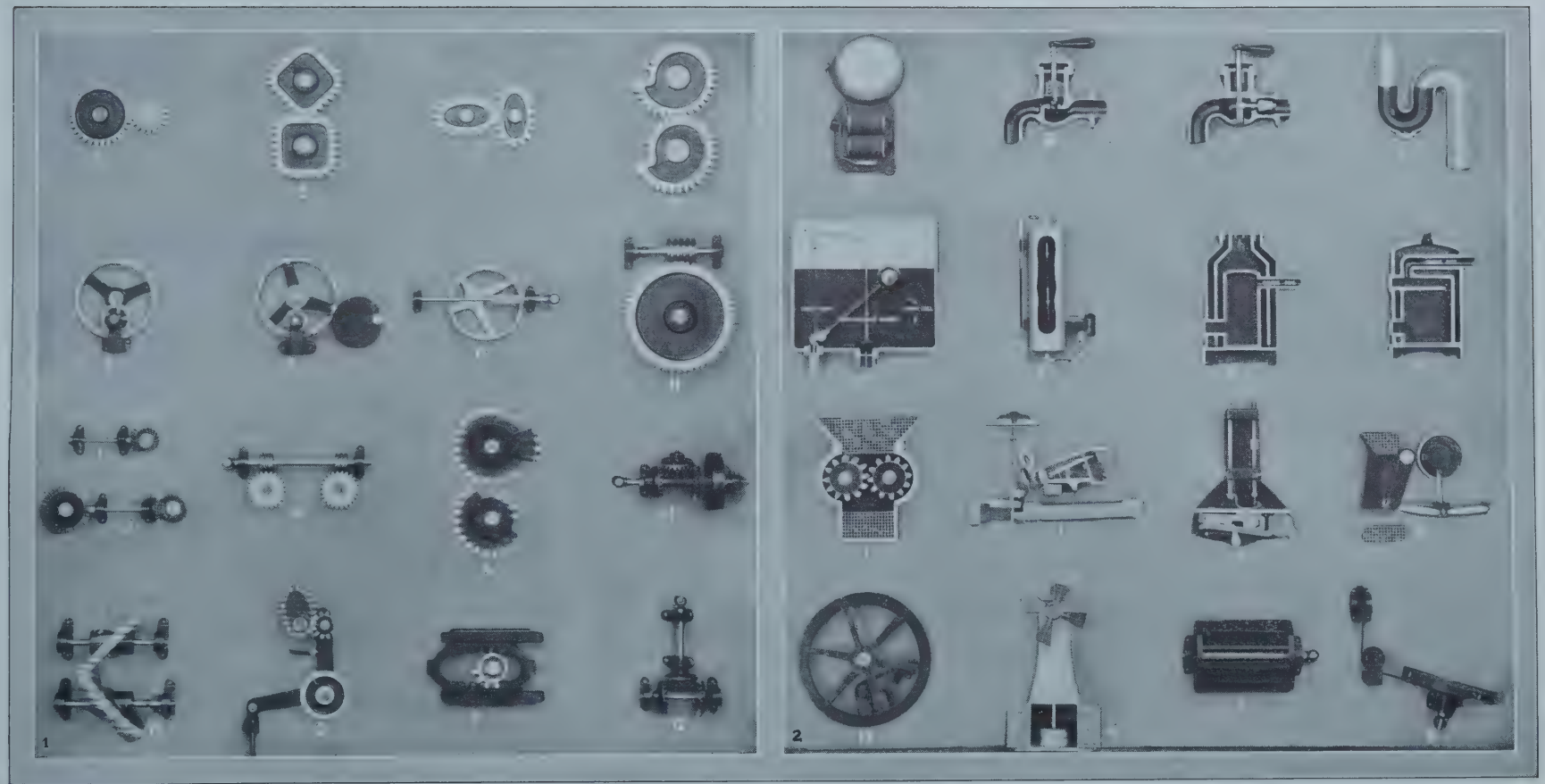
1. PARTS AND MOVEMENTS OF AUTOMOBILE

A. Bendix drive for self starter. B. Worm and worm wheel used for steering apparatus. C. Universal joint. D. Vacuum tank. E. Spark timer and distributor. F. Cross-section of a four-cylinder four-cycle gasoline engine showing cylinders and cylinder rods attached to drive shaft. G. Principle of a water cooling system. H. Multiple disc clutch. I. Hydraulic ram for jacking. J. Rear end and differential. K. Internal and external brake for foot and emergency brakes. L. Principle of gear shift. M. Power measuring dynamometer. N. Section of a carburettor. O. Speed reducer employing rollers and slots. P. Lazy tongs used to extend telephones

2. PRINCIPLE OF WATER TRANSMISSION

A. Well bucket using balanced lever to draw up bucket. B. Double well bucket, one used to balance the other. C. Bailing scoop to raise water from one level to another. D. Pendulum water lift to raise water for irrigation purposes. E. Double pump operated by a person shifting his own weight. F. Double bucket lift using wind mill as the power. G. Water turbine having the external wheel rotating. H. Water turbine having the internal wheel rotating. I. Undershot water wheel. J. Cross-section of simple force pump. K. Double discharge current power water lift for irrigation. L. Volute water turbine. M. Overshot water wheel. N. Water bucket lift. O. Paddle wheel for side wheel propulsion where the paddles remain vertical. P. Steering wheel and winch for boats

POWER TRANSMISSION



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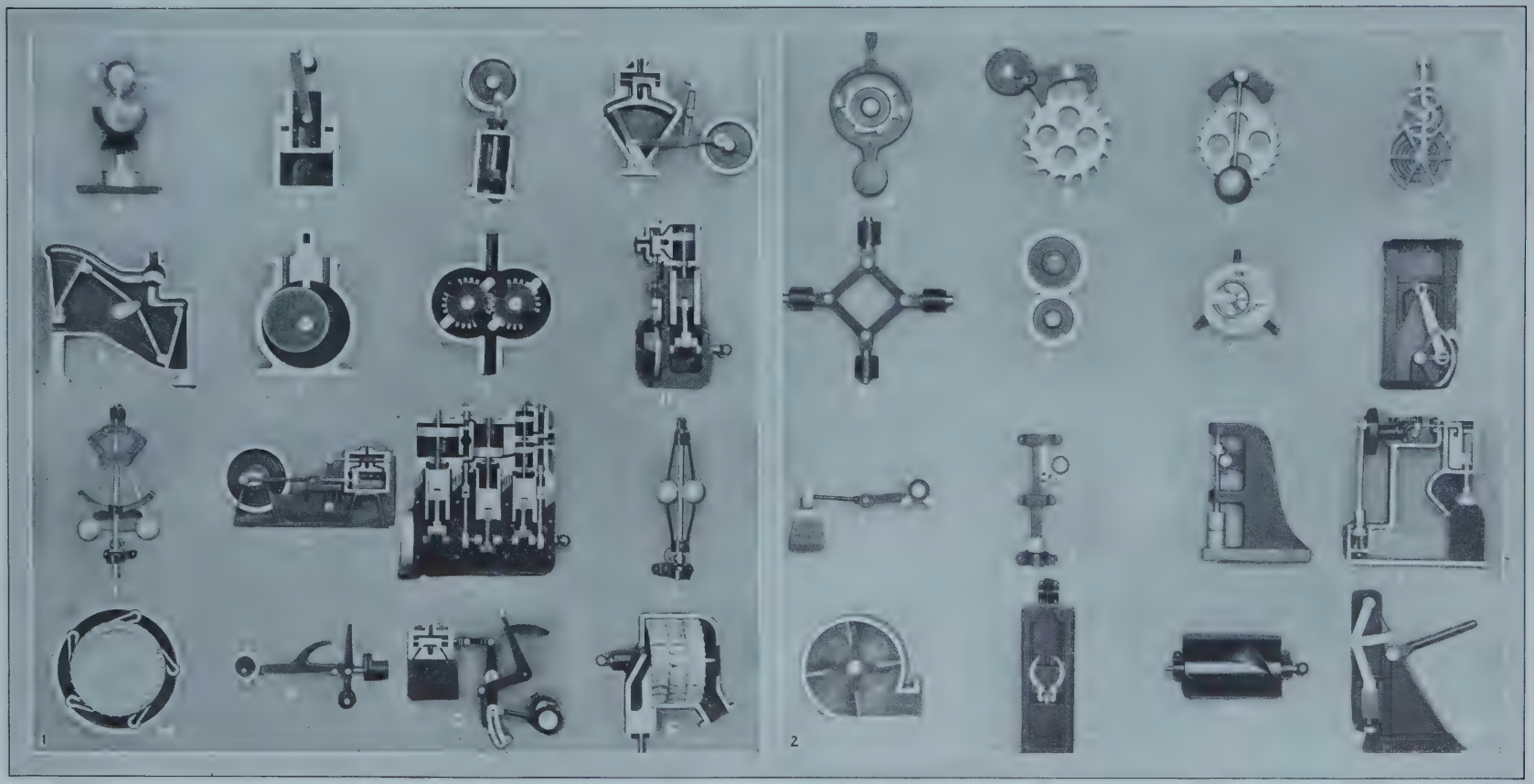
1. VARIOUS TYPES OF GEARS

A. Spur gears commonly used in machines. B. Square gears producing a variable speed from a constant speed; not commonly used. C. Elliptical gears rotating about their centre producing a variable speed governed by the shape of the ellipse. D. Scroll gears for increasing or decreasing the speed gradually during one revolution. E. Internal gearing producing rotation in the same direction. F. Gear combination producing a slow forward and quick back circular motion from the continuous circular motion of a gear wheel. G. Eccentric crown gear and pinion producing variable circular motion. H. Worm and worm wheel high speed reducer, used on rear ends of automobile trucks. I—J. Mitre and bevel gears for transmitting power at right angles. K. Left and right-hand worm gears and pinions. L. Sector gears producing two different speeds and stop during one revolution of the driver. M. Epicyclic gear train bevel gears. N. Swash plate gears invented for mixing machines; produces uniform rotation but a kneading action at the same time. O. Geared cam producing reciprocating motion to a bell crank. P. Sector pinion and double rack giving rectilinear reciprocating motion from the continual motion of a sector pinion. Q. Bevel gears and bevel gear sector producing uniform reciprocating circular motion

2. VARIOUS TYPES OF SIMPLE MECHANISMS

A. Continuous ringing electric bell. B. Faucet employing a screw to open valve; common type. C. Faucet using crank to open valve. D. Common S trap to collect dirt and prevent gases from entering household. E. Section of common flush tank showing operation. F. Household gas hot water heater. G. Section of hot air furnace for the household. H. Section of a steam or hot water furnace for the household. I. Gear type coal breaker. J. Piano key action and damper. K. Sewing machine producing lock stitch using only one thread; showing action of needle and interlocking mechanism for thread. L. Stone crusher with toggle joint. M. Horse power wheel. N. Windmill and grinder. O. Chinese tread wheel for power. P. Sloping tread wheel platform



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1. PRINCIPLE OF STEAM ENGINES AND TURBINES

A. Model illustrating the theory of Heron of Alexandria (*fl. c.* 100 B.C.). B. Trunk type steam engine similar to the ordinary gasolene engine. C. Steam engine with oscillating cylinder dispensing with valve and valve mechanism. D. Oscillating piston engine. E. Double oscillating piston steam engine, early form. F. Eccentric rotary pump or engine, commonly used for positive pressure pumping. G. Gear pump or engine. H. Cross-section of a vertical steam engine with simple sliding valve. I. Steam engine governor, centrifugal type. J. Cross-section of a horizontal slide valve steam engine. K. Cross-section of a triple expansion compound steam engine. L. Steam engine governor, centrifugal type. M. Pelton wheel type steam turbine. N. Hand reversing mechanism for single cylinder steam engine. O. Stephenson link reversing mechanism for steam engines. P. Reaction type steam turbine, commonly used in electrical power plants

2. CLOCK ESCAPEMENTS, HAMMERS, ETC.

A. Early form of clock escapement used in wooden clocks. B. One form of clock escapement. C. Common form of clock escapement. D. Watch escapement mechanism with balance wheel and hair spring. E. Four way link movement. F. Stop wind for watches and clocks. G. Early form of watch showing movement of balance wheel. H. Hand bailing press. I. Gravity trip hammer used in early forging methods. J. Gravity gear drop hammer. K. Gravity cam drop hammer. L. Pneumatic air hammer for light drop forgings. M. Centrifugal air blower. N. Pile driver. O. Conveyor using the principle of Archimedes screw. P. Hand punch using toggle joint

The compound eccentric consists of two parts of equal eccentricity, the stroke-varying mechanism being arranged to effect rotation of these two parts in opposite directions with the result that the resultant eccentricity may be varied at will from zero to maximum in either direction. This gear was fully described in *Engineering*, Oct. 16, 1925.

Another important feature of the new pump is the fact that instead of the central plane of the valve ports coinciding with the central plane of the revolving cylinder body, it is displaced so that the central planes of the cylinders and that of the valve ports are separated from each other. Fig. 6 is a diagrammatic figure which will make the explanation clear. One remarkable effect is the improvement in the matter of silence. The opening and closing of the ports causes water-hammer blows due to the high pressure in an incompressible fluid. These blows are no longer transmitted so as to cause sound vibrations in the enclosing cylinder body.

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POWHATAN. This group of Algonkin Indian tribes in the tide-water portion of Virginia and southern Maryland had been welded into a confederacy by the conquests of an able chief known by the same name, shortly before the settlement of Jamestown in 1607. His daughter Pocahontas married John Rolfe. After Powhatan's death they massacred 347 British settlers in 1622. Fourteen years of relentless warfare followed until the Indians submitted, only to rise again in 1641 and slay 500 whites. This war broke them, and though in 1669 2,100 remained of the original 8,000, they have now dwindled to some 700, mixed with negro and white blood, and known as Chickahominy, Pamunkey, etc.

(A. L. K.)

POWIS, EARLS AND MARQUESSES OF. Before the Norman Conquest the Welsh principality of Powis, comprising the county of Montgomery and parts of the counties of Brecknock, Radnor, Shropshire, Merioneth and Denbigh, was subject to the princes of North Wales. Early in the 12th century it was divided into upper and lower Powis. In 1283 Owen ap Griffin, prince of upper Powis, formally resigned his princely title (*nomen et circulum principatus*) and his lands to the English king Edward I. at Shrewsbury, and received the lands again as an English barony. (See *Montgomeryshire Collections*, 1868, vol. i.) This barony of Powis passed through female inheritance to the family of Cherleton and in 1421 to that of Grey. It fell into abeyance in 1551.

In 1587 Sir Edward Herbert (d. 1594), a younger son of William Herbert, earl of Pembroke, purchased some of the lands of the barony, including Red castle, afterwards Powis castle, near Welshpool, and in 1629 his son William (*c.* 1573–1656) was created Baron Powis. William's grandson, William, the 3rd baron (*c.* 1629–1696), was created earl of Powis in 1674 and Viscount Montgomery and marquess of Powis in 1687. The recognized head of the Roman Catholic aristocracy in England, Powis was suspected of complicity in some of the popish plots and was imprisoned in the Tower of London from 1678 to 1684. He followed James II. into exile and was created duke of Powis by the dethroned king. William, 2nd marquess, who had a somewhat chequered career as a Jacobite, died in October 1745, and when his son William, the 3rd marquess, died in 1748 the titles became extinct.

In 1748 Henry Arthur Herbert (d. 1772), who had been made Baron Herbert of Cherbury in 1743, was created Baron Powis and earl of Powis. The titles became extinct a second time when his son George Edward died in January 1801. George's sister and heiress, Henrietta Antonia (1758–1830), married Edward Clive (1754–1839), son and heir of the great Lord Clive. In 1804, he was created Baron Powis and earl of Powis.

POWNALL, THOMAS (1722–1805), British colonial statesman and soldier, born at Saltfleetby, Lincolnshire, was educated at Lincoln and at Trinity College, Cambridge, where he graduated in 1743. In 1753 he went to America as private secretary to Sir Danvers Osborn, just appointed governor of New York. Osborn committed suicide soon after reaching New York (Oct. 6), but Pownall remained in America, devoting himself to studying the condition of the American colonies. In 1756 he came home, and presented to Pitt a plan for a campaign against the French in Canada, to begin with the investment of Quebec. In 1757 Pitt appointed him governor of Massachusetts; he was transferred to South Carolina in February 1760. This office he held nominally for about a year; but he never went to South Carolina, and in June 1760 he returned to England. In 1762–1763 he was commissary-general of the British troops in Germany. He sat in parliament from 1768 to 1780, and died at Bath on Feb. 25, 1805. In 1764 he published (at first anonymously) his famous *Administration of the Colonies* advocating a union of all British possessions upon the basis of community of commercial interests.

See C. A. W. Pownall, *Thomas Pownall, M.P., F.R.S.* (1908).

POYNINGS, SIR EDWARD (1459–1521), lord deputy of Ireland, was the only son of Robert Poynings, second son of the 5th Baron Poynings. His mother was a daughter of Sir William Paston, and some of her correspondence is to be found in the *Paston Letters*. Robert Poynings was implicated in Jack Cade's rebellion, and Edward was himself concerned in a Kentish rising against Richard III., which compelled him to escape to the Continent. He attached himself to Henry, earl of Richmond, afterwards King Henry VII., with whom he returned to England in 1485. By Henry VII. Poynings was employed in the wars on the Continent, and in 1493 he was made governor of Calais. In the following year he went to Ireland as lord deputy under the viceroyalty of Prince Henry, afterwards King Henry VIII. Poynings immediately set about Anglicizing the government of Ireland, which he thoroughly accomplished, after inflicting punishment on the powerful Irish clans who supported the imposture of Perkin Warbeck. He then summoned the celebrated parliament of Drogheda, which met in December 1494, and enacted the "Statutes of Drogheda," famous in Irish history as "Poynings's law," subordinating the Irish legislature to that of England, till its repeal in 1782. After defeating Perkin Warbeck at Waterford and driving him out of Ireland, Poynings returned to England in 1496, and was appointed warden of the Cinque Ports. He was employed both in military commands and in diplomatic missions by Henry VII., and later by Henry VIII., his achievement being the negotiation of the "Holy League" in 1513.

See Sir Francis Bacon, *The History of the Reign of King Henry VII.* (1641); Richard Bagwell, *Ireland under the Tudors* (2 vols., 1885); J. T. Gilbert, *History of the Viceroys of Ireland* (Dublin, 1865); J. A. Froude, *The English in Ireland* (3 vols., 1872–74); Wilhelm Busch, *England under the Tudors*, ed. by James Gairdner (1895).

POYNTER, SIR EDWARD JOHN, 1ST BART. (1836–1919), English painter, son of Ambrose Poynter, architect, was born in Paris on the 20th of March, 1836. He pursued his art studies in England and in Paris (under Gleyre, 1856–1859), and exhibited his first picture at the Royal Academy in 1861. In 1869 he was elected an A.R.A., and in 1876 R.A.

In the decorative arts he practised freely as a designer in fresco, mosaic, stained glass, pottery, tile-work and the like. He was elected to the Royal Society of Painters in Water Colours in 1883.

As director for art in the Science and Art Department, and principal of the National Art Training Schools (now the Royal College of Art) at South Kensington Poynter proved himself a vigorous and successful administrator. He resigned his office in 1881, and in 1894 became director of the National Gallery. Under his rule the National Gallery of British Art, at Millbank, presented by the late Sir Henry Tate, became a department of the National Gallery. He edited the great *Illustrated Catalogue of the National Gallery* (1889–1900), in which every picture in the collection is reproduced.

On the death of Sir John Millais in 1896, Poynter was elected president of the Royal Academy, and was knighted. He was made a baronet in 1902. Poynter died in London on July 26, 1919.

See Cosmo Monkhouse, "Sir E. J. Poynter, P.R.A.: His Life and Work," *Art Annual* (1897); M. H. Spielmann, "Sir E. J. Poynter P.R.A., and his Studies," *The Magazine of Art* (1897).

POYNTING, JOHN HENRY (1852–1914), British physicist, was born at Monton, near Manchester, on Sept. 9, 1852. He studied at Owens college, Manchester, and at Trinity college, Cambridge. He was bracketed third wrangler in 1876. Poynting went as demonstrator in physics to Owens college, but returned to Cambridge in 1878 on his election as fellow of Trinity college. In 1880 he was appointed professor of physics at the Mason college, which afterwards became the University of Birmingham. He retained this post until his death at Birmingham on March 30, 1914.

Poynting carried out experiments over a period of 12 years to determine the gravitational constant and the mean density of the earth. He used a balance method and during the course of his experiments added considerable knowledge to the technique of accurate weighing. Poynting's best known work is that in the papers "On the Transfer of Energy in the Electromagnetic Field" (*Phil. Trans. A.*, 1884) and "On Electric Currents and the Electric and Magnetic Induction in the Surrounding Field" (*Phil. Trans. A.*, 1888). In the first paper Poynting showed that the flow of energy at a point could be expressed by a simple formula in terms of the electric and magnetic forces at that point. This is known as Poynting's theorem and the vector is also called by his name. Poynting also wrote papers on radiation and the pressure of light and several books.

Poynting's interests were very wide; he served as a justice of the peace, was chairman of the Birmingham Horticultural Society and acted as dean of the Faculty of Science. He was elected F.R.S. in 1888.

See his *Collected Scientific Papers*, edit. by G. A. Shakespear and G. Barlow (1920).

POZAREVAC or **PASSAROWITZ,** the capital of the Pozarevac department of Serbia, Yugoslavia. Pop. (1931) 14,055. It lies 8 m. from its harbour, Dubravitsa, on the Danube. The town has no special industry, but being a road centre, is the principal market of a large and fruitful plain. At Lubichevo, 2 m. W. is a State model farm, a stud farm, and a nursery for mulberries. Lignite is worked at Kostolats, 7 m. N. by E., and the hills in this district show many traces of Roman mines. Roman coins, sarcophagi and inscriptions are also found. The famous Treaty of Passarowitz between Austria and Turkey was signed here in 1718. The town was taken by the Serbs under Kara George in 1804, and in 1815 Prince Milosh of Serbia again defeated the Turks here. Germans occupied it in April 1941.

POZNAN or **POSEN,** a Polish province, bounded north by the province of Pomorze, east by the provinces of Warsaw and Lodz, south and west by Germany. The province was conquered by Germany in Sept. 1939. Area 9,243 sq.mi.; pop. (1931) 2,115,000; in 1935 92% were Poles, 7·9% Germans and 0·1% Jews. The Jews were formerly numerous in the province, but migrated to America in the second half of the 19th century, when the peasants organized co-operative societies. The Germans, who had settled under Government support, left after the reconstitution of the Polish state, in large numbers. The province, which contains 38 districts, has always formed a territorial unit since the dawn of history as Great Poland (Wielka Polska), the seat of the tribe which organized the Polish monarchy, and has always been one of the most enlightened, influential and patriotic parts of Poland. It is part of the central Polish plain, and consists of a low plateau intersected by the beds of the rivers Notec, Warta and Obra. These three rivers drain into the Oder, with which the Warta is also connected by the Obra canal. The east part of the province is in the basin of the Vistula, which is connected with the Notec by the Bydgoszcz canal. The surface is dotted with small lakes and ponds, and there are many broad fens and swamps. The soil is light and sandy, but much of the land reclaimed in the marshy districts is very fertile. The greater part of the province is under tillage, but 17·3% is occupied by forests. The principal crops are rye, wheat, oats, barley, potatoes, beets and hops. The vine is cultivated in the south-west corner, and tobacco is also grown. A feature of the country until World War II was the efficient organization of agricultural co-operative societies, culminating in the great union under Father Wawrzyniak, which enabled the Polish peasants to hold their own against their German competitors, and the fact that education made illiteracy, so prevalent in the "Congress Kingdom," a rarity in Poznan. The marshy tracts afford excellent pasture and support large numbers of cattle, horses, sheep and goats. The mineral resources of the province are small, but the industries, at first purely agricultural, such as distilling, brewing, sugar and tobacco, increased with the development of the Polish state. Locomotives are built at Poznan, while Bydgoszcz became the centre of the timber trade for all Poland. A timber exchange was established there, and the first paper mills in Poland. Trade is facilitated by the network of navigable rivers, canals and railways, while the roads are the best in the country. Trade after World War I suffered from the change of markets due to the transference of Poznan from Germany to Poland. There are several large towns: Poznan (272,000 in 1939), Bydgoszcz (141,000) and Gniezno (29,924 in 1931). Other towns are Inowroclaw, Ostrów, Leszno, Krotoszyn, Rawicz and the most ancient town of Poland, Kruszwica.

(A. B. Bo.; X.)

HISTORY

The history of the province of Western or "Great" Poland, of which Poznan (called by the Germans Posen) is the principal city (*see* p. 397), falls within the scope of the article POLAND. One of the oldest towns of the province is Gniezno (German Gnesen), originally the capital of the whole country, and still the seat of the primate of Poland. The tide of German immigration into the province flowed strongly in the 13th and the following centuries. The industrious German settlers were the principal factor in the development of trade and manufacture in the towns; they also did much to improve agriculture in the country. Since the re-union of the kingdom of Poland in the 14th century, the province of Poznan shared the fate of the united country.

During the 17th century, a Swedish invasion ruined the province, the commercial importance of the city began to suffer in consequence of the one-sidedly agrarian spirit of Polish legislation, and the strenuous efforts of the Jesuits, directed against the growth of Protestantism, introduced into the life of Poznan the unrest of religious feuds, which were prolonged till the 18th century.

At the first partition of Poland, in 1772, the districts to the north of the river Notec (German, Netze) fell to the share of Prussia. The rest of the province followed in 1793 and 1795, and was united with the territory acquired in 1772 to form the province of South Prussia. In 1807, after the peace of Tilsit, the province was incorporated with the grand duchy of Warsaw, but in 1815 it reverted to Prussia as the grand duchy of Posen.

The Prussian regime, during the first decades after the Congress of Vienna, was conciliatory: a Polish nobleman, prince Anthony Radziwiłł, was appointed lieutenant-governor of the province; there was a provincial assembly, and there were local representative bodies. About 1830, however, a new current set in with the presidency of Flottwell: the experiment of settling subsidized German colonists on Polish soil—started by Frederick the Great in the 18th century—was resumed, and the Polish language deprived of its position of equality with German in the Government offices, the law-courts, and the schools. In the '40s, the revolutionary movement spreading throughout Europe, manifested itself in Prussian Poland and an armed rising in 1848 was suppressed by military force. A highly reactionary Prussian Government arose out of the turmoil of the revolutionary year, and measures of repression against Polish organizations followed. But a resolutely anti-Polish policy on a large scale was only originated by Bismarck, and was carried out in earnest after the creation of the new German empire in 1871. To the landed gentry and the clergy, who had been the mainstay of Polish nationalism so far, there were now added a body of increasingly prosperous and enlightened peasants in the country, and a growing, wealthy Polish middle class in the towns,—all these ranks of society being united in organized opposition to the policy of Germanization. Bismarck aimed cruel blows at the Polish clergy in conducting his *Kulturkampf* against the Catholic element in the *Reich;* but the effect was only to rally the Polish masses more effectually round

the clergy, who became their leaders in economic as well as in political organization. More success was achieved by the measures in the field of education which gradually made the school system of the province thoroughly German while rendering it at the same time democratic, progressive and highly efficient. Similarly, in the development of the administrative system, improved efficiency and thorough Germanization went together. The powers of resistance of the Polish element, however, rapidly increased with its numbers and its prosperity; and the Prussian Government soon realized that only economic means would serve its ends. In 1888, the Colonizing Commission was established for the purpose of buying up Polish land for German colonists, and it was equipped with 100,000,000 marks (£5,000,000). The Polish element countered the attack by co-operative credit organizations, in which both the peasants and the middle class of the town took a prominent share; and soon the Poles succeeded in buying more land than they lost. The creation of a subsidized society—the Society of the Eastern Marches (known as the *H.K.T.* from the initials of its founders)—for the promotion of German advance in the east, the great increase of the funds at the disposal of the Colonizing Commission, the creation of a special fund of nearly half a million marks a year towards a campaign against the Polish middle class in the towns—all proved insufficient, and Bülow, Bismarck's most zealous successor, brought new legislative means into play: a bill in 1904 forbidding Poles to establish new peasant farms on soil of their own, and one in 1907 authorizing the Government to dispossess Polish landowners by force. These measures were accompanied by no less drastic ones in the field of education and administration: in 1901, much scandal was roused by the discussion in the Prussian parliament of the incidents at Wrzesnia (Wreschen), where Polish children had been beaten by German schoolmasters for refusing to say the Lord's Prayer in German; and in 1906, the Prussian Government was made somewhat ridiculous by the strike of some 100,000 Polish school-children, which, in spite of severe proceedings against their parents, continued for nearly a whole school year. In 1908, the notorious "Gagging bill" limited to a minimum the right of Polish citizens to form societies, and altogether forbade the use of Polish at public meetings.

The anti-Polish policy of Prussia, although occasionally criticized in the *Reichstag*, had, on the whole, both a majority of German opinion and the authority of the supreme power in the *Reich* behind it. But it was largely rendered futile by the disciplined organization of the entire Polish element, as well as by its large and continuous increase in numbers. While the German birth-rate began to fall rapidly, the birth-rate among Polish peasants remained very high; and the political struggle for the land in Prussian Poland resulted in a measure of agricultural prosperity which—in spite of drastic expulsions of foreign subjects, inaugurated by Bismarck in 1885—continued to attract immigrants from other parts of Poland. Prussian Poland shared in the material progress of Germany after 1870, and World War I found this province the most advanced and uniformly wealthy of all the three sections of Poland.

Even after all the losses and privations which the province, however out of sympathy with the German cause, had to undergo with the rest of Germany in 1914–18, the Prussian sector of Poland, when it shook off German domination shortly after the Armistice (Dec. 27, 1918), emerged as still the most prosperous of the three; its territory had not been devastated by actual warfare, as large portions both of Austrian and Russian Poland had. This gave the former Prussian Poles a certain advantage over the others; and they naturally clung to this advantage in the new and united Polish republic after the Peace of Versailles. A customs barrier continued, for a time, to separate the former Prussian province from the body of the new Poland; and a special "Ministry for former Prussian Poland" came into being, which existed for several years.

Such separatism was grounded on a somewhat distinct mentality which the struggle against Prussian rule had developed. The Poles under Prussia had acquired something of that crude belief in sheer force which was characteristic of Germany after 1870. They had not had the opportunities for intellectual refinement which home rule under Austria had given to their Galician brethren; but their peasantry had reached a much higher level of enlightenment than that of either Austrian or Russian Poland. In the new Polish State, in consequence of all this, the former Prussian province represented a solid block of hard-and-fast Nationalism as well as of uncompromising devotion to the Catholic Church, whose services to the national cause in Prussian times were gratefully remembered. Gradually, however, the ties of common political life began to produce their effect, and the parliamentary elections later found the population of former Prussian Poland differentiated politically on the same party lines as the rest of the republic. The new Polish university of Poznan (which had taken the place of a German academy), and other Polish educational and cultural institutions, worked for amalgamation.

Poznan, with half its borders along the German frontier, was difficult to defend in World War II and fell rapidly to the German army in Sept. 1939.

BIBLIOGRAPHY.—The German case, at the height of the anti-Polish policy on the eve of World War I, was summed up in an elaborate work by L. Bernhard, *Das polnische Gemeinwesen im preussischen Staate* (Leipzig, 1907). From the Polish point of view, the history of Prussian policy in Poznan has been told by Professor J. Buzek in *Historja polityki narodowościowej rządu pruskiego 1815–1908* (Lwów, 1909). For the history of the city of Poznan, *see* N. Pajzderski, *Poznan* (Lwów, 1922, ill.). (R. DY.)

POZNAN or **POSEN,** capital of the province of Poznan, in Poland, situated in a wide and sandy plain on the Warta, 180 mi. W. from Warsaw and 150 mi. E. from Berlin. Pop. (1939) 272,000. Germany conquered the province in Sept. 1939. Before World War I, half the population were Germans, who had been encouraged to settle by the Prussian government, and who returned to Germany after the restoration of Poland. The city is the centre of a network of railways connecting it with Warsaw, Berlin, Breslau and Torun. It is the centre of one of the five ecclesiastical provinces of the Catholic Church in Poland, and the seat of the most ancient Polish bishopric, founded in the 10th century. The old town (*Stare Miasto*) and the new town lie on the left bank of the Warta, with large suburbs on the right bank. There are 15 Roman Catholic churches, of which the cathedral contains many works of art and the tombs of the two first rulers of Poland. The town hall (*Ratusz*), rebuilt in 1552, is a magnificent building in the Romanesque style. A legacy of the former Prussian rule is the castle built by William II. There is a large library, the Raczynski library, two museums and a university. Industries are mainly connected with agriculture, such as distilling, brewing, sugar milling, agricultural machinery. The manufacture of locomotives was established after 1918. An annual fair was inaugurated in 1922, and there is an active trade, both by river and rail, in corn, cattle, wood, wool and potatoes.

Poznan is one of the oldest cities in Poland and the residence of the first king, Boleslaw the Brave, and of the first Polish bishop. The original settlement was on the right bank of the river, but German settlers in 1250 made the new town on the opposite bank a flourishing commercial centre. A charter in 1394 gave the city staple right for all wares passing from Poland into Germany, and from Germany into Poland. The German element was assimilated, though many foreigners settled there, including a colony of Scots. After the fires of 1536 and 1590, Poznan, formerly Gothic, was rebuilt in Renaissance style. The prosperity of Poznan declined with the economic decline of Poland in the 17th century, but revived in the 19th century, partly as the natural centre of a great agricultural region, partly as a bulwark of the Poles in their struggle against German penetration.

POZOBLANCO, a town of southern Spain in the province of Córdova, near the head-waters of the Guadamatillas and of other small sub-tributaries of the Guadiana. Pop. (1940), 13,466 (mun., 16,702). Its fairs are famed for their live stock and agricultural products. There are zinc and argentiferous lead mines near by, and manufactures of cloth and leather in the town.

POZZO DI BORGO, CARLO ANDREA, COUNT (1764–1842), Russian diplomatist, was born at Alata, near Ajaccio, of a noble Corsican family, on March 8, 1764, some four years before the cession of the island to France. He was educated at Pisa,

and in early life was closely associated with Napoleon and Joseph Bonaparte, the two families being at that time closely allied in politics. Pozzo was one of the two delegates sent to the National Assembly in Paris to demand the political incorporation of Corsica in France, and was subsequently a Corsican deputy to the Legislative Assembly, where he sat on the benches of the right until the events of August 1792. On his return to Corsica he was warmly received by Paoli, but found himself in opposition to the Bonaparte brothers, who were now veering to the Jacobin party. Under the new constitution Pozzo was elected *procureur-général-syndic,* that is, chief of the civil government, while Paoli commanded the army. With Paoli he refused to obey a summons to the bar of the Convention, and the definite breach with the Bonaparte family, who actively supported the revolutionary authorities, dates from this time. Eventually Paoli and Pozzo accepted foreign help, and from 1794 to 1796, during the English protectorate of Corsica, Pozzo was president of the council of state under Sir Gilbert Elliot. When Napoleon sent troops to occupy the island he was excepted from the general amnesty, and took refuge in Rome, but the French authorities demanded his expulsion, and gave orders for his arrest in northern Italy. After a short stay in London he accompanied in 1798 Elliot (now become Lord Minto) on an embassy to Vienna, where he lived for six years.

In 1804 through the influence of Prince Adam Czartoryski he entered the Russian diplomatic service. In 1805 he was Russian commissioner with the Anglo-Neapolitan, and in 1806 with the Prussian army. He was entrusted with an important mission to Constantinople in 1807, but the conclusion of the alliance between Alexander I. and Napoleon at Tilsit in July interrupted his career. He returned to Vienna, but on the demand of Napoleon for his extradition Metternich desired him to leave the capital. He then retired to London again and remained in England until 1812, when he was recalled by Alexander. He diligently sought to sow dissension in the Bonaparte household, and in a mission to Sweden he secured the co-operation of Bernadotte against Napoleon. On the entry of the allies into Paris he became commissary general to the provisional government.

At the Bourbon restoration Pozzo di Borgo became Russian ambassador at the Tuileries, and sought to secure a marriage between the duke of Berry and the Russian grandduchess Anna, Alexander's sister. He was present at the Congress of Vienna, and during the Hundred Days he joined Louis XVIII. in Belgium, where he was instructed to discuss the situation with Wellington. The tsar dreamed of allowing an appeal to the people of France on the subject of the government of France in accordance with his vague liberalizing tendencies, but Pozzo's suggestions in this direction were met by violent opposition, the duke refusing to make any concessions to what he regarded as rebellion; in St. Petersburg, on the other hand, Pozzo's attachment to the Bourbon dynasty was considered excessive. During the early years of his residence in Paris Pozzo laboured tirelessly to lessen the burdens laid on France by the allies and to shorten the period of foreign occupation. That his French sympathies were recognized in Paris is shown by the strange suggestion that he should enter the French ministry with the portfolio of foreign affairs.

Pozzo's influence at the Tuileries declined with the accession of Charles X., whose reactionary tendencies had always been distasteful to him; but at the revolution of 1830, when the Tsar Nicholas was reluctant to acknowledge Louis Philippe, he did good service in preventing difficulties with Russia. In 1832 he visited St. Petersburg; the next year he was in London renewing his relations with Wellington, and early in 1835 he was suddenly transferred to the London embassy in succession to Prince Lieven. Although he did not lose in official standing, Pozzo was aware that this change was due to suspicions long harboured in various quarters in St. Petersburg that his diplomacy was too favourable to French interests. In London his health suffered, and he retired from the service in 1839 to Paris, where he died on Feb. 15, 1842. He had been made a count and peer of France in 1818.

See Ouvaroff, *Stein et Pozzo* (St. Petersburg, 1846); *Correspondance diplomatique du comte Pozzo di Borgo et du comte de Nesselrode,* ed. by Charles Pozzo di Borgo (2 vols., Paris, 1890–1897); Vicomte A. Maggiolo, *Corse, France et Russie. Pozzo di Borgo, 1764–1842* (Paris, 1890); J. B. H. R. Capefigure, *Les Diplomates européens* (4 vols., 1843–1847).

POZZUOLI (anc. PUTEOLI, *q.v.*), a seaport and episcopal see of Campania, Italy, in the province of Naples, 7½ mi. W. of it by rail. Pop. (1936), 24,594 (town); 29,690 (commune). It is on the base of a hill projecting into the Bay of Pozzuoli, separated from the main portion of the Gulf of Naples by the promontory of Posilipo. The volcanic *pozzolana* earth (also found near Rome), used now as in Roman times for making cement and concrete, derives its name from the place. In the middle ages Pozzuoli was frequently sacked and also damaged by the natural convulsions of 1198 and 1538. It has large ironworks and melting furnaces; while to the west is a large artillery factory.

PRABHU, the small writer caste of Western India, corresponding to the Kayasth of Bengal. They stand high socially and professionally.

PRACTICE AND PROCEDURE. The practice and procedure in the English and United States courts stems from a common source, the common-law and equity procedures as developed in England from the 14th to the 18th centuries. While later innovations had considerable similarities, yet certain diversities developed in the two countries. That fact, plus the variations among the American states themselves, makes desirable the separate treatment of the subject for England and for the United States.

ENGLAND

The practice and procedure of the high court of justice in England is regulated by the Judicature act, 1925 (which repealed and consolidated nearly all the former Judicature acts), and the various rules of court made pursuant to various acts passed in and since 1883. Lest the Judicature acts and rules as so framed should not provide for every contingency, it was expressly provided by rule in 1883 that "where no other provision is made by the Judicature Act or Rules the procedure and practice existing in 1883 should remain in force." The object of the Judicature acts and the rules made thereunder was to improve a system of practice and procedure which had grown up through the centuries. Although those concerned to defend the ancient order were wont to say that it made for precision, particularly in the matter of pleadings, there can be no doubt that its advantages were, or became, hidden under its chief defects—prolixity and technicality.

The following is an attempt to state, in outline, the practice and procedure in the high court in England. In the performance of his task the writer has kept one fact constantly in mind; namely, that if the *reason* for a particular rule or canon of procedure is appreciated, the rule will be better understood. The rules of procedure did not spring into being in a single day; they are the result of years of experience. And it will always be found that whether it be sound or not there is a reason for every rule, howsoever technical it may appear to be.

Some Technical Terms.—He who is minded to study the modern rules of practice and procedure must understand the meaning of various words (often Latin words) and phrases some of which are now obsolete. The following brief glossary may suffice. *Assets* in English law means the property of a debtor in the hands of his representative sufficient for the satisfaction of his creditors or legatees; the word also occurs in the phrase "administration of assets." (*See* Order 55, rules 3, 4.) An *associate* is an officer of the supreme court, whose duties are to draw up the list of causes, enter verdicts, hand the records to the parties, etc., and generally to conduct the business of trials. *In forma pauperis* is the legal phrase for a method of bringing or defending a case in court on the part of persons without means. *Information* (*q.v.*) is a proceeding on behalf of the crown against a subject otherwise than by indictment. Certain suits might formerly be filed in chancery by way of information in the name of the attorney general. Informations are still filed by the attorney general in revenue cases in the queen's bench. *Judgment summons* is a summons issued under the Debtors act, 1869, citing a defendant against whom judgment has been entered to appear and be examined as to his means, and to show cause why he should not be committed for nonpayment of his debts. *Summons* is, in English

law, (1) a command by a superior authority to attend at a given time or place or to do some public duty; (2) a document containing such command, and not infrequently also expressing the consequence entailed by neglect to obey.

Various Forms of "Proceeding."—In the high court of justice, civil actions are begun by obtaining from the officers of the court a document known as a "writ of summons." In this document are stated the names of the parties and the nature of the claim made (which in the case of liquidated sums of money must be precise and particular). It is sealed and issued to the party suing it out, and served on the opposing party, not by an officer of the court but by an agent of the plaintiff. The tenor of the writ is to require the defendant to appear and answer the claim, and to indicate the consequences.

Many proceedings in the high court are initiated by forms of summons different from the writ of summons. Of those issued in the high court three classes merit mention:

1. For determining interlocutory matters of practice and procedure arising in "a pending cause or matter." These are now limited as far as possible to a general summons for directions introduced in 1883 so as to discourage frequent and expensive applications to the masters or judges of the high court on questions of detail. These summonses are sealed and issued on application at the offices of the high court. The matters raised are dealt with by a master with an appeal to a judge in chambers summarily. In matters of practice and procedure there is no appeal from a judge at chambers without leave from him or from the court of appeal.

2. For determining certain classes of questions with more dispatch and less cost than is entailed by action or petition. This kind of summons is known as an "originating summons," because under its proceedings may be originated without writ for certain kinds of relief specified in the rules (Rules of the Supreme Court, O. 55, r. 3). The originating summons may be used in all divisions of the high court, but is chiefly employed in the chancery division, where it to a great extent supersedes actions for the administration of trusts or of the estates of deceased persons, and for the foreclosure of mortgages. A similar but not identical procedure was created with reference to questions of title, etc., to real property. In the queen's bench and probate divisions the originating summons is used for determining summarily questions as to property between husband and wife, or the right to custody of children, and many other matters (O. 54, rr. 4 B–4 F), but there is nothing to prevent a summons of this kind issuing in the queen's bench for the determination of some such question as the construction of a bill of lading. The proceedings on an originating summons are conducted summarily at chambers without pleadings, and the evidence is usually written. In the chancery division when the questions raised are important the summons is often adjourned into court. An appeal lies to the court of appeal from decisions on originating summonses. The forms of summonses and the procedure thereon in civil cases in the high court are regulated by the Rules of the Supreme Court.

3. Certain proceedings on the crown side of the queen's bench division are begun by summons (*e.g.*, applications for bail); and in vacation writs of habeas corpus, mandamus, prohibition and certiorari are asked for by summons as the full court is not in session. (*See* Crown Office rules, 1906.)

Mandamus has always been regarded as an exceptional remedy to supplement the deficiencies of the common law, or defects of justice. The writ is used to compel inferior courts to hear and determine according to law cases within their jurisdiction; *e.g.*, where a county court or justices in petty or quarter sessions refuse to assume a jurisdiction which they possess to deal with a matter brought before them. It has been employed to compel municipal bodies to discharge their duties as to providing proper sewerage for their districts, etc. The courts do not prescribe the specific manner in which the duty is to be discharged, but do not stay their hands until substantial compliance is established.

Besides the prerogative common-law writ there are a number of orders, made by the high court under statutory authority, and described as, or as being in the nature of, mandamus; *e.g.*, mandamus to proceed to the election of a corporate officer of a municipal corporation (Municipal Corporations act, 1882, s. 225); orders in the nature of mandamus to justices to hear and determine a matter within their jurisdiction, or to state and sign a case under the enactments relating to special cases.

At common law mandamus lies only for the performance of acts of a public or official character. The enforcement of merely private obligations, such as those arising from contracts, is not within its scope. But now a mandamus may be granted by an interlocutory order of the high court in all cases in which it shall appear to the court just or convenient that such an order should be made. (O. 53.) The remedy which is thus created is an attempt to engraft upon the old common-law remedy by damages a right in the nature of specific performance of the duty in question. It is not limited to cases in which the prerogative writ would be granted; but mandamus is not granted when the result desired can be obtained by some remedy equally convenient, beneficial and effective, or a particular and different remedy is provided by statute. An action for mandamus does not lie against judicial officers such as justices. The mandamus issued in the action is no longer a writ of mandamus, but a judgment or order having effect equivalent to the writ formerly used. (*See* INJUNCTION.)

The jurisdiction of the high court, derived from the court of chancery, to decree specific performance of contracts has some resemblance to mandamus in the domains of public or quasi-public law.

Action at Law.—The term "action" in English law means at the high court of justice "a civil proceeding commenced by writ of summons or in such other manner as may be prescribed by rules of court" (*e.g.*, by *originating summons*). The proceeding thus commenced ends by judgment and execution. The stages in an English action are the *writ*, by which the persons against whom relief is claimed are summoned before the court; the *pleadings* and interlocutory steps, by which the issues between the parties are adjusted; the *trial*, at which the issues of fact and law involved are brought before the tribunal; the *judgment*, by which the relief sought is granted or refused; and *execution*, by which the law gives to the successful party the fruits of the judgment.

The procedure varies according as the action is in the high court, a county court or one of the other local courts of record which still survive; but there is no substantial difference in the incidents of trial, judgment and execution in any of these courts.

An action is said to "lie" when the law provides a remedy for some particular act or omission by a subject which infringes the legal rights of another subject. An act of such a character is said to give a "cause of action."

Action against the Crown.—Until 1947 the crown was not liable in tort, and for a breach by the state of a contract between the state and a subject, the remedy of the subject was not by action against the agents of the state who acted for the state in the making or breach of the contract, but against the crown itself by the petition of right, which was granted only on the fiat of the attorney general. By virtue of the Crown Proceedings act, 1947, however, any claim which might formerly have been enforced by petition of right may be enforced in accordance (broadly speaking) with the ordinary rules of procedure. The act further provided (by s.2) that (subject to certain exceptions) the crown shall be liable (1) for tort committed by its servants or agents, (2) for breach of the duty which a master is liable, at common law, to his servant or agent and (3) for breach of any duty attaching at common law to the ownership, occupation, possession or control of property. It is important to notice, however, that the servant or agent here referred to must be in the paid service of the crown. This very general liability of the crown is cut down in two certain important respects. Thus no proceedings in tort lie against the crown for anything done or omitted by an officer of the post office in relation to a postal packet. The crown, however, may in certain circumstances be liable to some extent for the loss of a registered inland postal packet. Again, the act makes special provision as to the liability of the crown (in tort) for anything done or omitted by a member of the armed forces.

Broadly speaking, neither the crown nor the soldier is liable for anything done by the soldier when on duty, or when on any land, premises or vehicle used for the purposes of the armed forces.

But notwithstanding all that is to be found in this act, the old maxim of the constitution—"the sovereign can do no wrong"—still prevails, for it was provided by s. 40 (1) that nothing in the act was to apply to proceedings brought against or to authorize proceedings to be brought against the sovereign in his private capacity.

The Writ of Summons.—This is the universal means of commencing an action in the high court. It is addressed to the defendant, and may be either generally or specially endorsed with a statement of the nature of the claim made. The latter form of endorsement is allowed in certain cases (*see* section *Application for Summary Judgment* below). The writ may be issued out of the central office or out of a district registry, and the plaintiff may name on his writ the division of the high court in which he proposes to have the case tried. There are special rules governing the issue of writs in probate and admiralty actions. The writ remains in force for 12 months, but may be renewed for good cause after the expiration of that time. Service must be personal, unless where substituted service is allowed, and in special cases, such as actions to recover land and admiralty actions. Service out of the jurisdiction of a writ or notice of a writ is allowed only by leave of a judge. Notice of the issue of a writ and not the writ itself is served on a defendant who is neither a British subject nor in the British commonwealth. The law is contained in the Rules of the Supreme Court, especially Orders ii–xi and xiv.

Appearance.—Every writ has upon it a memorandum pointing out to the defendant that he must, in due course, enter an appearance, otherwise judgment may be signed against him in default. Appearance is entered by the defendant delivering to the proper officer a memorandum stating the name of his solicitor or that he will defend in person (O. 12, r. 8). If a defendant is appearing in person (*i.e.*, without a solicitor) he may enter an appearance by posting the appearance to the proper officer (O. 12, r. 8a). He must give notice of appearance to the plaintiff or his solicitor. He must give his address for service which, if he has entered appearance in London, must be within three miles of the royal courts of justice, and if in a district registry, the address must be within the district. In the vast majority of cases the defendant leaves it to his solicitor to enter appearance for him. He may enter a conditional appearance if he disputes the jurisdiction of the court, or desires to allege some informality or irregularity in the service of the writ (O. 12, r. 30).

If the defendant does not enter an appearance and the writ has been specially endorsed (*see* below), the plaintiff may sign judgment in default for his debt and costs (O. 13, r. 3). But this rule does not apply where the defendant is an infant or a lunatic—the court, in the exercise of its parental jurisdiction, prohibiting such litigants from compromising without leave. Where, however, a defendant does not appear to a writ in which the plaintiff claims damages or other relief which cannot be claimed in a specially endorsed writ, the plaintiff can only sign on what is called interlocutory judgment, which leaves the *quantum* of the damages to be assessed in such manner as the court may think right (O. 13, r. 5). But judgment for the possession of land may be obtained owing to default in appearance. These rules as to default, however, are subject to this—that any judgment by default may be set aside on such terms as to costs or otherwise as to the court shall seem just (O. 13, r. 10). As a general rule, however, if the judgment has been regularly signed, it will be set aside only on very stringent terms, and the defendant must show that he has a meritorious defense.

Application for Summary Judgment.—Appearance having been entered, the next step is taken by the plaintiff. If the writ has been specially endorsed, he may issue a summons for judgment. In all actions in the queen's bench division (except actions for libel, slander, malicious prosecution, false imprisonment, seduction, or breach of promise of marriage, and actions in which fraud is alleged by the plaintiff) a writ may be specially endorsed with or accompanied by a statement of claim or of the remedy or relief which the plaintiff claims to be entitled to. A summons for judgment can be issued only if the writ is specially endorsed. It must be supported by an affidavit; the plaintiff must depose that in his belief there is no defense save (in a proper case) as to the amount of damages. Prior to 1937 the specially endorsed writ was allowed only in actions in which the claim was for a liquidated sum, or (in certain cases) for possession, or in actions of detinue. In practice, it is seldom used in any other case. If the defendant does not appear, or if he appears and shows no cause to the contrary, judgment will be given forthwith by the master in chambers. Where, however, the defendant appears in answer to the summons and shows by affidavit or otherwise that he has a defense, going to the whole cause of action, leave to defend will be given, and the master will then give directions as to the further conduct of the suit. Sometimes it will appear that the defendant has no answer to part of the claim. In that case the master generally orders payment to the plaintiff's solicitors in a certain time, or judgment in default, and gives directions as to the balance. In rare cases the master will order money sought to be brought into court as a condition of leave to defend. But a plaintiff ought not to proceed for summary judgment unless he has substantial grounds for believing there is no defense to the action. Should it turn out that there is a defense of which he must, or ought to, have known, he runs the risk of having to pay the costs.

This (which has just been described) is the celebrated procedure under Order 14. Unknown to the public, and to a large section of the legal profession, enormous sums of money change hands each year in consequence of orders made by masters in chambers.

Having decided to give leave to defend, the next duty of the master is to say how the case shall be tried. If the issue is clear and simple he has power to send it for trial into the short cause list. In that case it is set down for trial without pleadings, and it comes on for trial before a judge alone in a very short space of time. Where, however, service issues are raised necessitating an order for discovery and pleadings, directions are given providing for those matters and settling the place of trial—whether in London or at assizes. If the amount is less than £100, however, the case is generally remitted for trial in the county court, the costs being left to the county court judge. If it involves a technical or scientific inquiry, or the examination of accounts, the master may send it to an official referee. Finally, if the parties agree, he may order it to be tried before a master, who fixes a time and day and hears the whole case with witnesses. His decision on a reference of this kind is subject to an appeal to a divisional court.

From the decision of a master on a summons for judgment, an appeal lies to the judge in chambers, who may reverse or vary the master's order. It not infrequently happens that the party who is unsuccessful before the master carries in fresh evidence before the judge in chambers. From the judge an appeal lies (with leave) to the court of appeal, subject to this, that where the judge has given unconditional leave to defend, there is no further appeal of any kind.

Summons for Directions.—In all other cases commenced by writ and subject to an exception to be presently mentioned, the plaintiff in every action must take out a summons for directions (O. 30, r. 1). This he does seven days after the pleadings have been closed. This rule, however, does not apply to admiralty actions, or to an action where the writ is specially endorsed, or to any proceeding commenced by originating summons or to an action for infringement of a patent, although in any of those cases the plaintiff may apply for directions. When giving directions the master deals with discovery and inspection of documents, interrogations, letters and the place and mode of trial. He may order evidence to be given by affidavit (on conditions); order certain facts to be proved by statement on oath of information and belief; limit the number of experts and the right of appeal; and make such orders as to pleading as may be just. If a plaintiff fails to take out a summons for directions, the defendant may apply for the action to be dismissed for want of prosecution (O. 30, r. 7 [8]).

Parties.—All persons may be joined in one action as plain-

tiffs in whom any right to relief arising out of the same transaction is alleged to exist, whether jointly or severally, or in the alternative where, if such persons brought suit separately, a common question of law or fact would arise (O. 16, r. 1). Should it appear, however, that any such joinder may embarrass or delay the trial, separate trials may be ordered (*ibid.*). Again, if an action is by accident brought by the wrong plaintiff a new plaintiff may be substituted or added (O. 16, r. 2). As regards defendant, all persons may be joined as such against whom the right to any relief is alleged to exist, whether jointly or severally or in the alternative (O. 16, r. 4). If numerous persons having the same interest in the cause or matter desire to assert or defend their rights, the court may authorize one or more of them to represent all (O. 16, r. 9). As a corollary to the above rules it is important to notice that the court has ample power to strike out parties improperly joined, and to add others who should be before the court in order that the matters in dispute may be effectually determined (O. 16, r. 11). As regards lunatics and infants the rules are strict to prevent anything in the nature of a settlement or compromise of an action save with the consent of the court or a judge. Money recovered by infant or lunatic may be kept in court or otherwise protected for the benefit of the party concerned.

Any poor person (*i.e.*, a person who is not worth more than £50 or such larger sum not exceeding £100 as may be allowed in special circumstances or a person whose usual income is not more than £2 or in special cases £4 a week) may sue or defend without paying court fees and may have a solicitor and counsel assigned to him free of charge. (*See* generally O. 16 and 22 *et seq.*)

Third-Party Procedure.—It is obvious that where A has a claim against B, B may have a claim against C which arises, or which he desires to assert, only because A has brought an action against him. It would be unfortunate and would involve unnecessary expense to all parties if B were bound to refrain from suing C until A had sued him. A remedy for this is provided by what is known as third-party procedure (O. 16, r. 48), under which, where a defendant claims contribution or indemnity against a person not a party to the action, he may, by leave, issue a third-party notice. To that notice (which corresponds to a writ) the third party must appear, otherwise judgment may go against him by default (O. 16, rr. 49, 50). If he does appear, suitable directions may be given so that all the questions between all the parties may be tried in the same action (O. 16, r. 52). The third party may bring a fourth party from whom he seeks indemnity subject to the same rules as prevail in relation to third parties (O. 16, r. 54B).

Change of Parties.—An action does not abate because of the marriage, death or bankruptcy, etc., of any party thereto, if the cause of action survives (O. 17, r. 1), and where any marriage, etc., takes place, or there is any devolution of estate by operation of law, the court may order that the husband, personal representative, trustee or other successor to interest of any party shall be made a party and served with notice of the proceedings (O. 17, r. 2). Similarly, any person, who by reason of a marriage, death, bankruptcy or assignment after action brought acquires an interest in the dispute may apply to be made a party (O. 17, r. 4).

Several causes of action may be joined in the same action; but the court may order that there shall be separate trials if the various causes of action which appear upon the record cannot be conveniently tried together (O. 18, r. 1). This rule is subject to one notable exception; namely, that no other cause of action can be joined with an action for the recovery of land, except by leave of the court (O. 18, r. 1). Application for leave is made ex parte to a master before the writ is served.

The Pleadings.—Normally, in an action tried in the queen's bench division, "pleadings" are delivered. They consist of a statement of claim, the defense (and counterclaim, if any) and reply and, in rare cases, a rejoinder. No pleading subsequent to defense can, however, be delivered without leave.

A pleading is the term applied in English law to the preparation of the statement of the facts on which either party to a civil action founds his claim to a decision in his favour on the questions involved in the proceeding; and also to the document in which these statements are embodied. The term "pleadings" is used for the collected whole of the statements of both parties; the term "pleading" for each separate part of the pleadings.

The object of the pleadings is to secure that both parties shall know what are the real issues between them. A plaintiff must (in certain cases) deliver a statement of claim; a defendant must put in a defense and he may also plead a setoff or counterclaim. The plaintiff must (in certain cases) reply to the defense, and must put in a defense to the counterclaim. The rules of pleading are so framed as to restrict the length of pleadings as much as possible. So "every pleading shall contain, and contain only, a statement in a summary form of the material facts on which the party pleading relies for his claim or defence, as the case may be, but not the evidence by which they are to be proved." The pleader must confine himself to material facts—but an allegation may be material though it is not necessary. He must confine himself, too, to facts material at that stage of the action.

With a view to avoiding prolixity, the rules provide that a contract which is to be implied from a series of letters or conversations, or from various circumstances, may be referred to as a fact without setting out all the letters, etc., in detail. But reference to those letters, etc., and the substance of material conversation must be given. Matters of law need not be pleaded to. But even though it may necessitate a long and elaborate statement, all material facts must be set out in a pleading. If material, dates, names and items are not given, the pleader may be ordered to give particulars. A pleading may contain alternative and inconsistent allegations.

As indicated above, particulars may be ordered if a pleading is not sufficiently explicit. Particulars may be necessary to indicate to the opponent the nature of the evidence required by him.

With regard to the defense, it is seldom enough merely to traverse (*i.e.*, deny or refuse to admit) the matters in the statement of claim. For example, if the plaintiff sets up a contract which was in fact made, it would be idle for the defendant merely to deny the existence of a contract. He should, in a proper case, confess (*i.e.*, admit) the contract and *avoid* the effect of that confession by (1) setting up the statute of fraud or limitations or by setting up (2) that the contract has been duly performed or rescinded; or (3) that it was illegal; or (4) that some condition precedent to his liability has not been performed. In an action of debt a mere denial of the debt is expressly declared by the rules to be inadmissible; and in an action for liquidated sums the defense must deny the order or contract, the delivery or the amount claimed. Again, in an action for money had and received, the defense must deny the receipt of the money, or the existence of those facts which are alleged to make such receipt by the defendant a receipt to the use of the plaintiff. If the defendant desires to deny the right of a plaintiff to sue in a representative capacity, he must do so specifically (O. 21, r. 5). While the defendant should make every denial which is really necessary, he should avoid denying matters which are really immaterial. If he does so, the court has power to make him pay any extra costs occasioned thereby (O. 21, r. 9).

With regard to counterclaims, a defendant may counterclaim not only against the plaintiff but against other parties to the action, and against a person who is not a party (O. 21, r. 11). But whereas a counterclaim against a plaintiff and a person already a party is merely delivered, a counterclaim involving a third party must be served on him like a writ. Such third party must appear as if he were a defendant to an action, and, having done so, may deliver a defense without any leave from the court (O. 21, r. 14). If there is a counterclaim on the record, and the original action is stayed, discontinued or dismissed, the counterclaim can nevertheless be proceeded with (O. 21, r. 16). As to defenses generally, one or two survivals from ancient times are to be found in the rules. Thus it is still competent for a defendant, in certain cases, to plead "not guilty by statute"—as when, for example, an action is brought for illegal distress. But it is unsafe to use this plea, as no other plea can be added save by leave (O. 19, r. 12; O. 19, r. 20). Again, a plea "in abatement"

(*e.g.*, that a third person should have been added as plaintiff) is not allowed. Finally in an action for the recovery of land against a defendant who is in possession by himself or his tenant the defendant (unless he has some equitable defense) need only plead that he is in possession. This puts everything in issue and enables him to raise any defense—even the statute of limitations (O. 21, r. 21). The reason assigned for this (by Lord Justice William Brett, later Viscount Esher) is that the plaintiff in an action for recovery of land must recover on the strength of his own title and not through any defect in the defendant's title. "Possession is nine points of the law."

Payment into Court.—There is no part of the procedure in civil actions more important to the litigant than that which enables a defendant to pay money into court. By a judicious payment into court a defendant may bring proceedings to an end, and so avoid the costs of what may be an expensive action. Further, if he pays in enough or more than enough to satisfy the plaintiff's claim, the plaintiff will have to bear all costs incurred subsequent to the date of payment-in.

The rules provide that in any action for debt or damages (not, *e.g.*, in an action for an account) or in an admiralty action, the defendant, at any time after appearance, may, upon notice to the plaintiff, pay into court a sum of money in satisfaction of the claim, or, where several causes of action are joined in one action, in satisfaction of one or more causes of action; and that if the defendant pleads tender, he must bring the amount tendered into court. In his notice (which must be in writing) the defendant must specify the cause of action to which the payment is related, and state whether he admits or denies liability (O. 22, r. 1). Within seven days of a notice of payment-in, the plaintiff may, by notice, accept the payment in satisfaction, and then becomes entitled to receive payment out of court, which must be made to him or his solicitor. Thereupon the action is stayed as to the cause of action in respect of which the payment is made (*ibid.*, rr. 2 [1] [2]). If the plaintiff accepts the amount paid in, or accepts a sum paid in respect of one cause of action, and gives notice that he abandons his other causes of action, he may tax his costs incurred down to the date of payment-in, and sign judgment for those costs (*ibid.*, r. 2 [3]). But this rule (O. 22, r. 2) does not apply to admiralty actions, or in cases where there is a plea of tender.

A special privilege is conferred on the plaintiff in an action for defamation. Having taken money out in satisfaction, he may apply for leave to make a statement in open court on terms approved by a judge (O. 22, r. 2 [4]).

One of two or more defendants sued in the same action may pay into court, but in that case, although the action is stayed as regards that defendant, the money cannot be paid out except in pursuance of an order of the court disposing of the whole action (O. 22, r. 4).

Except in certain actions for libel (*see* below), the fact of payment-in must not be mentioned in the pleadings or to the judge or jury until after the trial. The judge may then take the fact into account when deciding upon costs (*ibid.*, r. 6).

This rule applies in an ordinary action for libel; but in an action for libel brought against a newspaper, the defendant may plead absence of malice, publication without gross negligence, apology and *payment into court*, by virtue of the Libel acts, 1843 and 1845. (*ibid.*, r. 6) In such a case, the payment into court is mentioned in the pleadings.

There is one case in which the defendant ought certainly, in his own interest, to pay money into court. This is where, in answer to a claim for a liquidated sum, he has made a tender before action. Tender of what is due is a complete defense to an action; but where there is a plea of tender upon the record, it will not avail the defendant unless he has brought the amount tendered into court. And this is good sense, because the defendant's attitude must be that he always was and still is ready and willing to pay his debt. But where money has been paid into court with a plea of tender, the plaintiff cannot terminate the action by taking that money out of court; for he will thereby admit the defense and the costs of the whole action will be the defendant's.

But it is not always necessary for a defendant to admit liability for the sum paid in. In any action of debt he may pay in without admitting liability (except when he pleads tender). This is a mere offer to secure peace, which may appear with any other defense; *e.g.*, a denial of the contract or a plea of performance.

To the general rule that it rests with plaintiff to say whether he will or will not accept money paid into court, there is an exception in any case where the plaintiff is an infant or a person of unsound mind. Acceptance of a sum paid in involves (or may involve) a compromise of the action, and the court, exercising a parental jurisdiction in such matters, will refuse to allow a compromise which may not be fair to the plaintiff. And so the court has power, not only to refuse to allow a compromise, but it may provide, by order, for the money being retained in court and invested or otherwise disposed of for the benefit of the infant (until he attains the age of 21) or lunatic as the case may be. (*See* generally O. 22, r. 14.)

Reply and Subsequent Pleadings.—The defense having been delivered, the plaintiff may find it necessary to deliver a reply. Under the old rules a plaintiff was always entitled to reply—even if it was only to join issue. But now a mere joinder of issue is unnecessary and (O. 27, r. 13) no reply or subsequent pleading (*e.g.*, rejoinder, surrejoinder, etc.) can be delivered without order except in certain admiralty cases (O. 23). A defendant must not suggest a new cause of action in his reply, for that would be what the old pleaders called a "departure." And the reason is plain. To a new cause of action the defendant must be enabled to put in a defense in accordance with the rules. A new cause of action must therefore appear in an amended statement of claim.

Cases may occur in which, although the plaintiff had a good cause of action when he issued his writ, something happened afterward to satisfy his claim or discharge the cause of action. For example, he may accept payment of the debt sued for, or a sum of money by way of compromise of a claim for damages. Such acceptance or compromise would constitute a defense. If it takes place before the expiration of the time limited for defense, the defendant may raise it in his defense, signifying that it arose since action brought (O. 24, r. 1). And even if it arises after that time, the defendant may raise it by leave (O. 24, r. 2). The plaintiff may thereupon "confess" such defense and tax his costs up to the time when it was delivered (O. 24, r. 3) unless the court shall otherwise order. A similar rule obtains with reference to a reply which sets up new matter in defense to a setoff or counterclaim. A counterclaim may be founded on facts which have arisen since action brought, but it must be phrased as so arising.

Discontinuance.—In certain circumstances an action may be discontinued, or a defense withdrawn. Thus at any time before receipt of defense, or after receipt thereof before taking any proceeding other than interlocutory (*e.g.*, a summons for particulars), the plaintiff may, without leave, by notice in writing discontinue the whole action, or withdraw any part of it as against all or any of the defendants, subject to the payment of costs (O. 26, r. 1).

Proceedings in Lieu of Demurrer.—In former days it was competent for a defendant to "demur" to the statement of claim on the ground that it disclosed no cause of action. The result was that many a claim was defeated and costs were often incurred merely because the plaintiff had not put his case in proper form. Demurrer was later abolished (O. 25, r. 1) but any party may raise a point of law by his pleading, and the point so raised shall be disposed of at or after the trial subject to this, that if the parties consent or the court so orders the point may be set down for hearing and disposed of before the trial (O. 25, r. 2). If the decision substantially disposes of the whole action, the action may be dismissed (O. 25, r. 3). This course may be conveniently adopted where it is obvious that a serious question arises as to whether the statement of claim as drafted discloses any cause of action, or the defense any answer in law to the claim.

Striking Out Pleadings.—The court may order a pleading to be struck out on the ground that it discloses no reasonable cause

of action or answer (O. 25, r. 4). In any such case, or if the action or defense be shown by the pleadings to be frivolous or vexatious, it may be stayed or dismissed, or judgment may be entered for the defendant accordingly as may be just (*ibid.*). To succeed in such an application, an objecting party must be able to point to some defect in the pleading itself. The rule is acted upon only in plain and obvious cases. So if, in an action on a contract, it be clear that there is no contract between the plaintiff and the defendant; or no contract valid in law; or that the matter is already *res judicata*, or where the statement of claim on the face of it shows that there is a good defense, it will be struck out.

But the court will generally give a party leave to amend a pleading before striking it out. Apart from the rule above mentioned (and O. 19, r. 25, which enables anything scandalous or vexatious, or which tends to delay, etc., the trial of an action, to be struck out) the court has inherent jurisdiction to stay all proceedings before it which are obviously frivolous or vexatious or an abuse of its process. An application to strike out on these grounds should be supported by an affidavit. Discontinuance by the plaintiff does not affect a counterclaim, but a counterclaim cannot be set up after discontinuance.

A defendant may by leave, and only by leave, and upon terms, withdraw the whole or part of his defense or counterclaim. If the defense is withdrawn, the plaintiff can sign judgment in default of defense. An application so to withdraw may be made at any time. A cause entered for trial may be withdrawn by either plaintiff or defendant upon producing a consent in writing to the proper officer (O. 26, r. 2). The plaintiff must pay the defendant's costs if he discontinue an action (O. 26, r. 3); and if he bring another action for the same or substantially the same cause, it may be stayed if the costs of the former action are not paid (O. 26, r. 4).

Default of Pleading.—The rules of pleading are enforced by this—that if a party does not plead as and when required, he may, if he is a plaintiff, have his action dismissed, if he is a defendant, have judgment signed against him. Thus if a plaintiff being bound to deliver a statement of claim does not do so within the time allowed, the defendant may apply to have the action dismissed for want of prosecution, and on the hearing of the application the court may either dismiss the action or make such order as shall be thought just (O. 27, r. 1). Where the plaintiff delivers his statement of claim after the application has been made, the court will generally make no order save that he pay the costs. The plaintiff need not deliver a statement of claim save under an order for directions, for which he must himself apply. If he does not so apply within 14 days of the defendant's appearance the defendant may have the action dismissed (O. 30, r. 8). A plaintiff may be in default in delivering a reply and defense to a counterclaim. If so, the defendant's only remedy is to move for judgment under O. 27, r. 11, even when the counterclaim is for a liquidated demand and even if some other person has been made a defendant to the counterclaim.

A defendant may make default either in not entering an appearance or in not putting in his defense. If he has not appeared, and, the writ not being especially endorsed, he has had a statement of claim filed against him in default, he must appear and deliver his defense within ten days of the filing of the statement of claim. Otherwise he may have judgment signed against him with costs (O. 21, rr. 2–9). In such a case, however, if the plaintiff could have signed judgment merely in default of appearance, he can only have such costs as he would have had in that case. In other words, he will not be allowed the costs of the statement of claim. If a defendant has appeared to the writ other considerations arise. If the writ was specially endorsed he must deliver a defense within ten days unless the plaintiff has proceeded for summary judgment (O. 21, r. 6), and in other cases if a separate statement of claim has been delivered he must deliver his defense within the time limited by the summons for directions (O. 21, r. 8).

The procedure to be adopted if the defendant has not put in a defense depends upon the nature of the action. (See *Appearance*, above.)

Close of Pleadings.—There comes a time in every action when the pleadings are deemed to be closed. Where no reply or subsequent pleading is ordered then within four days of the delivery of the last pleading, or where a reply has been ordered within a certain time, at the end of that period the pleadings are to be deemed closed and all statements therein put in issue (O. 27, r. 13). This, however, does not apply to a reply to a counterclaim which is really a defense. Unless the plaintiff obtains leave to reply to a counterclaim, the statements of fact which it contains shall be deemed to be admitted after the expiration of ten days, unless a reply has been ordered, in which case, if the order is not complied with, the facts will be deemed to be admitted.

Amendment.—In former times the ends of justice were often defeated, and the litigant was put to an enormous amount of unnecessary expense, because the powers of the court to allow amendment of pleadings were greatly restricted. Now, however, the court or a judge may at any time, and on such terms as to costs or otherwise as may be thought right, amend any deficit in any proceedings, and all necessary amendments shall be made for the purpose of determining the real question or issue raised by or depending on the proceedings (O. 28, r. 12).

Amendment of Pleadings.—The court or a judge may at any stage of the proceedings allow either party to alter or amend his endorsement or pleadings in such manner and on such terms as may be just, and all such amendments shall be made as may be necessary for the purpose of determining the real question in controversy between the parties (O. 28, r. 1). Under this rule amendment will always be allowed, if it can be made without injustice to the other side. While a new cause of action may be introduced into the statement of claim by amendment, if the plaintiff at the same time seeks to stand on his original claim, leaving his writ unamended, this is practically a discontinuance, for the new claim is wholly unsupported by the writ. Such an amendment will only be allowed on the terms that the plaintiff pays all costs down to the time of the amendment, and that all proceedings are stayed until those costs are paid.

A common informer is but seldom allowed to amend his statement of claim in an action for penalties. Amendment is often allowed on an application to strike out a pleading as embarrassing or because it discloses no cause of action—*ut res magis valeat quam pereat.* Although, when a statement of claim is delivered the plaintiff may therein alter, modify or extend his claim without any amendment of the writ, he cannot add a claim on a wholly new and different cause of action except by leave; and if leave is given the writ should be amended. The writ or the statement of claim *must* be amended in one case; *i.e.*, where the plaintiff recovers by verdict of a jury more than the amount he has actually claimed. Otherwise he cannot recover the amount of the verdict. Amendment may be allowed at any time but it should obviously be made at the earliest possible moment. A defendant may have no answer to the claim as amended. A plaintiff may find it necessary to confess an amended defense and stop his action; or, where the amendment involves a payment of money into court, he may be content with the amount paid in.

A plaintiff may, in certain cases, and within a certain time, amend his statement of claim, whether endorsed on the writ or not, without leave (O. 28, r. 2). But he cannot, in the exercise of this privilege, add a cause of action which has accrued to him since the writ—although he can do that by leave. Nor can he add new parties. If he has delivered particulars with the statement of claim he can amend them under this rule; but particulars delivered otherwise can be amended only by leave. Under this rule a special endorsement can be amended provided the claim is one which can be specially endorsed. A similar rule (O. 28, r. 3) applies to a counterclaim. But it is important to notice that any amendment so made without leave may be disallowed—or allowed only upon terms—on the application of the other side if the justice of the case so requires (O. 28, r. 4).

It has been stated that amendment to statement of claim or counterclaim without leave can be made only within a certain time. All other amendments to claim or defense, or to any other pleading, can be made only by the leave of the court or a judge

and upon such terms as to costs as may be just (O. 28, r. 6). If an order giving leave to amend is made and the amendment is not made within the time limited or within 14 days of the date of the order, the order is void, unless the time is extended by the court or a judge (O. 28, r. 7). Moreover, the amended pleading must be delivered to the opposite party within the time allowing the same (O. 28, r. 10).

Actions By or Against Firms.—If a firm desires to bring an action, or anyone desires to bring an action against a firm, in the firm name, special considerations arise. Broadly speaking, a firm consisting of more than one person carrying on a business within the jurisdiction may sue or be sued in the firm name, but subject to this—that the names of the partners must, if required, be revealed to the other side. Where, however, a man carries on business in a name other than his own, he can sue only in his own name, but he may be sued in the name of his firm. He must, however, reveal his true name if required. Service of process on a firm may be effected either upon any one of the partners, or upon the manager at the place of business of the firm. The person served must be told, at the time, whether he is served as a partner or as manager. A firm cannot enter an appearance as such: it must appear by one of the partners personally; but an alleged partner may appear with a denial that he is a partner. The property of the firm within the jurisdiction can be seized in execution of a judgment against the firm, and so can the property of individual partners. This is but a summary of O. 48A, which provides a complete code of rules on the subject. It must be carefully studied by anyone who is concerned in an action by or against a firm.

Discovery.—The pleadings having been closed, the parties in most cases proceed to have discovery, either of facts or documents or both. The English common-law courts were originally unable to compel a litigant before a trial to disclose the facts and documents on which he relied. In equity, however, a different rule prevailed, there being an absolute right to discovery of all material facts on which a case was founded. Now the practice is regulated by the Rules of the Supreme Court, 1883, Order 31. Discovery is of two kinds; namely, by interrogatories and by affidavit of documents, provision being also made for the production and inspection of documents. Where a party to a suit can make an affidavit stating that in his belief certain specified documents are or have been in the possession of some other party, the court may make an order that such party state on affidavit whether he has or ever had any of those documents in his possession, or if he has parted with them or what has become of them. A further application may then be made by notice to the party who has admitted possession of the documents for production and inspection. Copies also may be taken of the more important documents. There is also discovery of facts obtained by means of interrogatories; *i.e.*, written questions addressed on behalf of one party, before trial, to the other party, who is bound to answer them in writing upon oath. In order to prevent needless expense the party seeking discovery used to have to secure the cost of it by paying into court a sum of money, generally not less than £5, but this rule was later abolished. Objection may be taken to discovery either of a fact or a document on the ground of privilege or that the matters sought to be discovered are criminatory.

Thus all documents and communications passing between a litigant and his legal advisers are absolutely privileged and need not be disclosed. Again, where an admission of a fact or the production of a document might involve the admission of a criminal offense, the litigant may refuse to give discovery. Where the opposite party is not satisfied with an affidavit of documents, or the answer to an interrogatory, he may in certain cases apply for a further and better affidavit or answer, and in some cases the master to whom the application is made will himself examine a document in order to see whether it shall be disclosed or not. The advantage of discovery lies in this—that it forces a litigant to reveal his case on oath. It is one thing to make a statement or deny a fact in a pleading. That merely has effect to put the matter in issue. It is a much more serious matter to have to swear to a fact in an affidavit, because, in the case of the answer to an interrogatory, it may be put in evidence by the opposite party at the trial. Many an action is brought to a speedy end by an order for discovery, because the litigant is wholly unable to swear to the truth of the claim or defense which he has put upon his pleadings. Discovery will not be allowed if the remedy sought to be enforced is of a penal nature, or if the plaintiff is relying on a forfeiture.

Evidence on Commission.—Cases often arise in which it is impossible because of illness or absence to secure the attendance of a witness at the trial. In such circumstances the court has power (conferred by O. 37, r. 5 *et seq.*) to direct that the evidence be taken anywhere before an officer of the court or any other person. It must be shown, however, that the witness will be unable to attend, either because of illness or because he is out of the jurisdiction, and cannot be compelled to attend by subpoena. Even a plaintiff may be allowed to give evidence on commission, but this is a privilege seldom granted. The evidence of the witness is written down and signed by him and can be put in at the trial. In certain foreign countries, where evidence cannot be taken on commission, it is secured by letters of request, which are sent through the foreign office.

Admission.—Although the pleadings show that everything is in issue in an action, it is competent for either party to give notice that he admits the truth of the whole or part of his opponent's case (O. 32, r. 1). This secures the costs of proving those facts, and, if the whole cause of action is admitted, enables the party to whom the admission is made to apply for judgment (O. 32, r. 6). Apart from this, either party may give notice to the other to admit facts and if he refuses to do so unreasonably he may have to pay the costs of the necessary proof of those facts (*ibid.*, [4]). Similarly notice may be given to admit documents; indeed the costs of proving any document may be disallowed if the notice is not given (O. 32, r. 3).

Special Case.—The parties to any cause or matter may concur in stating the questions of law arising therein in the form of a special case for the opinion of the court (O. 34, r. 1), and the court may order a question of law to be decided either by special case or otherwise before any question of fact is tried (O. 34, r. 2).

Transfer and Consolidation of Action.—Action may be transferred from one division of the high court to another, or from one judge to another by order of the lord chancellor but subject to the consent of the president of the division (O. 49, r. 1). Causes pending in the same division may be consolidated with each other (O. 49, r. 8).

Application and Proceedings at Chambers.—All applications at chambers (*i.e.*, before a master or a judge) are made by summons unless they are made ex parte; that is to say, by one side only. Applications at chambers generally are regulated by O. 54, while O. 55 prescribes the rules observed in chambers in the chancery division.

Proceedings in District Registries.—To meet the convenience of suitors who do not live in or near London, district registries have been established in various parts of the country. Proceedings can be taken in a district registry only in an action in which the writ has been issued out of that registry. Broadly speaking, the powers of a district registrar are similar to those of a master of the supreme court. In certain cases, however, where an action has been commenced in a registry the defendant can as of right have it moved to London, and the court has power in all cases to move an action from a registry to London or vice versa. (*See* generally O. 35.) As to appeals from district registries *see* APPEAL. Proceedings by poor persons under the Matrimonial Causes acts in district registries are provided for by O. 35a.

Trial.—The places and mode of trial are fixed by the order made on a summons for directions. Where a case is to be tried in London, it is assigned to one of three lists—the jury list, the London nonjury list and the short nonjury list (O. 36 r. 1A and 29 [1]). The master, when making the order, tries to form an opinion as to the time which the hearing will last. As a rule a case sent to the short nonjury list will not require more than two hours. The plaintiff must give notice of trial (O. 36, r. 11), and if he fails to

do so, within the time prescribed by the rules, the defendant may do so, or else apply to have the action dismissed for want of prosecution (O. 36, r. 12). Trial follows upon the completion of the steps necessary to bring the parties before the court and to adjust the issues upon which the court is to adjudicate, which may be summed up in the term pleading. In England the trial is usually in open court, and it is rare to try cases *in camera*, or to attempt to exclude the public from the hearing. In practice hearing *in camera* is ordered only where to try in open court would be to defeat the ends of justice. The essential part of the trial is that there should be full opportunity to both sides for evidence and argument on the questions in dispute.

In the high court of justice in England several modes of trial are now used:

1. Trial by judge with a jury used in the queen's bench division and in probate and matrimonial cases. There is a right to have a jury as a matter of course in actions of defamation, false imprisonment, malicious prosecution, seduction and breach of promise of marriage.

2. Trial by a judge without a jury is invariable in the chancery division and is common in other divisions. Cases in the chancery division are not tried with a jury unless a special order is made (O. 36, r. 3); and the high court in cases in which trial without jury could be ordered without consent still retains the power of so trying them, and has also acquired power to direct trial without a jury of any issue requiring prolonged examination of documents or accounts or scientific or local investigation.

3. Trial with assessors, usually in admiralty cases (the assessors being nautical), but rare in other divisions.

4. Trial by an official referee in certain cases involving much detail (R.S.C., O. 36).

5. Where the parties consent, trial may be had of any case in the queen's bench division before a master in chambers.

A speedy trial may be ordered in certain cases (O. 36, r. 1A), but the power conferred by this order is sparingly exercised.

The parties may be represented in the high court by counsel or may conduct their case in person. The trial is carried on by stating to the court the pleadings if any and by opening the plaintiff's case. This is followed by the evidence of the witnesses, who are sworn and examined and cross-examined. On the completion of the plaintiff's case and evidence, the defendant's case is stated and evidence adduced in support of it. The plaintiff or his counsel has, as a rule, the reply or last word unless the defendant has called no evidence. If when the trial is called the plaintiff appears and the defendant does not, the plaintiff may prove his case (O. 36, r. 31). If the plaintiff does not appear, the defendant may have judgment dismissing the action, and may prove his counterclaim if he has one (O. 36, r. 32). But any judgment by default may be set aside on terms.

At the conclusion the judge sums up the law and facts of the case to the jury and their verdict is returned, or if there is no jury the judge gives judgment stating his conclusion on the law and the facts involved. He then directs that judgment shall be entered as he thinks right (O. 36, r. 39), and a memorandum is endorsed on the judgment pointing out that if it is not obeyed, the defendant will be liable to process of execution (O. 41, r. 5).

Juries.—In England the trial jury (also called petty jury or traverse jury) consists of 12 jurors, except in the county court where the number is 8. Women are now summoned as jurors, but a husband and wife cannot be summoned on the same occasion. A woman may, however, claim exemption on the ground that by reason of pregnancy or some other feminine condition or ailment she is or will be unfit to serve. Either party to the suit may apply to the court for an order that the jury shall consist wholly of men or wholly of women. In civil but not in criminal cases the trial may by consent be by fewer than 12 jurors, and the verdict may by consent be that of the majority.

The jurors are selected from the inhabitants of the county, borough or other area for which the court to which they are summoned is commissioned to act.

Exemptions from juries include members of the legislature and judges, ministers of various denominations, practising barristers and solicitors, registered medical practitioners and dentists and officers and soldiers of the regular army. Persons over 60 are exempt but not disqualified. Lists of the jurors are prepared by the overseers in rural parishes and by the town clerks in boroughs, and are submitted to justices for revision. When jurors are required for a civil or criminal trial they are summoned by the sheriff or, if he cannot act, by the coroner.

For the purpose of civil trials in the superior courts there is only one list of jurors, special juries having been abolished.

The jurors are the judges of fact upon the evidence laid before them. Their province is strictly limited to questions of fact, and within that province they are still further restricted to matters proved by evidence in the course of the trial and in theory must not act upon their own personal knowledge and observation except so far as it proceeds from what is called a "view" of the subject matter of the litigation.

While the jury is in legal theory absolute as to matters of fact, it is in practice largely controlled by the judges. Not only does the judge at the trial decide as to the relevancy of the evidence tendered to the issues to be proved, and as to the admissibility of questions put to a witness, but he also advises the jury as to the logical bearing of the evidence admitted upon the matters to be found by the jury. The rules as to admissibility of evidence, largely based upon scholastic logic, sometimes difficult to apply, and almost unknown in continental jurisprudence, coupled with the right of an English judge to sum up the evidence (denied to French judges) and to express his own opinion as to its value (denied to U.S. judges), fetter to some extent the independence or limit the chances of error of the jury.

The appellate court will not upset a verdict when there is substantial and conflicting evidence before the jury. In such cases it is for the jury to say which side is to be believed, and the court will not interfere with the verdict. To upset a verdict on the ground that there is no evidence to go to the jury implies that the judge at the trial ought to have withdrawn the case from the jury. Under modern procedure, in order to avoid the risk of a new trial, it is not uncommon to take the verdict of a jury on the hypothesis that there was evidence for their consideration, and to leave the unsuccessful party to apply for judgment notwithstanding the verdict. The question whether there was any evidence proper to be submitted to the jury arises oftenest in cases involving an imputation of negligence; *e.g.*, in an action of damages against a railway company for injuries sustained in a collision.

This statement indicates existing practice but scarcely determines what relation between the facts proved and the conclusion to be established is necessary to make the facts evidence from which a jury may infer the conclusion. The true explanation is to be found in the principle of relevancy. Any fact which is relevant to the issue constitutes evidence to go before the jury, and roughly speaking, if there is a connection, as cause and effect, between any fact and the fact to be proved, the former is relevant. As regards damages the court has always had wide powers, as damages are often a question of law. But when the amount of the damages awarded by a jury is challenged as excessive or inadequate, the appellate court, if it considers the amount unreasonably large or unreasonably small, must order a new trial unless both parties consent to a reduction or increase of the damages to a figure fixed by the court; see *Watt* v. *Watt* (1905), App. Cas. 115.

Judgment and Execution.—Execution is allowed as a matter of course after judgment except where it has for some reason been stayed; *e.g.*, where an appeal is pending. (*See* generally R.S.C., O. 42.) A judgment for the recovery of money or costs is enforced, as a rule, by writ of *fieri facias* addressed to the sheriff, and directing him to cause to be made (*fieri facias*) of the goods and chattels of the debtor a levy of a sum sufficient to satisfy the judgment and costs, which carry interest at 4% per annum. The seizure effected by the sheriff or his officer, under this writ, of the property of the debtor, is what is popularly known as "the putting in" of an execution. The seizure should be carried out with all possible dispatch. The sheriff or his officer must not break open

the debtor's house in effecting a seizure, for "a man's house is his castle"; but this principle applies only to a dwelling house, and a barn or outhouse unconnected with the dwelling house may be broken into. The sheriff on receipt of the writ endorses it on the day, hour, month and year when he received it; and the writ binds the debtor's goods as at the date of its delivery, except as regards goods sold before seizure in market overt, or purchased for value, without notice before actual seizure (Sale of Goods act, 1893, s. 26, which supersedes s. 16 of the Statute of Frauds and s. 1 of the Mercantile Law Amendment act, 1856).

This rule is limited to goods, and does not apply to the money or bank notes of the debtor which are not bound by the writ till seized under it (*Johnson* v. *Pickering*, Oct. 14, 1907, C.A.). The mere seizure of the goods, however, although, subject to such exceptions as those just stated, it binds the interest of the debtor, and gives the sheriff such an interest in the goods as will enable him to sue for the recovery of their possession, does not pass the property in the goods to the sheriff. The goods are in the custody of the law. But the property remains in the debtor who may get rid of the execution on payment of the claim and fees of the sheriff. The wearing apparel, bedding, tools, etc., of the debtor to the value of £5 are protected. Competing claims as to the ownership of the goods seized are brought before the courts by the procedure of "interpleader." In the queen's bench division, the sheriff issues a summons before a master in chambers calling upon the execution creditors and claimant to appear and state their respective cases. If the claim is not admitted by the execution creditor, an issue is directed to try the merits and either party may ask the master to try the issue himself. This he generally does at the earliest possible opportunity, for the sheriff being in possession, costs are mounting up. Otherwise the "issue" is reported for trial to the high court or county court, the claimant being directed to bring the amount of the sheriff's valuation into court. That money being in court, the sheriff withdraws. After seizure the sheriff must retain possession, and, in default of payment by the execution debtor, proceed to sell. Where the judgment debt, including legal expenses, exceeds £20, the sale must be by public auction, unless the court otherwise orders, and must be publicly advertised. The proceeds of sale, after deduction of the sheriff's fees and expenses, become the property of the execution creditor to the extent of his claim.

Under the law of bankruptcy, the sheriff, in case of sale under a judgment for a sum exceeding £20, is required to hold the proceeds for 14 days in case notice of bankruptcy proceedings should be served upon him. (*See* BANKRUPTCY.) Imprisonment for debt in execution of civil judgment was abolished except in cases of default in the nature of contempt, unsatisfied by judgments for penalties, defaults by persons in a fiduciary character and defaults by judgment debtors.

Writ of Elegit.—The writ of elegit is a process enabling the creditor to satisfy his judgment debt out of the lands of the debtor. It derives its name from the election of the creditor in favour of this mode of recovery. It is founded on the Statute of Westminster (1285, 13 Ed. I. c. 18), under which the sheriff was required to deliver to the creditor all the chattels (except oxen and beasts of the plow) and *half* the lands of the debtor until the debt was satisfied. By the Judgments act, 1838, the remedy was extended to *all* the debtor's lands, and by the Bankruptcy act, 1883 (now replaced by the Bankruptcy act, 1914), the writ no longer extends to the debtor's goods. The writ is enforceable against legal interests whether in possession or remainder but not against equitable interests in land. When the debtor's interest is equitable recourse is had to equitable execution by the appointment of a receiver or to bankruptcy proceedings. (*See* R.S.C., O. 43.)

Writs of Possession and Delivery.—Judgments for the recovery or for the delivery of the possession of land are enforceable by writ of possession. The recovery of specific chattels is obtained by writ of delivery (R.S.C., O. 47, 48).

Writ of Sequestration.—Where a judgment directing the payment of money into court, or the performance by the defendant of any act within a limited time, has not been complied with, or where a corporation has wilfully disobeyed a judgment, a writ of sequestration is issued, to not less than four sequestrators, ordering them to enter upon the real estate of the party in default, and to "sequester" the rents and profits until the judgment has been obeyed (R.S.C., O. 43, r. 6).

Equitable Execution.—Where a judgment creditor is otherwise unable to reach the property of his debtor he may obtain equitable execution, usually by the appointment of a receiver, who collects the rents and profits of the debtor's land for the benefit of the creditor (R.S.C., O. 1, rr. 15A–22). But receivers may be appointed of interests in personal property belonging to the debtor by virtue of the Judicature act, 1873, s. 25 (8). The plaintiff may apply ex parte for leave to issue a summons for the appointment of a receiver and for an injunction to restrain the defendant from parting with his property pending the hearing of the summons. Such an application may be heard by a master.

Attachment.—A judgment creditor may "attach" debts due by third parties to his debtor by what are known as garnishee proceedings. A garnishee order *nisi* may be made by a master of the queen's bench on the application of the judgment creditor. It must be supported by an affidavit in which the judgment creditor or his solicitor swears positively that there is a debt owing by the garnishee to the judgment debtor—a *debitum in praesenti*, which may however be *solvendum in futuro*. Enormous sums of money are "garnisheed" in the course of the year to answer judgments from the queen's bench division. Stock and shares belonging to a judgment debtor may be charged by a charging order, so as, in the first instance, to prevent transfer of the stock or payment of the dividends, and ultimately to enable the judgment creditor to realize his charge. A writ of attachment of the person of a defaulting debtor or party may be obtained in a variety of cases akin to contempt (*e.g.*, against a person failing to comply with an order to answer interrogatories, or against a solicitor not entering an appearance in an action, in breach of his written undertaking to do so), and in the cases where imprisonment for debt is still preserved by the Debtors act, 1869 (R.S.C., O. xliv). Contempt of court (*q.v.*) in its ordinary forms is also punishable by summary committal.

Another form of execution analogous to the attachment of a debt is a charging order. This directs that any stock, funds or shares of a public company in England, standing in the name of a debtor in his own right or in the name of any person in his trust for him, shall stand charged with the payment of the judgment debt and interest. The charge cannot be enforced for six calendar months after the order (O. 46, r. 1).

Interpleader.—This in English law is the form of action by which a person, who is sued at law by two or more parties claiming adversely to each other for the recovery of money or goods wherein he has no interest, obtains relief by procuring the rival claimants to try their rights between or among themselves only. Originally the only relief available to the possessor against such adverse claims was by means of a bill of interpleader in equity. The Interpleader act, 1831, enabled the defendant in such cases, on application to the court, to have the original action stayed and converted into a trial between the two claimants. The Common Law Procedure act of 1860 further extended the power of the common-law courts in interpleader; and the Judicature act, 1875 (repealed and re-enacted by the Judicature act, 1925), provides that the practice and procedure under these two statutes should apply to all divisions of the high court of justice. The Judicature act also extended the remedy of interpleader to a debtor or other person liable in respect of a debt alleged to be assigned, when the assignment was disputed. In 1883 the acts of 1831 and 1860 were embodied in the form of rules by the Rules of the Supreme Court (1883), O. 47, by reference to which all questions of interpleader in the high court of justice are now determined. Interpleader is the equivalent of multiplepoinding in Scots law.

Costs.—When giving judgment in England, the judge usually deals with the costs of the action, as to which he has an absolute discretion, although it must, of course, be exercised judicially. The term "costs" denotes the expenses incurred (1) in employing a lawyer in his professional capacity for purposes other than

litigation; (2) in instituting and carrying on litigation whether with or without the aid of a lawyer.

The retainer of a solicitor implies a contract to pay to him his proper charges and disbursements with respect to the work done by him as a solicitor. In cases of conveyancing his remuneration is for the most part regulated by scales ad valorem on the value of the property dealt with (Solicitors' Remuneration order, 1882), and clients are free to make written agreements for the conduct of any class of nonlitigious business, fixing the costs by a percentage on the value of the amount involved. So far as litigious business is concerned, the arrangement known as "no cure no pay" is objected to by the courts and the profession as leading to speculative actions, and stipulations as to a share of the proceeds of a successful action are champertous and illegal. An English solicitor's bill drawn in the old form is a voluminous itemized narrative of every act done by him in the cause or matter with a charge set against each entry and often against each letter written. Before the solicitor can recover from his client the amount of his charges, he must deliver a signed bill of costs and wait a month before suing.

The high court has a threefold jurisdiction to deal with solicitors' costs: (1) by virtue of its jurisdiction over them as its officers; (2) statutory, under the Solicitors act, 1843, and other legislation; (3) ordinary, to ascertain the reasonableness of charges made the subject of a claim.

The client can, as a matter of course, get an order for taxation within a month of the delivery of the solicitor's bill, and either client or solicitor can get such an order as of course within 12 months of delivery. After expiry of that time the court may order taxation if the special circumstances call for it, and even so late as up to 12 months after actual payment.

Costs as between solicitor and client are taxed in the same office as litigious costs, and objections to the decisions of the taxing officer, if properly made, can be taken for review to a judge of the high court and to the court of appeal.

The expenses of litigation fall in the first instance on the person who undertakes the proceedings or retains and employs the lawyer. It is in accordance with the ordinary ideas of justice that the expenses of the successful party to litigation should be defrayed by the unsuccessful party, a notion expressed in the phrase "costs follow the event." But there are many special circumstances which interfere to modify the application of this rule. The action, though successful, may be in its nature frivolous or vexatious, or it may have been brought in a higher court where a lower court would have been competent to deal with it. On the other hand the defendant, although he has escaped a judgment against him, may by his conduct have rendered the action necessary or otherwise justifiable. In such cases the rule that costs should follow the event would be felt to work an injustice, and exceptions to its operation have therefore been devised. In the law of England the provisions as to litigious costs, though now simpler than of old, are still elaborate and complicated, and the costs themselves are on a higher scale than is known in most other countries.

Except as regards appeals to the house of lords and suits in equity, the right to recover costs from the opposite party in litigation has always depended on statute law or on rules made under statutory authority. "Costs are the creature of statute." The house of lords has declared its competence to grant costs on appeals independently of statute.

In the judicial committee of the privy council the power to award, in its discretion, costs on appeals from the colonies or other matters referred to it is given by s. 15 of the Judicial Committee act, 1833; and the costs are taxed by the registrar of the council.

The general rule now in force in the supreme court of judicature is as follows: "Subject to the provisions of the Judicature Acts and the rules of the court made thereunder, . . . the costs of and incident to all proceedings in the Supreme Court, including the administration of estates and trusts, shall be in the discretion of the court or judge. . . . Provided (1) that nothing herein contained shall deprive an executor, administrator, trustee or mortgagee who has not unreasonably instituted, carried on or resisted any proceedings of any right to costs out of a particular estate or fund to which he would be entitled under the rules hitherto . . . acted upon in the chancery division . . ."

The rule above stated applies to civil proceedings on the crown side of the queen's bench division, including mandamus, prohibition quo warranto and certiorari (*R.* v. *Woodhouse,* 1906, 2 K.B. 502, 540); and to proceedings on the revenue side of that division (O. 68, r. 1); but it does not apply to criminal proceedings in the high court, which are regulated by the crown office rules of 1906, or by statutes dealing with particular breaches of the law, and as to procedure in taxing costs by O. 65, r. 27, of the Rules of the Supreme Court.

The rule is also subject to specific provision empowering the courts to limit the costs to be adjudged against the unsuccessful party in proceedings in the high court, which could and should have been instituted in a county court (*e.g.,* actions of contract under £100 or actions of tort in which less than £10 is recovered), unless the plaintiff, claiming a liquidated sum, has taken proceedings under O. 14 in the high court, in which case he *may* get high court costs if he recovers more than £20.

Costs of interlocutory proceedings in the course of a litigation are sometimes said to be "costs in the cause"; that is, they abide the results of the principal issue. A party succeeding in interlocutory proceedings, and paying the costs therein made "costs in the cause," would recover the amount of such costs if he had a judgment for costs on the result of the whole trial, but not otherwise. But it is usual now not to tax the costs of interlocutory proceedings till after final judgment.

When an order to pay the costs of litigation is made the costs are taxed in the central office of the high court, unless the court when making the order fixes the amount to be paid (R.S.C., O. 65, r. 23).

The taxation is effected, under an elaborate set of regulations, by reference to the prescribed scales, and on what is known as the lower scale, unless the court has specially ordered taxation on the higher scale (R.S.C., O. 65, rr. 8, 9, appendix N).

In the taxation of litigious costs two methods are still adopted, known as "between party and party" and "between solicitor and client." Unless a special order is made the first of the two methods is adopted. Formerly "party and party" costs were found to be a very imperfect indemnity to the successful litigant, because many items which his solicitor would be entitled to charge against him for the purposes of the litigation were not recoverable from his unsuccessful opponent. The high court can, in exercise of the equitable jurisdiction derived from the court of chancery, make orders on the losing party to pay the costs of the winner as between solicitor and client. These orders are not often made except in the chancery division. But even where party and party costs only are ordered to be paid under the present practice (dating from 1902), the taxing office allows against the unsuccessful party all costs, charges and expenses necessary or proper for the attainment of justice or defending the rights of the successful party, but not costs incurred through overcaution, negligence or by paying special fees to counsel or special fees to witnesses or other persons, or by any other unusual expenses (R.S.C., O. 65, rr. 27, 29). This practice tends to give an approximate indemnity, while preventing oppression of the losing party by making him pay for lavish expenditure by his opponent. The taxation is subject to review by a judge on formal objections carried on, and an appeal lies to the Court of Appeal.

Cost of Litigation.—Complaint is often made of the cost of litigation. It is important to notice, however, that the losing party to a suit who is condemned in costs need pay only the amount allowed on taxation. Counsel may have 1,000 guineas on his brief; but the taxing master may afterward determine that "the other side" shall pay only one-tenth of that fee. What he pays his own solicitor is the litigant's own concern, but, subject to this, a client can always ask to have his solicitor's bill taxed. An examination of a number of bills of costs which one or other of the parties to a suit has been ordered to pay (subject to taxation) shows that the larger items are counsel's fees, fees to expert wit-

nesses, expenses of witnesses and (in some cases) the cost of copying documents. So far as the solicitor is concerned, these are all out-of-pocket items. The solicitor's own charges may, of course, be considerable if the preparation of the case has involved a large number of interviews and the examination of many documents, but in the average case the principal item is preparing the brief. The actual court fees are trifling; as regards fees to counsel, it must be observed that, subject to the rule that he must never act without a minimum fee of one guinea, a member of the bar is free to demand what he pleases, and to all intents the whole bar is open to the litigant. Similarly an expert witness may name his own fee. Unless (1) counsel and experts be compelled to act for less than what they consider a living wage, (2) the rule which provides that evidence shall be given *orally* is altered and (3) litigation can be conducted without copies of all relevant documents for the use of counsel and the judge, it is difficult to see how costs can be reduced. It is well to remember, too, that in many a heavy case which occupies the time of a judge for a considerable period, the costs of all parties are slight when compared with the amount at stake in the suit.

(*See* ADMIRALTY, HIGH COURT OF; APPEAL; ARBITRATION; COUNTY COURT; EVIDENCE.) (W. V. B.)

UNITED STATES

The practice and procedure of the courts in the various jurisdictions of the United States was originally derived from the English common-law system of court administration. But since each state or territory, and the federal government, also, now has its own system of courts and its own procedure, a considerable diversity exists. In general, a reform of the common-law procedure has occurred in many ways similar to the English reforms of the 19th century. The extent of the reform varies in the different jurisdictions. The most far-reaching change was that of the so-called code reform of procedure inaugurated by the code of civil procedure adopted in New York in 1848 and (by the early 1950s) in force in 32 U.S. states and territories and the federal system. A later reform was that of the Federal Rules of Civil Procedure, adopted in the United States courts in 1938 and copied in many of the states, as noted below.

The Code Reform.—In 1847 the New York legislature instructed a commission "to provide for the abolition of the present forms of actions and pleadings in cases at common law; for a uniform course of proceeding in all cases whether of legal or equitable cognizance, and for the abandonment of all Latin and other foreign tongues, so far as the same shall by them be deemed practicable, and of any form and proceeding not necessary to ascertain or preserve the rights of the parties" (N.Y. laws, 1847, C. 59, § 8). During the following year the commission reported a code which was adopted on April 12, 1848. This measure, which served as the model for other codes in the United States, was largely the work of David Dudley Field, a member of the commission. It is often called the "Field code."

The chief characteristic and most fundamental part of the code is its single form of action for all cases. The distinctions of the common-law actions and of their forms were abolished; the separation in procedure of equitable from legal relief was abandoned. As a substitute, the codifiers planned a blended system of law and equity with only one form of action to be known as the *civil action.* In effect, this is the same step taken in England a generation later in the Supreme Court of Judicature act (1873). The full benefits of this reform were not attained in all the states, for many courts considered the ancient forms of action to rest upon distinctions fundamental in the law. Furthermore, some courts took a hostile attitude toward the attempted union of actions at law and suits in equity. Here the history and tradition of the separate systems of law and equity proved strong obstacles to a complete amalgamation. It has therefore often been held that the theory of the action, whether legal or equitable, must be pointed out in the pleadings. In fact, however, the difference between law and equity actions is chiefly in the remedy to be granted and this should not be an objection to the single action or the simpler forms of pleading.

Perhaps the obstacle which has seemed greatest to the courts in preventing a complete union of law and equity is the requirement common to the state constitutions that the right of trial by jury shall remain inviolate. This is construed to mean a preservation of the jury trial right substantially as it was at the time of the original adoption of the constitutions. In view of the historical practice of jury trials in courts of law, this means in effect that in modern substitutes for action at law, jury trial is a matter of right, while in equitable claims no such right exists. Some courts in protecting the constitutional right continue to force a division of all actions into "law actions" and "equity actions." A more convenient rule and one more in keeping with the code principle is followed in many states, where the question of the form of trial is not allowed to affect the pleading in advance of the trial. If an issue arises at the trial as to the existence of a right to jury trial in either party, it is then determined by the nature of the issues developed in the pleadings in the light of the historical method of trying such issues.

Another important characteristic of the code is its emphasis upon pleading facts, not conclusions of law or evidence. *Fact pleading* was substituted for the *issue pleading* of the common law. This part of the code reform has been comparatively unsuccessful, because no clear line of demarcation exists between statements of fact and statements of law. An additional change wrought by the code was the adoption of the equity principles of greater freedom of joining parties and of rendering judgments in part for or against the various parties, as the justice of the case may require (the *split judgment* of equity). In spite of the fact that the code reform has not met with the same degree of success in all the states, it seems in general to have been in accord with the desires of the people for simpler judicial procedure. Modern plans for further reform are all in the direction of a greater simplification of practice.

Federal Rules of Civil Procedure.—These plans found realistic embodiment in the Federal Rules of Civil Procedure, adopted by the supreme court of the United States for regulation of the practice in the United States district courts. The rules represent the culmination of a long struggle for reform in the federal system carried on by leaders of the bar. Traditionally the procedure in these trial courts had been divided, although a single judge sat in both law and equity cases. In equity the practice was uniform in the many district courts under rules promulgated by the supreme court. But on the law side each district court was supposed to conform to the practice at law in the courts of the state where it was sitting, subject, however, to a considerable and constantly increasing number of congressional statutes dealing with specific procedural details. The resulting hodgepodge had led the American Bar association to press with vigour from 1912 on for the grant of complete rule-making authority to the supreme court, so that a single uniform system might be developed. Legislation was not forthcoming for several years, however, because of long opposition from senators convinced of the need of preserving their local practice. At length, upon adoption of the Rule-Making act on June 19, 1934 (now 28 U.S.C., § 2072, as amended), the supreme court appointed an advisory committee of lawyers and law teachers to consider and present a draft of rules. The committee consulted extensively with members of the bar and bench and teachers in the law schools and, after the publication and revision of preliminary drafts, made its final report, which the court accepted in 1937. After the set of rules was reported to and lay before congress for a full session, as required by the statute, they became effective on Sept. 16, 1938. The committee remained in office, recommending amendments from time to time, of which those effective March 19, 1948, brought the rules extensively down to date, and that effective Aug. 1, 1951, added a complete rule governing the taking of property by eminent domain (Rule 71A, Condemnation of Property).

This system, both in the manner of its adoption—upon report of a court-appointed drafting committee—and in the substance of the procedure set forth, became a model for reform generally throughout the states. The directly imitating states are noted below; but there is hardly a state which has not been affected by

the movement in some degree or at least had its bar fired with zeal for thoroughgoing reform. The system was designed to employ all the best features of English and U.S. state practice acts or codes, and it is generally regarded as materially ensuring simple, flexible and effective court administration.

State of Pleading.—It has been customary to classify the U.S. states as "code" or "noncode," depending upon whether they have adopted the Field code or not. Since the federal rules represented in essence an advanced and refined stage of code pleading, the distinction still had validity thereafter, although the lines of demarcation became more blurred. The system inaugurated in New York in 1848 had by mid-20th century been adopted in the following jurisdictions: Alaska (1900); Arizona (1864); Arkansas (1868); California (1850); Colorado (1877); Connecticut (1879); Illinois (1934); Indiana (1852); Iowa (1851); Idaho (1864); Kansas (1859); Kentucky (1851); Minnesota (1851); Missouri (1849); Montana (1865); Nebraska (1855); Nevada (1860); New Jersey (1948); New Mexico (1897); New York (1848); North Carolina (1868); North Dakota (1862); Ohio (1853); Oklahoma (1890); Oregon (1854); Puerto Rico (1904); South Carolina (1870); South Dakota (1862); Utah (1870); Washington (1854); Wyoming (1869); Wisconsin (1856); and the United States—a total of 30 states, 2 territories and the vast federal system, consisting of 86 district courts having exclusive federal jurisdiction and the courts of the District of Columbia, Alaska and Guam. In Arkansas, Iowa, Kentucky and Oregon a formal distinction between actions at law and suits in equity, and in Illinois a formal labelling, is still maintained, though the same judges hear both in the same courts.

The federal rules, as applicable in the United States courts, were also fully adopted in the following jurisdictions: Alaska (1949); Arizona (1940); Colorado (1941); Minnesota (1952); New Jersey (1948); New Mexico (1942); Puerto Rico (1943); Utah (1950); and Delaware (1948) for the courts of law only. Beyond this they have been followed extensively, although not completely, in revisions of practice in Florida (1950), Iowa (1943), Missouri (1944) and Texas (1941); while at various intervals specific sections have been adopted in Maryland, New York, Pennsylvania, South Dakota and Washington, and individual rules in California, Connecticut and North Dakota. An occasional rule, notably Federal Rule 16, authorizing the holding of pretrial conferences by the judge, has been adopted yet more widely. In Nebraska, where the rules were adopted in 1943, they were immediately repealed by the state legislature—a unique experience matched only by the action of Florida in first adopting (1870) and then repudiating (1873) code pleading in the hectic reconstruction days following the American Civil War.

Of the above jurisdictions Delaware, Florida, Maryland, Pennsylvania and Texas have not been traditionally viewed as code states; but their approach to the federal system makes them at least "quasi code" states, a somewhat vague classification indicating considerable resemblance to the code system, in which should certainly be included Massachusetts and Michigan. States which had adopted the federal pretrial rule by mid-century included New Hampshire, Virginia and West Virginia. A partial revision of procedure in Virginia in 1950 did not follow the federal model, although an extensive motion practice, in lieu of a formal complaint and answer, tended toward modern adaptability. So, too, the Georgia practice has long had a considerable flexibility; and the Louisiana code of practice, based upon the civil law of that state, has naturally a lessened emphasis upon formal pleading. Less trace of the modern approach appears in Alabama, Maine, Mississippi, Rhode Island and Tennessee, although these can hardly be termed "common-law" jurisdictions. For the ancient practice has been ameliorated in many ways, such as the breaking down of the old distinctions between law and equity, by the pleading of "equitable defenses" in "actions at law" and the free transfer of cases from one side to the other of the court, and by the blotting out or broadening of the former forms of action. True, the surface diversity thus shown among U.S. jurisdictions is accentuated by such barriers as the localization of the bar, so that an attorney of one state cannot appear as counsel in the courts of another state except by special permission requested of and granted by the court for the limited occasion. Underneath, however, is a substantial similarity of objective which could be more easily and fully achieved by uniform rules identically followed throughout the union. Wide state adoption of the federal rules is an obviously desirable trend toward such uniformity.

Course of Proceedings in a Civil Action.—Notice to the defendant at the institution of suit and an opportunity to present his side of the case are essential to the U.S., as to any, system of justice. In many of the states (some of which have adopted the code procedure), the traditional practice of issuing a writ in the name of the state directing the sheriff to make the summons is followed. In others, however, the writ of the sovereign is supplanted by a simple written summons to appear, signed by the plaintiff or his attorney and served upon the defendant by anyone not a party—usually by a clerk in the office of the plaintiff's attorney. Even in these jurisdictions, when the plaintiff claims some extraordinary or provisional remedy, such as attachment of the defendant's property, arrest of the defendant or an injunction, notice is given in the form of a court order served by some public officer, such as the sheriff. It is necessary that proper *service* of the summons be had, for unless the defendant is legally notified of the action, no *jurisdiction* is acquired over his person. Moreover, unless the action is brought to the proper court, *jurisdiction over the subject matter* does not exist. Next come the pleadings, the first step being the filing by the plaintiff of his *complaint* or *petition* (the *declaration* or *count* of the common law). This contains the names of the parties and the court, a statement of the facts constituting the plaintiff's cause of action and a demand for the judgment to which he thinks himself entitled. The complaint is served upon the defendant with the summons or after the parties are in court or else is supplied to the defendant by the court clerk. If the defendant desires to defend, his first move is to enter an *appearance*, which may be done, without his presence in court, by a written notice of appearance by his attorney or by filing an *answer* to the complaint. By *demurring*, the defendant may question the legal sufficiency of the complaint. But if the demurrer is abolished, as in Illinois and New York, he moves for judgment and thus raises the same issue. In the defendant's answer he may deny the plaintiff's allegations or he may admit them and allege new matter in his defense or as a basis for a *counterclaim* against the plaintiff. To this the plaintiff under most codes may file a *reply* (corresponding to the common-law *replication*), and at this stage the pleadings are generally required by the statute to come to an end. Thereafter follows the actual trial with the production of evidence by the parties, followed by the verdict, if a jury is present, and judgment. If the defeated party so desires he may then take an appeal to some appellate tribunal. (*See* APPEAL: *In the United States.*) When the judgment is finally effective, extensive proceedings are available to secure its enforcement.

The new federal system followed this same course in substance, but with some change of emphasis from formal pleadings of fact to short and succinct statements of claim or defense, ending usually with the answer or, in any event, with a reply to a counterclaim. The old demurrer was abolished and objections may be presented either by answer or by a motion, including a motion for summary judgment, supported by affidavits or depositions on the merits. Stress is placed on reaching the merits quickly, rather than on form. Hence, that each party may be thoroughly apprised of all elements of the case at once and may thus prepare his case completely in advance of trial, there is an extensive system of discovery by the taking of depositions, submission of interrogatories, requests for admission and the production of documents and so on. Wide adoption of the optional provision for pretrial conference, settling the issues and dispensing with formalities of proof of detail, adds to this sense of full preparation and often facilitates settlements. There is practically complete freedom of joinder of actions, both of parties and of causes, as well as of counterclaims. New parties may be summoned in or impleaded to answer claims developed in the case. Provisions governing trials, including waiver of jury trial by failure to make seasonable claim therefor, simplifying the appeals and abolishing the noting of formal excep-

tions and other like restrictions, round out the system. This is often supported by an accompanying movement, also supported by the American Bar association, for improved court structure and administration, of which the main feature is a unified court, sitting in various divisions as required, under a single administrative control headed by the chief justice, assisted by an administrative director.

Criminal Procedure.—Here again the English practice is the source. Indictment by a grand jury is still an essential step in a criminal prosecution in many jurisdictions for capital and many other serious crimes. This body varies in number in the different jurisdictions but usually consists of not less than 12 and not more than 23 persons, at least 12 of whom must concur in presenting an indictment. It may act upon its own knowledge, upon an information of the prosecutor or upon a complaint made under oath by a private person before a committing magistrate. The indictment, which is usually prepared beforehand by the prosecutor and given to the grand jury for its consideration, serves as the prosecution's complaint at the trial. A number of technical rules apply to the indictment, making criminal procedure very rigid. Thus, in many jurisdictions unless the indictment describes the offense with great particularity, including its time and place of occurrence and the accused's name, it may be quashed. Such technicalities are a relic of ancient common-law times when the accused was favoured because of the serious penalties imposed for minor offenses. But as the reason for these rules is now gone, authorities today advocate a procedure requiring only that reasonable notice of the ground of complaint be given the accused. In a considerable number of states an information by the prosecutor was substituted for the indictment by the grand jury. An information suffices in the federal courts except in offenses punishable by more than one year's imprisonment. Trial by jury is usually a constitutional guarantee except in minor offenses. But in Maryland and Connecticut the accused may elect a trial to the court if he so chooses. The American Law institute, an organization of judges, lawyers and law teachers with headquarters in Philadelphia, Pa., recommended an advanced and simplified Model Code of Criminal Procedure (1931), which has been adopted in some states, as substantially in Connecticut in its pleading aspects as early as 1929. More lately the supreme court, under statutory authority and following its plan of drafting first employed as to the civil rules, adopted the report of its Advisory Committee on Rules of Criminal Procedure recommending the Federal Rules of Criminal Procedure, which became effective throughout the federal system on March 21, 1946. (*See* ADMIRALTY JURISDICTION; APPEAL; ARBITRATION; CRIMINAL LAW; EVIDENCE; JUDICIAL REFORM; PROBATE; SUPREME COURT OF THE UNITED STATES.)

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PRADIER, JAMES (1792–1852), French sculptor, was born at Geneva, Switz. He was a member of the French academy, and a popular sculptor of the preromantic period, representing in France the drawing-room classicism which Antonio Canova illustrated at Rome. His chief works are the Niobe group (1822), "Atalanta" (1850), "Psyche" (1824), "Sappho" (1852) (all in the Louvre), "Prometheus" (Tuileries Gardens), a bas-relief on the triumphal arch of the Carrousel, the figures of "Fame" on the Arc de l'Etoile and a statue of J. J. Rousseau for Geneva. Besides the above-noted works mention should be made of his "Three Graces" (1821).

PRADILLA, FRANCISCO (1848–1921), Spanish painter, was born at Villanueva da Gallago (Saragossa). He studied first at the Fernando academy and then at the Spanish academy in Rome, of which he was afterward director, and became the leading historical painter of modern Spain. In 1896 he was appointed director of the Madrid museum. Though he is best known for such large historical compositions as "Joan the Mad" (gold medal, Paris, 1878) and "The Surrender of Granada" (gold medal, Munich, 1883), in which he discarded the heavy colouring of Laurens for a lighter and more atmospheric key, he has painted many excellent genre pictures in the manner of M. J. M. B. Fortuny, and some decorative compositions in which he follows the example of G. B. Tiepolo. The best of these are his decorations in the Murgo palace in Madrid. Among his best-known works are "Elopement," "Strand at Vigo," "Procession in Venice," "La Fiorella," "Reading on the Balcony," "Don Alfonso the Warrior" and "Don Alfonso the Scholar." He became a member of the Berlin academy and died in Madrid on Oct. 30, 1921.

PRAED, WINTHROP MACKWORTH (1802–1839), English poet, was born in London on July 26, 1802, son of William Mackworth Praed, sergeant-at-law. His mother belonged to the New England family of Winthrop. At Eton Praed founded a manuscript periodical *Apis matina*, which was followed by the *Etonian* (1820–21). After a brilliant career at Trinity college, Cambridge, he joined the Middle Temple, was called to the bar in 1829, and went to the Norfolk circuit. However, he was inclined toward politics, and after a year or two he devoted himself entirely to political life. While at Cambridge he leaned to Whiggism, and even to the autumn of 1829 his feelings were bent toward the same side; but during the agitation for parliamentary reform his opinions changed, and when he was returned to parliament for St. Germans (Dec. 17, 1830) he was supported by the Tory party. He sat for that borough until Dec. 1832, and on its extinction contested the borough of St. Ives, the Cornish estates of the Praeds being within the borough limits. The squibs which he wrote on this occasion were collected in a volume printed at Penzance in 1833 entitled *Trash, Dedicated without Respect to James Halse, Esq., M.P.*, his successful competitor. Praed sat for Great Yarmouth from 1835 to 1837, and was secretary to the board of control during Sir Robert Peel's short administration. He sat for Aylesbury from 1837 until his death.

During the progress of the Reform bill he advocated the creation of three-cornered constituencies, in which each voter should have the power of giving two votes only, and maintained that freeholds within boroughs should confer votes for the boroughs and not for the county. Neither of these suggestions was then adopted, but the former ultimately formed part of the Reform bill of 1866. He died on July 15, 1839, in London.

Praed's lighter poetry was the perfection of ease. Austin Dobson praised his "sparkling wit, the clearness and finish of his style, and the flexibility and unflagging vivacity of his rhythm" (Ward's *English Poets*). It abounded in happy allusions to the characters and follies of the day. His humorous verse found numerous imitators.

His poems were first edited by R. W. Griswold (1844); another U.S. edition, by W. A. Whitmore, appeared in 1859; an authorized edition with a memoir by Derwent Coleridge appeared in 1864; *The Political and Occasional Poems of W. M. Praed* (1888).

PRAEFECT, the title of various Roman officials, civil and military (*praefectus*). A praefect was not a magistrate proper; he was the deputy of a superior magistrate.

City Praefect.—The city praefect (*praefectus urbis*) acted at Rome as the deputy of the chief magistrate or magistrates during his or their absence from the city. He represented the consul or consuls when he or they were absent on a campaign or on other public duties, such as the celebration of the annual Latin festival on the Alban Mount. The absence of all the chief

magistrates for more than a single day rendered the appointment of a praefect obligatory; after the institution of the praetorship (367 B.C.) the necessity only arose exceptionally, as it rarely happened that both the consuls and the praetor were absent simultaneously. But a praefect was appointed during the enforced absence of all the higher magistrates at the Latin festival. The right of appointing a praefect belonged to the magistrate whose deputy he was. No formalities in the appointment and no legal qualifications on the part of the praefect were required. The praefect had all the powers of the magistrate whose deputy he was, but his office expired on the return of his superior.

Under the empire a new city prefecture was introduced. Augustus occasionally appointed a city praefect to represent him in his absence from Italy, although the praetors, or even consuls, remained in the capital. In the absence of Tiberius at Capreae during the last 11 years of his reign (A.D. 26–37), the city prefecture, hitherto temporary, became a permanent magistracy; henceforth the praefect held office even during the presence of the emperor in Rome. He was chosen by the emperor; his office might be held for years or for life. The praefect was not allowed to quit the city for more than a day at a time. His duty was the preservation of peace in the capital; he was, in fact, the chief of the police, with the superintendence of the streets, markets and public buildings. He was entrusted by Augustus with a summary criminal jurisdiction over slaves and rioters, which was gradually extended until it embraced all offences by whomsoever committed. In the 3rd century A.D., appeals to the emperor in civil cases were handed over to the praefect. An appeal lay from the praefect to the emperor. The praefect commanded the city cohorts (*cohortes urbanae*), which formed part of the garrison of Rome and ranked above the line regiments, though below the guards (*see* PRAETORIANS). The military power thus placed in the hands of the chief of the police was one of the most sorely-felt innovations of the empire. The changes of Diocletian and Constantine extended the power of the praefect, in whom, after the removal from Rome of the highest officials, the whole military, administrative and judicial powers were centred.

Judicial Praefects.—Under the republic judicial praefects (*praefecti iuri dicendo*) were sent annually from Rome as deputies of the praetors to administer justice in certain towns of the Italian allies. These towns were called prefectures (*praefecturae*). After the social war (90–89 B.C.), when all Italy had received the Roman franchise, such prefectures ceased to exist.

Praetorian Praefects.—Under the empire the praetorians or imperial guards were commanded by praefects (*praefecti praetorio*), who were chosen by the emperor and held office at his pleasure. In course of time the command seems to have been enlarged so as to include all the troops in Italy except the corps commanded by the city praefect (*cohortes urbanae*). Further, the praetorian praefect acquired a criminal jurisdiction which he exercised as the representative of the emperor. A similar jurisdiction in civil cases was acquired by him not later than the time of Severus. Hence a knowledge of law became a qualification for the post, which was held by the first jurists of the age (*e.g.*, Papinian), while the military qualification fell into the background. Under Constantine the institution of the *magistri militum* deprived the praetorian prefecture of its military character, but left it the highest civil office of the empire.

Various Other Praefects.—The title of "praefect" was borne by various other Roman officials, of whom we may mention the following:—

(1) *Praefectus Aegypti* (afterwards *Praefectus augustalis*).—The government of Egypt was entrusted to a viceroy with the title of "praefect" and was surrounded by royal pomp instead of the usual insignia of a Roman magistrate. He was under the immediate orders of the emperor. The exceptional position thus accorded to Egypt was due to its peculiar character and status as an imperial domain and to its very high importance as the granary of Rome.

(2) *Praefectus Vigilum*, the commander of the *cohortes vigilum*, a night police force instituted by Augustus (A.D. 6). One of the principal duties of this force was that of serving as a fire brigade. The *praefectus vigilum* besides commanding the *cohortes vigilum* exercised criminal jurisdiction in cases of incendiarism and offences committed during the night.

BIBLIOGRAPHY.—The different praefects are fully discussed in Mommsen, *Römisches Staatsrecht* (1887), vols. II., III.; *see* also T. M. Taylor, *Constitutional and Political History of Rome* (1899); A. H. J. Greenidge, *Roman Public Life* (1901); J. E. Sandys, *Companion to Latin Studies* (1921).

For the French *préfet see* PREFECT.

PRAEMUNIRE, in English law an offence so called from the introductory words of the writ of summons issued to the defendant to answer the charge, "Praemunire facias A.B.," etc., *i.e.*, "cause A.B. to be forewarned." From this the word came to be used to denote the offences, usually ecclesiastical, prosecuted by means of such a writ, and also the penalties they incurred. From the beginning of the 14th century papal aggression had been particularly active, more especially in two forms. The one, the disposal of ecclesiastical benefices, before the same became vacant, to men of the pope's own choosing; the other, the encouragement of resort to himself and his curia rather than to the courts of the country. The Statute of Provisors (1306), passed in the reign of Edward I., was, according to Coke, the foundation of all subsequent statutes of praemunire. This statute enacted "that no tax imposed by any religious persons should be sent out of the country whether under the name of rent, tallage, tribute or any kind of imposition." A much greater check on the freedom of action of the popes was imposed by the Statute of Provisors (1350–51) and the Statute of Praemunire passed in the reign of Edward III. The former ordained the free election of all dignities and benefices elective in the manner as they were granted by the king's progenitors. The Statute of Praemunire (the first statute so called), 1353, enacts "that all the people of the king's ligeance of what condition that they be, which shall draw any out of the realm in plea" or any matter of which the cognizance properly belongs to the king's court shall be allowed two months in which to answer for their contempt of the king's rights in transferring their pleas abroad. Many other statutes followed that of 1353, but that passed in the 16th year of Richard II.'s reign is usually referred to as *the* Statute of Praemunire. The Royal Marriage Act, 1772, is the last which subjects anyone to the penalties of a praemunire. A peer charged with praemunire is not entitled to trial by his peers, but is to be tried by a jury. The most famous historical instance of a prosecution of the Statute of Praemunire was that of Cardinal Wolsey in 1529.

See E. Coke, *Institutes* (1628, etc.); J. Reeves, *History of English Law* (1783–84); H. Hallam, *Middle Ages* (1818); T. E. Tomlin, *Law Dictionary* (1838); H. J. Stephen, *Commentaries on the Laws of England* (1841–45); W. Stubbs, *Constitutional History* (1866); J. F. Stephen, *History of Criminal Law of England* (1883).

PRAENESTE (mod. Palestrina), a very ancient city of Latium, lies 23 m. E. of Rome by the Via Praenestina (*see* below), on a spur of the Apennines facing the Alban hills. To the natural strength of the place and its commanding situation Praeneste owed in large measure its historical importance. Objects in metal and ivory discovered in the earliest graves prove that as early as the 8th or 7th century B.C. Praeneste had reached a considerable degree of civilization and stood in commercial relations not only with Etruria but with the East. In 499 B.C., according to Livy, it formed an alliance with Rome. After Rome had been weakened by the Gallic invasion (390) Praeneste joined in a long struggle with Rome which culminated in the great Latin War (340–338), in which the Romans were victorious, and Praeneste was punished by the loss of part of its territory. It continued in the position of a city in alliance with Rome down to the Social War, when it received the Roman franchise.

As an allied city it furnished contingents to the Roman army and possessed the right of exile (*ius exilii*), *i.e.*, persons banished from Rome were allowed to reside at Praeneste. The nuts of Praeneste were famous and its roses were amongst the finest in Italy. The Latin spoken at Praeneste was somewhat peculiar, and was ridiculed by the Romans, *e.g.*, by Plautus. In the civil wars the younger Marius was blockaded in the town by the Sullans (82 B.C.); and on its capture Marius slew himself, the

male inhabitants were massacred in cold blood, and a military colony was settled on part of its territory, while the city was removed from the hill-side to the lower ground at the Madonna dell' Aquila, and the temple of Fortune enlarged so as to include the space occupied by the older city. Under the empire Praeneste, from its elevated situation and cool salubrious air, became a favourite summer resort of the wealthy Romans, whose villas studded the neighbourhood. Horace ranked it with Tibur and Baiae, though as a fact it never became so fashionable a residence as Tibur or the Alban hills. Still, Augustus resorted thither; here Tiberius recovered from a dangerous illness, and here Hadrian and Marcus Aurelius had villas. Amongst private owners were Pliny the younger and Symmachus.

But Praeneste was chiefly famed for its great temple of Fortune and for its oracle, in connection with the temple, known as the "Praenestine lots" (*sortes praenestinae*). The oldest portion of the sanctuary was, however, that situated on the lowest terrace but one. Here is a grotto in the natural rock, containing a beautiful coloured mosaic pavement, representing a sea-scene—a temple of Poseidon on the shore, with various fish swimming in the sea. To the east of this was a basilica in two storeys. As extended by Sulla the sanctuary of Fortune occupied a series of five vast terraces, which, resting on gigantic substructions of masonry and connected with each other by grand staircases, rose one above the other on the hill in the form of the side of a pyramid, crowned on the highest terrace by the small round temple of Fortune. This immense complex, probably by far the largest sanctuary in Italy, must have presented a most imposing aspect, visible as it was from a great part of Latium, from Rome, and even from the sea.

The modern town of Palestrina, a collection of narrow alleys, stands on the terraces once occupied by the temple of Fortune. On the summit of the hill (2,471 ft.), nearly a mile from the town, stood the ancient citadel, the site of which is now occupied by a few poor houses (Castel San Pietro) and a ruined mediaeval castle of the Colonna. Considerable portions of the southern wall of the ancient citadel, built in very massive Cyclopean masonry of blocks of limestone, are to be seen; and the two walls, also polygonal, which formerly united the citadel with the town, can be traced. The calendar set up by the grammarian M. Verrius Flaccus in the forum of Praeneste was discovered in 1771. Excavations made in the ancient necropolis, which lay on a plateau surrounded by valleys at the foot of the hill, have yielded important results for the history of the art and manufactures of Praeneste. The Ficorni casket, engraved with pictures of the arrival of the Argonauts in Bithynia and the victory of Pollux over Amycus, was found in 1738.

Most of the objects discovered in the necropolis are preserved in the Roman collections, especially in the Villa Giulia, the Museo Pigorini (Collegio Romano) and the Vatican.

See E. Fernique, *Préneste* (Bibliothèque des Écoles Françaises, *fasc.* 17, 1880); *Corp. inscr. etrusc.* vol. ii; R. S. Conway, *Italic Dialects*, i, 311 *seq.* (1897); T. Ashby in *Papers of the British School at Rome*, i, 132 *seq.*; H. C. Bradshaw, *ibid.* ix, 257 *seq.*; R. Delbrück, *Hellenistische Bauten in Latium*, p. 47 *seq.* (1907); R. van Deman Magoffin, *Topography and Municipal History of Praeneste* (Johns Hopkins University Studies, xxvi, 9, 10; Baltimore, 1908); D. Randall-MacIver, *Iron Age in Italy* (1927). (J. G. Fr.; R. S. Co.; T. A.)

PRAENESTINA, VIA, an ancient road of Italy, leading from Rome east by south to Praeneste, a distance of 23 mi., Gabii being situated almost exactly half-way. At the ninth mile the road crosses a ravine by the well-preserved and lofty Ponte di Nona, with seven arches, the finest ancient bridge in the neighbourhood of Rome. In the stretch, for a few miles beyond Gabii it is now only used as a track, and well preserved.

See T. Ashby in *Papers of the British School at Rome*, i, 149 *sqq.*

PRAESEPE, a loose star-cluster in the constellation Cancer having a "bee-hive" shape. It is a favourite object for telescopes of low power. The cluster is located at a distance from the sun of about 600 light-years.

PRAETOR, originally a military title (a leader; Lat. *prae . . . ire*), was the designation of the highest magistrates in the Latin towns.

Under the republic the Roman consuls were at first called praetors; by the Licinian law of 367 B.C., a new magistrate was created who was to be a colleague of the consuls, though with lesser powers. This new magistrate was entrusted with the jurisdiction in civil cases; in other respects his powers resembled those of the consuls. His title was the city praetor (*praetor urbanus*), and when the number of praetors was increased, the city praetor always ranked first. To this new magistrate the title of "praetor" was thenceforward restricted. About 242 B.C. the increase of a foreign population in Rome necessitated the creation of a second praetor for the decision of suits between foreigners (*peregrini*) or between citizens and foreigners (*praetor peregrinus*). About 227 two more praetors were added to administer the provinces of Sicily and Sardinia. The conquest of Spain occasioned the appointment of two more in 197. The number of praetors remained stationary until Sulla's time (82 B.C.). But in the interval their duties multiplied. On the one hand, five new provinces were added to the Roman dominions; on the other new and permanent jury courts (*quaestiones perpetuae*) were instituted at Rome, over which the praetors were called on to preside. To meet this increase of business the tenure of office of the praetors and also of the consuls was practically prolonged from one to two years, with the distinction that in their second year of office they bore the titles of propraetor and proconsul instead of praetor and consul. The prolongation of office formed the basis of Sulla's arrangements. He increased the number of the praetors from six to eight, and ordained that henceforward all the eight should in their first year administer justice at Rome and in their second should as propraetors undertake the government of provinces. The courts over which the praetors presided, in addition to those of the city praetor and the foreign praetor, dealt with the following offences: oppression of the provincials by governors (*repetundarum*), bribery (*ambitus*), embezzlement (*peculatus*), treason (*maiestatis*), murder (*de sicariis et veneficis*), and forgery (*falsi*). Later, more provinces were added and more courts constituted, including that of *Gallia Cisalpina*. Iulius Caesar increased the number of praetors.

The praetors were elected, like the consuls by the *comitia centuriata* (*see* Comitia) and with the same formalities. They held office for a year. The insignia of the praetor were those of the higher Roman magistrates—the purple-edged robe (*toga praetexta*) and the ivory chair (*sella curulis*); in Rome he was attended by two lictors, in the provinces by six. The praetors elect cast lots to determine the department which each of them should administer. A praetor as a civil judge at or before his entry on office published an edict setting forth the rules and law procedure by which he intended to be guided. These rules were often accepted by his successors, and corrected and amplified from year to year, became, under the title of the "perpetual" edicts, one of the most important factors in moulding Roman law. Their tendency was to smooth away the anomalies of the civil law by substituting rules of equity for the letter of the law.

Under the Empire.—Under the empire various special functions were assigned to certain praetors, such as the two treasury praetors (*praetores aerarii*), appointed by Augustus in 23 B.C.; the ward praetor (*praetor tutelaris*), appointed by Marcus Aurelius to deal with the affairs of minors; and the liberation praetor (*praetor de liberalibus causis*), who tried cases turning on the liberation of slaves. Of the praetorships with special jurisdiction (especially the ward praetorship and the liberation praetorship) some lasted into the 4th century and were copied in the constitution of Constantinople.

Besides their judicial functions, the praetors as colleagues of the consuls, possessed the consular powers, which they exercised in the absence of the consuls; but in the presence of a consul they exercised them only at the command either of the consul or the senate. (For the praetor as provincial governor *see* Province.)

Bibliography.—A full account of the praetorship will be found in Mommsen, *Römisches staatsrecht* (1887); T. M. Taylor's *Constitutional and Political History of Rome* (1899) will also be found useful. *See* also A. H. J. Greenidge, *Roman Public Life* (1901); J. E. Sandys, *Companion to Latin Studies* (1921); W. E. Heitland, *The Roman Republic* (1923).

PRAETORIANS. In the early Roman republic, *praetor* (*q.v.*) meant commander of the army: later *praetor* and *propraetor* were the usual titles for provincial governors with military powers. Accordingly, the general's quarters in a camp came to be called *praetorium*, and one of the gates *porta praetoria*, and the general's bodyguard *cohors praetoria*. Under the empire *cohortes praetoriae* formed the imperial bodyguard. This, as founded by Augustus, consisted of nine cohorts, each 1,000 strong, some part of which was always with the emperor, whether in Rome or elsewhere. Tiberius concentrated this force on the eastern edge of Rome in fortified barracks. The men were recruited voluntarily, in Italy or Italianized districts, and enjoyed better pay and shorter service than the regular army; they were commanded by *praefecti praetorio*. This force was the only body of troops in Rome (save a few *cohortes urbanae* and some non-Roman personal guards of the emperor), or, indeed, anywhere near the capital. Accordingly it could make or unmake emperors in crises—at the accession of Claudius in A.D. 41, in 68–69, and again late in the second century.

See J. E. Sandys, *Companion to Latin Studies* (1921).

PRAETORIUS, MICHAEL (1571–1621), German musical historian, theorist and composer, was born at Kreuzberg, Thuringia, on Feb. 15, 1571. His father's name was Michael Schultze, and the name was latinized as Praetorius. He studied philosophy at Frankfort-on-Oder, and on the death of his brother, on whose support he relied, he was given a post as organist in the town. He was organist and later kapellmeister and secretary to the duke of Brunswick-Wolfenbüttel, and was rewarded for his services with the priory of Ringelheim, near Goslar. He died at Wolfenbüttel on Feb. 15, 1621. The most important of his compositions are: *Polyhymnia* (15 vols.), *Musae Sioniae* (16 vols.), and *Musa Aonia* (9 vols.), all written partly to Latin and partly to German words. But more precious than all these is the *Syntagma musicum* (3 vols. and a *cahier* of plates. 4to, Wittenberg and Wolfenbüttel, 1615–20). For a full description of the work *see* Grove's *Dictionary of Music* (3rd ed., 1927).

PRAETUTTII, also called Πραιτεττιοί, a tribe of ancient Italy inhabiting the south of Picenum (*q.v.*). Their territory lay between the rivers Vomanum and Tessinnus (Pliny iii. §110), and therefore included Castrum Novum, Interamnia and the Truentus, as well as probably the original of Hadria.

PRAGMATIC SANCTION, originally a term of the later Roman law, is found in the Theodosian and Justinian codes (Lat. *pragmatica sanctio*, from the Gr. πρᾶγμα, business). It was a decision of the state dealing with some interest greater than a question in dispute between private persons, and was given for some community (*universitas hominum*) and for a public cause. In more recent times it was adopted by those countries which followed the Roman law, and in particular by despotically governed countries, to signify an expression of the will of the sovereign defining the limits of his own power or regulating the succession. Justinian regulated the government of Italy by pragmatic sanctions after it had been reconquered from the Ostrogoths. In after ages the king of France, Charles VII., imposed limits on the claims of the popes to exercise jurisdiction in his dominions by the pragmatic sanction of Bourges in 1438. The emperor Charles VI. settled the law of succession for the dominions of the house of Habsburg by pragmatic sanction that was first published on April 19, 1713 (*see* AUSTRIA, EMPIRE OF). Philip V., the first of the Bourbon kings of Spain, introduced the Salic law by a pragmatic sanction, and his descendant, Ferdinand VII., revoked it by another. The term was not used in England.

PRAGMATISM, in philosophy, a theory or method of dealing with real things (Gr. πράγματα: *cf.* πραγματικός versed in affairs). "Pragmatic," as here employed is not used in the common colloquial sense of "pragmatical," *i.e.*, "fussy and positive," nor in the historical sense, as in "Pragmatic Sanction," of "relating to affairs of state," but in the sense of practical or efficient. Pragmatism, as a general philosophic doctrine or mental attitude, can only be understood as part of a reaction against the intellectualistic speculation which has characterized most of modern metaphysics. It arises from a general awakening to the fact that the growth of our psychological and biological knowledge must profoundly transform the traditional epistemology. It follows that "pragmatic" lines of thought may originate from a multiplicity of considerations and in a variety of contexts. These, however, may be conveniently classified under four main heads—psychological, logical, ethical and religious—and the history of the subject shows that all these have contributed to the development of pragmatism.

1. Psychologically, pragmatism starts from the efficacy and all-pervasiveness of mental activity, and points out that interest, attention, selection, purpose, bias, desire, emotion, satisfaction, etc., colour and control all our cognitive processes. It insists that all thought is personal and purposive and that "pure" thought is a figment. A judgment which is not prompted by motives and inspired by interest, which has not for its aim the satisfaction of a cognitive purpose, is psychologically impossible, and it is, therefore, mistaken to construct a logic which abstracts from all these facts. Nor is the presence of such non-intellectual factors in thinking necessarily deleterious: at any rate they are ineradicable.

2. In its logical aspect pragmatism originates in a criticism of fundamental conceptions like "truth," "error," "fact" and "reality," the current accounts of which it finds untenable or unmeaning. "Truth," for example, cannot be defined as the agreement or correspondence of thought with "reality," for how can thought determine whether it correctly "copies" what transcends it? Nor can our truth be a copy of a transcendent and absolute truth (Dewey). If it be asked, therefore, what such phrases mean, it is found that their meaning is really defined by their use. The real difference between two conceptions lies in their application, in the different consequences for the purposes of life which their acceptance carries. When no such "practical" difference can be found, conceptions are identical; when they will not "work," *i.e.*, when they thwart the purpose which demanded them, they are false; when they are inapplicable they are unmeaning (A. Sidgwick). Hence the "principle of Peirce" may be formulated as being that "every truth has practical consequences, and these are the test of its truth." It is clear that this (1) implicitly considers truth as a value, and so connects it with the conception of good, and (2) openly raises the question—What is truth, and how is it to be distinguished from error? This accordingly becomes the central problem of pragmatism. This same issue also arises independently out of the breakdown of rationalistic theories of knowledge (F. H. Bradley, H. H. Joachim). Logical analysis, after assuming that truth is independent and not of our making, has to confess that all logical operations involve an apparently arbitrary interference with their data (Bradley).

3. The ethical affinities of pragmatism spring from the perception that all knowing is referred to a purpose. This at once renders it "useful," *i.e.*, a means to an end or "good." Completely "useless" knowledge becomes impossible, though the uses of knowledge may still vary greatly in character, in directness, and in the extent and force of their appeal to different minds. This relation to a "good" must not, however, be construed as a doctrine of ethics in the narrower sense; nor is its "utilitarianism" to be confused with the hedonism of the British associationists. "Useful" means "good for an (any) end," and the "good" which the "true" claims must be understood as cognitive. But cognitive "good" and moral "good" are brought into close connection, as species of teleological "good" and contributory to "the Good." Thus only the generic, not the specific, difference between them is abolished. The "true" becomes a sort of *value*, like the beautiful and the (moral) good. Moreover, since the "real" is the object of the "true," and can be distinguished from the "unreal" only by developing superior value in the process of cognition which arrives at it, the notions of "reality" and "fact" also turn out to be disguised forms of value. Thus the dualism between judgments of fact and judgments of value disappears: whatever "facts" we recognize are seen to be relative to the complex of human purposes to which they are revealed. It should further be noted that pragmatism conceives "practice" very widely: it includes everything related to the control of experience. The dualism, therefore, between "practice" and "theory" also vanishes; a "theory" unrelated to practice (however,

indirectly) is simply an illusion.

4. Pragmatism has very distinctly a connection with religion, because it explains, and to some extent justifies, the faith-attitude or will to believe, and those who study the psychology of religion cannot but be impressed with the pragmatic nature of this attitude. If the whole of a man's personality goes to the making of the truth he accepts, it is clear that his beliefs are not matters of "pure reason," and that his passional and volitional nature must contribute to them and cannot validly be excluded. His religion also is ultimately a vital attitude which rests on his interests and on his choices between alternatives which are real for him. It is not however asserted that his mere willing to believe is a proof of the truth of what he wishes to believe, any more than a will to disbelieve justifies disbelief. His will to believe merely recognizes that choice is necessary and implies risk, and puts him in a position to obtain verification (or disproof). The pragmatic claim for religion, therefore, is that to those who will take the first step and will to believe an encouraging amount of the appropriate verifications accrues. It is further pointed out that this procedure is quite consonant with the practice of science with regard to its axioms. Originally these are always postulates which have to be assumed before they can be proved, and thus in a way "make" the evidence which confirms them. Scientific and religious verification therefore, though superficially distinct, are alike in kind.

The *pragmatic doctrine of truth,* which it is now possible to outline, results from a convergence of the above lines of argument. Because truth is a value and vitally valuable, and all meaning depends on its context and its relation to us, there cannot be any abstract "absolute" truth disconnected from all human purposes. Because all truth is primarily a claim which may turn out to be false, it has to be tested. To test it is to try to distinguish between truth and falsity, and to answer the question—What renders the claim of a judgment to be true, really true? Now such testing, though it varies greatly in different departments of knowledge, is always effected by the consequences to which the claim leads when acted on. Only if they are "good" is the claim validated and the reasoning judged to be "right": only if they are tested does the theory of truth become intelligible and that of error explicable. If, therefore, a logic fails to employ the pragmatic test, it is doomed to remain purely formal, and the possibility of applying its doctrines to actual knowing, and their real validity, remain in doubt. By applying the pragmatic test on the other hand, it is possible to describe how truths are developed and errors corrected, and how in general old truths are adjusted to new situations. This "making of truth" is conceived as making for greater satisfaction and greater control of experience. It renders the truth of any time relative to the knowledge of the time, and precludes the notion of any rigid, static or incorrigible truth. Thus truth is continually being made and re-made. If the new truth seems to be such that our cognitive purposes would have been better served by it than they were by the truth we had at the time, it is antedated and said to have been "true all along." If an old truth is improved upon, it is revalued as "false." To this double process there is no actual end, but ideally an "absolute" truth (or system of truths) would be a truth which would be adequate to every purpose.

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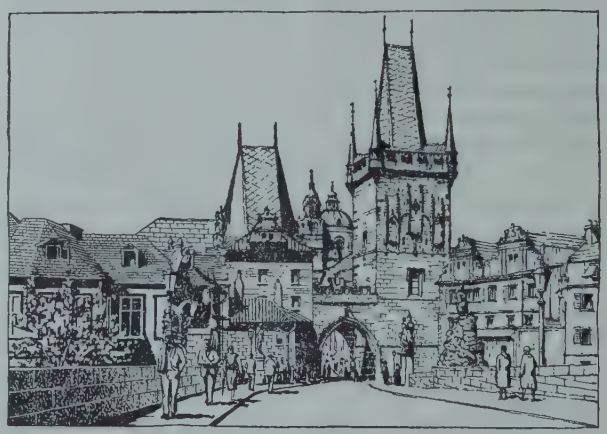
(F. C. S. S.)

PRAGUE (prāg; Czech *Praha;* Ger. *Prag*), capital of Bohemia and Czechoslovakia, situated on both banks of a large meander of the Vltava. There is ample evidence that the site has been continuously inhabited since Palaeolithic times but its fixed population dates from the Neolithic period, when the advantages of a more open plant association in the valley slopes were exploited by an agricultural people. A fertile soil, mild climate, the shelter of surrounding heights and terraced valley slopes contributed to establish a strong and flourishing settlement which avoided the floor of the valley, subject to inundations.

History.—The early history of the town is obscure and legendary but the site was doubtless selected by Slav chieftains as a convenient central position from which to govern their dominions. Historical records after the 10th century indicate a large settlement protected by two castles, one on a hill of the right bank—the Vyšehrad, and a later one on the Hradčany hill of the opposite bank. Geographically the town has never formed a perfect route centre and its supremacy as a political centre is largely the artificial creation of the successive rulers of Bohemia, who systematically furthered its growth. German colonists, invited to settle by King Vratislav during the 11th century, founded a settlement on the right bank at a place known as Pořič, now forming part of the "New Town" (Prague II.), and later a second settlement, the "Old Town" (Prague I.), was built and walled in by them. About the same period the Jews had a separate settlement first under the shadow of the Vyšehrad but later between the Old Town and the river, and now known as Prague V. or Josef's Town.



BY COURTESY OF G. K. GEERLING

THE WEST END OF CHARLES BRIDGE, IN PRAGUE, CZECHOSLOVAKIA

In the early part of the 19th century Prague, which had become almost a German city, felt the stirrings of a movement to revive the Czech nationality. At first purely literary and fostered by the "Society of the Bohemian Museum," founded 1822, it gradually assumed a political character. In 1848 a Slav congress was held in Prague. Trouble and conflict occurred between students and soldiers of the garrison, and barricades were erected but the town surrendered after a short bombardment. From that time on the history of Prague was the history of the rebirth of the Czechoslovak nation. Once more it was occupied by the Prussians in 1866, this time without resistance, and here the treaty of peace between Austria and Prussia was signed. Czech feeling and cultural life in Prague grew rapidly until its triumph resulted in the establishment of the republic of Czechoslovakia in 1918, with Prague as the capital. But in March 1939 Prague was occupied by Germans, and Hitler established a protectorate.

Topography.—The larger part of the modern town lies on the east or right bank of the Vltava, the houses spreading up the terraced slopes, often interrupted by parks, and overflowing into side-valleys. This is predominantly the commercial and industrial side of the town, though the "Old Town" and the adjacent parts of the "New Town" retain their ancient appearance. The former is remarkable for several features. Here is the "Ring" or market place with the fine old 14th century town hall, faced by the Týn church (14th–15th centuries) memorable as the religious centre of the Hussite movement and for its tomb of Tycho Brahe, the astronomer. Leading from the town hall to the limit of the old town is the Celetna ulice, at the extremity of which is the so-

called powder tower, an elaborate building occupying the site of one of the old gates, at the corner of the Přikopy, which, with its continuations, is on the site of a trench that once encircled the fortifications of the old town. These and the fortifications around the new town are now laid out as parks. The new town lacks the crooked streets and quaint relics of the old, which surpasses it in romantic beauty and interest, but has much that is worth notice, *e.g.*, the National museum (1891) at the head of the Wenceslas place, and the 14th century Karlov church, restored in the 18th century.

The districts on the western bank of the river are mainly residential, with the exception of Holešovice-Bubna, and are dominated by Hradčany hill, on the summit of which lies the vast fortified palace of the ancient kings of Bohemia, now the headquarters of the government and the residence of the president. In the centre of the palace area stands the cathedral of St. Vitus, founded in 930 by the prince-saint Wenceslas, rebuilt by Charles IV and restored in recent times; castle and cathedral epitomize the history of the Czech state.

Industries, Education, etc.—Prague is pre-eminently the financial centre and the first manufacturing town of Czechoslovakia, including in its varied industries flour-milling, sugar-refining, brewing, tanning, the preparation of fertilizers and chemicals and the manufacture of furniture, foodstuffs and all types of heavy machinery, notably agricultural implements, rolling stock and river-barges. The re-orientation of the railways in Czechoslovakia has centralized traffic upon the capital, where electrification and enlargement are in progress, while it is also the terminus of Elbe-Vltava shipping; rapid progress is also being made in the direction of making it a centre of commercial aviation. The trade of the city was stimulated in 1920 by the establishment of a sample fair held twice a year and through which it is recovering much of its early importance as a leading centre of European trade.

Culturally too Prague is recovering its ancient leadership through its Czech and German universities and technical schools, while the charm of its numerous handsome buildings and monuments with historical associations, and the attraction of their architecture, even of the many flamboyant examples of Baroque style, are responsible for a growing number of foreign visitors.

The population numbered 676,657 in 1921, 94·2% Czech and 4·6% German. Of the total 468,375 live on the right, the remainder on the left bank of the river, 395,119 are Roman Catholics, 30,961 Protestants, 85,960 belong to the Czechoslovak church, 31,751 are of the Jewish faith and 127,676 are without any confession. In 1930 the total population was 848,823.

See also under CZECHOSLOVAKIA and BOHEMIA, and Count Lützow, *Prague* in "Mediaeval Towns" Series (1902); H. Rudolphi, *Lage, Entwickelung und Bedeutung von Prag*, Geog. Zeitschrift (Leipzig, 1916); J. Moscheles, *Prague*, Geografiska Annaler (Stockholm, 1920); for a complete demographic study (in Czech and French) *see* Dr. A. Boháč, *Hlvavní Město Praha* (Prague, 1923). (W. S. L.)

Battle of Prague, May 6, 1757.—This, the first great victory of Frederick the Great over the Austrians in the SEVEN YEARS' WAR, is described under the latter heading. The town also gives its name to other battles, notably that of 1620, the first important battle in the THIRTY YEARS' WAR (*q.v.*).

PRAGUERIE, THE, a revolt of the French nobility against King Charles VII in 1440, so named because a similar rising had recently taken place in Prague, Bohemia. It was caused by the desire of the princes and great vassals to regain control of the king's council. The instigator was Charles I, duke of Bourbon, who three years before had attempted an unsuccessful rising. He and his bastard brother Alexander were joined by the former favourite Georges de la Trémoïlle, by John V, duke of Brittany, who allied himself with the English, by John II, duke of Alençon, by Louis, count of Vendôme, and by captains of mercenaries like Antoine de Chabannes and Jean de la Roche who were opposed to the recent military reforms.

The duke of Bourbon gained over to their side the 16-year-old dauphin Louis—afterward Louis XI—and proposed to set aside the king in his favour, making him regent. Louis was readily induced to rebel; but the country was saved from a serious civil war by the energy of the king's officers and the solid loyalty of his "good cities."

The constable de Richemont marched with the king's troops into Poitou, his old battleground with Georges de la Trémoïlle, and in two months he had subdued the whole country. Charles VII then attempted to ensure the loyalty of the duke of Bourbon by the gift of a large pension, forgave all the rebellious gentry and installed his son in Dauphiné (*see* LOUIS XI).

PRAIRIE, a level tract of grassy and generally treeless country, generally restricted to tracts so characterized in the central parts of North America (adopted from the Fr. *prairie*, a meadow-tract). In the United States the prairies may roughly be taken to extend from southern Michigan and western Ohio over Illinois (especially designated the Prairie State), Indiana, Missouri, Iowa, Wisconsin and Minnesota, and west of the Missouri to the foothills of the Rocky mountains. In Canada they extend from the same mountains to a line somewhat to the east of Winnipeg. The word prairie is used in a large number of compound names referring to natural and other features, flora, fauna, etc., characteristic of the prairies. Examples are: *prairie chicken* or *prairie hen*, a name for the pinnated grouse, also applied to the sharp-tailed grouse; *prairie-dog*, a rodent of the squirrel family.

For detailed description of the prairie scenery and its distinctive types of life *see* D. A. Dondore, *The Prairie and the Making of Middle America: Four Centuries of Description* (1927); B. Shimek, *Papers on the Prairie* (Iowa City, 1925).

PRAIRIE CHICKEN or **PRAIRIE HEN** (*Tympanuchus cupido*), a North American grouse inhabiting the prairies of the Mississippi valley north to Manitoba and south to Louisiana and Texas. The male has a neck tuft of ten or more rounded feathers, reduced in the female. The lesser prairie hen (*T. pallidicinctus*) is smaller and has more buff above. It is confined to southwest Kansas and western Texas. The Attwater prairie hen (*T. a. attwateri*) inhabits the coast districts of Louisiana and Texas.

PRAIRIE DOG (*Cynomys*), a heavy-bodied, short-tailed ground squirrel of the western United States and northern Mexico, named for its barking voice. The black-tailed species (*C. ludovicianus*) of the great plains lives in large colonies or towns. Formerly these areas covered many miles and contained many thousands of these rodents, but they have been nearly exterminated. The burrows have raised funnel-shaped entrances, serving to keep out water. Three white-tailed species are found in mountain meadows and high plateaus in the Rockies. All species are buff-coloured, from 10 to 12 in. long, plus tail 2 to 4 in. Rattlesnakes, burrowing owls and the large black-footed ferret are also found in the burrows, but this does not indicate a happy family arrangement, since these animals prey on young "dogs." (*See* RODENTIA.) (J. E. HL.)

PRAIRIE DU CHIEN, a city of southwestern Wisconsin, U.S.A., on the Mississippi river, 3 mi. above the mouth of the Wisconsin; the county seat of Crawford county. It is on federal highway 18, and is served by the Burlington route and the Chicago, Milwaukee, St. Paul and Pacific railways. Pop. (1950) 5,392; (1940) 4,622. It is the seat of a Roman Catholic boarding and day high school for girls, and has various manufacturing industries. Historically it is one of the most interesting spots in the state. In 1680 it was visited successively by Father Hennepin and the trader Daniel Greysolon, sieur du Lhut. In 1685 the French built a fort (St. Nicholas) of which the British assumed possession after the close of the French and Indian War. In 1816 Fort Crawford was erected, and in 1820 Joseph Rolette established a permanent depot of the American Fur company. The first U.S. court in what is now Wisconsin was opened there in 1823 by Judge James Duane Doty. The Milwaukee railroad reached this point in 1857. The city was chartered in 1872.

PRAKRIT LANGUAGES, term applied to the vernacular (*prakṛta*, natural) languages of India as opposed to the literary Sanskrit (*saṁskṛta*, purified). There were two main groups of ancient Indo-Aryan dialects, or Primary Prakrits; viz., the language of the Midland or Āryāvarta, and that of what is called the Outer Band. The language of the Midland was crystallized in the shape of literary Sanskrit before 300 B.C. Beside it, all the Primary Prakrits continued to develop under the usual laws of phonetics, and, as vernaculars, reached a secondary stage marked

by a tendency to simplify harsh combinations of consonants and the broader diphthongs, the synthetic processes of declension and conjugation remaining as a whole unaltered. Although the literary dialect of the Midland became fixed, the vernacular of the same tract continued to develop along with the other Primary Prakrits, but owing to the existence of a literary standard by its side its development was to a certain extent retarded.

The Secondary Prakrits, in their turn, received literary culture. In their earliest stage one of them became the sacred language of Buddhism, under the name of Pali (*q.v.*). In a still later stage several Secondary Prakrits became generally employed for a new literature, both sacred and profane. Three of them were used for the propagation of the Jaina religion (*see* JAINS), and they were also vehicles for independent secular works, and largely employed in the Indian drama, in which Brahmans, heroes and people of high rank spoke in Sanskrit, while the other characters expressed themselves in some Secondary Prakrit according to nationality or profession. This later stage of the Secondary Prakrits is known as the Prakrit *par excellence*. In its turn it was fixed by grammarians, and as a literary language ceased to grow, while as a vernacular it went on in its own course. This further development was looked upon as corruption, and its result hence received the name of *Apabhraṁśa*. Again in their turn the *Apabhraṁśas* received literary cultivation and a stereotyped form, while as vernaculars they went on into the stage of the Tertiary Prakrits and become the modern Indo-Aryan languages.

In the Prakrit stage of the Secondary Prakrits we see as before —a Midland language, and the dialects of the Outer Band. The Prakrit of the Midland was known as Śaurasēnī, from Sūrasēna, the name of the country round Mathurā (Muttra). It was the language of the territories having the Gangetic Doab for their centre. To the west it probably extended as far as the modern Lahore and to the east as far as the confluence of the Jumna and the Ganges. Conquests carried the language to Rajputana and Gujarat. The development of Saurasēnī was retarded by the influence of its great neighbour Sanskrit. Moreover, both being sprung from the same original—the Primary Prakrit of the Midland—its vocabulary, making allowances for phonetic changes, is the same as in that language.

The Prakrits of the Outer Band, all more closely connected with each other than any one of them was to Śaurasēnī, were Māgadhī, Ardhamāgadhī, Māhārāṣṭrī, and an unknown Prakrit of the North-west. Māgadhī was spoken in the eastern half of the Gangetic plain. Its proper home was Māgadha, the modern South Bihar, but it extended far beyond these limits at very early times. Judging from the modern vernaculars, its western limit must have been about the longitude of the city of Benares. Between it and Saurasēnī (*i.e.*, in the modern Oudh and the country to its south) lay Ardhamāgadhīmī "half Magādhī." Māhārāṣṭrī was the language of Māhārāṣtra, the great kingdom extending southwards from the river Nerbudda to the Kistna and sometimes including the southern part of the modern Bombay Presidency and Hyderabad. Its language therefore lay south of Saurasēnī. West of Saurasēnī, in the Western Punjab, there must have been another Prakrit of which we have no record, although we know a little about its later *Apabhraṁśa* form. Here there were also speakers of Dardic (*see* INDO-ARYAN LANGUAGES), and the local Prakrit, to judge from the modern Tertiary vernacular, was a mixed form of speech. We have a detailed description of only one *Apabhraṁśa*—the Nāgara—the *Apabhraṁśa* of the Śaurasēnī spoken in the neighbourhood of Gujarat, and therefore somewhat mixed with Māhārāṣṭrī. We may, however, conclude that there was an *Apabhraṁśa* corresponding to each Prakrit, so that we have, in addition to Śaurasēna, a Māgadha, an Ardhamāgadha and a Māhārāṣṭra *Apabhraṁśa*. Native writers describe more than one local *Apabhraṁśa*, such as Vrācaḍa, the ancient dialect of Sind. There were numerous Prakrit subdialects to which it is not necessary to refer. These *Apabhraṁśas* are the direct parents of the modern vernacular.

Māhārāṣṭrī is the Prakrit best known to us. It early obtained literary pre-eminence, was the subject of long treatises by native grammarians, and became the language of lyric poetry and of the formal epic (*kāvya*). Dramatic works have been written in it, and it was also the vehicle of many later scriptures of the Jaina religion. The older Jaina writings were composed in Ardhamāgadhī. The Māgadhī we have brief accounts by native grammarians and short sentences scattered through the plays. Śaurasēnī is the usual prose dialect of the plays, and is also employed for the sacred writings of one of the Jaina sects.

The following is a list of the Indo-Aryan vernaculars, showing, when known, the names of the *Apabhraṁśas* from which they are sprung:—

Apabhraṁśa.	Modern language.
	A. Language of the Midland.
Śaurasēna . .	Western Hindi
	B. Intermediate Languages.
Āvanta . .	Rājasthānī
” . .	Pahārī Languages
Gaurjaṛa . .	Gujarātī
Śaurasēna . .	Pañjābī
Ardhamāgadha	Eastern Hindī
	C. Outer Languages.
	(*a*) *North-Western Group.*
Unknown . .	Kāshmīrī (with a Dardic basis)
” . .	Kōhistānī (with a Dardic basis)
” . .	Lahndā or Western Pañjābī
Vracada . .	Sindhī
	(*b*) *Southern Language.*
Māhārāṣṭra .	Marāṭhī
	(*c*) *Eastern Group.*
Māgadha . .	Bihārī
” . .	Oriyā
” . .	Bengali
” . .	Assamese

Language.—Originally real vernaculars with tendencies towards certain phonetic changes, the dialects were taken in hand by grammatical systematizers.

Subsequent writers followed these rules and not the living speech, even though they were writing in what was meant to be a vernacular. Moreover, at an early date, the Prakrits, *qua* literary languages, began to lose their characteristics as local forms of speech. A writer composed in Māhārāṣṭrī because it was the particular Prakrit employed for lyrics and in formal epics. In dramatic literature, Śaurasēnī and Māgadhī were put into the mouths of characters in particular walks in life, whatever the nationality of the dramatist might have been.

(Contractions: Skr.=Sanskrit. Pr.=Prakrit. S.=Saurasēnī. Mg.=Māgadhī. AMg.=Ardhamāgadhī. M.=Māhārāṣṭrī. Ap.=Nāgara Apabhraṁśa.)

Vocabulary.—The vocabulary of S. is to all intents and purposes the same as that of Skr. In the languages of the Outer Band there are numerous provincial words (dēśī or dēśya), the originals of which belonged to Primary Prakrits other than those of the Midland. In the Outer Band there is also a rich variety of grammatical forms, many of which are found in the Veda and not in classical Sanskrit, and some which cannot be traced to any known Primary Prakrit form, but which must have existed in that stage and preceding it, far back into ancient Indo-European times.

An elaborate system of phonetics was developed by the grammarians. They are of interest as showing the tendencies at work and bring out especially in the case of compound consonants the substitution, mainly by a process of assimilation, of a slurred for a distinct pronunciation.

Declension.—Pr. has preserved the three genders of Skr., but has lost the dual number. As a rule, the gender of a noun follows that of the Skr. original, though in AMg. there is already a tendency to substitute the masculine for the neuter, and in Ap. these two genders are frequently confused, if the distinction is not altogether neglected. In the formation of cases, the phonetic rules just given are fully applied, but there are also other deviations from the Skr. original. The consonantal stems of Skr. declension are frequently given vocalic endings, and there is a

general tendency to assimilate their declension to that of *a*-bases, which is helped by the free use of pleonastic suffixes ending in *a*, which are added to the base without affecting its meaning. Of these the most common are *-ka-*, *-ḍa-*, and *-alla-*, *-illa-* or *-ulla-*. The first of these was also very common in Skr., but its use was much extended in Pr. In accordance with the general rule, the *k* is liable to elision. It may even be doubled. *-Ḍa-* is confined to Ap., and may be used alone or together with the other two. *-Illa-* is most common in the Outer languages, and especially so in AMg. and M.

All the Skr. cases are preserved except the dative which has altogether disappeared in the Midland, but has survived in the singular number in the Outer languages. Everywhere the genitive can be employed in its place. Most of the case-forms are derived from Sanskrit according to the phonetic rules, but Ap. has a number of dialectic forms which cannot be referred to that language (*cf.* the remarks above about *-hi* = *θĭ*). It also rarely distinguishes between the nominative and the accusative.

The declension of neuter *a*-bases closely resembles the above, differing only in the nominative and accusative singular and plural. Ap. has almost lost the neuter termination in the singular. Feminine *a*-stems are declined on the same lines, but the cases have run more into each other, the instrumental, genitive and locative singular being identical in form. Very similarly are declined the bases ending in other vowels. The few still ending in consonants and which have not become merged in the *a*-declension, present numerous apparent irregularities.

All the Skr. pronouns appear in Pr., but often in extremely abraded shapes. There is also a most luxuriant growth of by-forms, the genitive plural of the pronoun of the second person being, *e.g.*, represented by no less than 25 different words in M. alone. We also find forms which have no original in classical Skr.

Conjugation.—The Pr. verb shows even more decay than does the noun. With a few isolated exceptions, all trace of the second, or consonantal, conjugation of Skr. has disappeared, and all verbs are now conjugated after the analogy of the *a*-conjugation, which falls into two classes, the first being the *a*-conjugation proper, and the second the *ē*-conjugation, in which the *ē* represents the *aya* of the Skr. 10th class and of causal and denominative verbs. The present participle is the only form which has everywhere survived. All the past tenses (imperfect, perfect and aorists) have fallen into disuse, leaving only a few sporadic remains, their place being supplied, as in the case of the tertiary vernaculars, by the participles, with or without auxiliary verbs. The present tense of the verb substantive has survived from Skr., but it is usual to employ *atthi* (=Skr. *asti*) for both numbers and all persons of the present, and *āsī* (=*āsīt*) for both numbers and all persons of the past. The latter has survived in the modern Punjabi *sī*, was. Another verb substantive (Skr. √ *bhū*) has also survived, generally in the form *hōi* or *huvaï* for *bhavati*. Its usual past participle is *hūa-*, or Mg. *hūḍa-*, S. *bhūḍa*. The forms given here are important when the history of the Tertiary Prakrits comes under consideration. These two verbs substantive make periphrastic tenses with other participles, and, in the case of the past participles and gerundives of transitive verbs (both of which are passive in signification), the agent or subject is put into the instrumental case, the participle being used either personally or impersonally, as in the tertiary languages. The gerundive, or future passive participle, is also used impersonally in the case of intransitive verbs.

Besides the participles, the infinitive and the indeclinable participle (gerund) have also survived. So also the passive voice, conjugated in the same tenses as the active. The causal has been already mentioned. There are also numerous denominative verbs (many of them onomatopoeic), and a good supply of examples of frequentative and desiderative bases, mostly formed, with the necessary phonetic modifications, as in Skr. Many direct representatives of Skr. participles in *-ta-* (without the *i*) and *-na-* also appear. As usual there is a tendency to simplification, and the termination *ia* is commonly added to the Pr. present base, instead of following Skr. analogy. All the three forms of the future passive participle or gerundive in *-tavya-*, *-anīya-* and *-ya-* have survived. The infinitive has survived, not only with the form corresponding to the classical Sanskrit termination *-tum*, but also with several old Vedic forms. The same is the case with the gerund, in which both the classical forms in *-tvā* and *-(t)ya* have survived, but with the loss of the distinctive use which obtained in Sanskrit. Besides these there are also survivals of Vedic forms, and even of Primary Prakrit forms not found in the Veda. The passive is generally formed by adding *-jja* or, in S. and Mg., *-īa-* to the root or, more often, to the present stem.

The only tenses which are fully conjugated in Pr. are the present, the imperative, the future and the optative. Except in Ap., the personal terminations in general correspond to the Skr. ones, but in Ap. there are some forms which probably go back to unrecorded Primary Prakrits. The imperative similarly follows the Skr. imperative. The base of the optative is generally formed by adding *-ejja-* in the Outer languages and *-ēa-* in S. The Skr. future termination *-isya-* is represented by *-issa-* or *-ihi-*.

Prakrit Literature.—The great mass of Prakrit literature is devoted to the Jaina religion. The oldest Jaina *sūtras* were in Ardhamāgadhī, while the non-canonical books of the Svētāmbara sect were in a form of Māhārāṣṭri, and the canon of the Digambaras appears to have been in a form of Saurasēnī. Prakrit also appears in secular literature. In artificial lyric poetry it is pre-eminent. The *Sattasaï* (*Saptaśaptikā*) was compiled at some time between the 3rd and 7th centuries A.D. by Hāla. It has had numerous imitators, both in Sanskrit and in the modern vernaculars, such as the Satsaï of Bihārī Lāl (17th century A.D.). Hāla's work is important as showing the existence of a large Prakrit literature at the time when it was compiled. Most of this is lost. In Prakrit we have the *Rāvaṇavaha* or *Sētubandha* (attributed to Pravarasēna, before A.D. 700), dealing with the subject of the *Rāmāyaṇa;* the *Gaüḍavaha* of Vākpati (7th–8th century A.D.), celebrating the conquests of Bengal by Yásōvarman, king of Kanauj, and the *Kumārapālacarita,* or the last eight cantos of the huge *Dvyāśraya Mahākāvya* written by Hēmacandra (A.D. 1150), to serve as a series of illustrations to the author's Sanskrit and Prakrit grammar, the *Sidda-hēmacandra.* The cantos are in Prakrit, and illustrate the rules of that portion of his work. Dramatic literature has also an example in the *Karpūra-mañjarī* ("Camphor-cluster," the name of the heroine) by Rāja-śēkhara (A.D. 900), a comedy of intrigue. An important source of our knowledge of Prakrit, and especially of dialectic Prakrit, is the Sanskrit drama. In works of this class many of the characters speak in Prakrit, different dialects being employed for different purposes. Generally speaking, Śaurasēnī is employed for prose and Māhārāṣṭri (the language of lyric poetry) for the songs, but special characters also speak special dialects according to their supposed nationality or profession. The result is that in the Sanskrit drama we have a valuable reflection of the local dialects.

BIBLIOGRAPHY.—*See* R. Pischel's *Grammatik der Prākritsprachen* (Strasbourg, 1900). As an introduction to the study of the language, the best work is H. Jacobi's *Ausgewählte Erzählungen in Mâhârashṭrî zur Einführung in das Studium des Prâkrit, Grammatik, Text, Wörterbuch* (Leipzig, 1886). The best editions of the grammars are E. B. Cowell's of Vararuci's *Prākṛta-Prakāśa* (1868), R. Pischel's of Hēmacandra (Halle, 1877, 1889), and E. Hultzsch's of Śiṁharāja's *Prākṛtarūpāvatāra* (1909). For *Dēśya* words, *see* Pischel's *The Dēśînâmamâlâ of Hemachandra* (Bombay, 1880). For *Apabhraṁśa,* in addition to his edition of Hēmacandra's grammar, *see* the same author's *Materialen zur Kenntnis des Apabhraṁśa* (1902). For *Apabhraṁśa* texts published in Europe, mention may be made of Dhanavāla's *Bhavisatta Kaha* (Munich, 1918), and Haribhadra's *Sanatkumāsacaritom* (Munich, 1921), both edited by H. Jacobi with valuable introductory essays, dealing with the whole question of Prakrit. For the mutual relationship of the various Prakrits, *see* S. Konow, "Mâhârâshṭrî and Mârâthî," in the *Indian Antiquary* (1903), xxxii., 180 *sqq.* For Jaina Prakrit, *see* under JAINS. In the secular texts the best editions are: A. Weber, *Das Saptataçatakam des Hāla* (Leipzig, 1881); another edition by Durgāprasād and Kāśīnāth Pāṇḍurang Parab under the title of *The Gâthasaptaśatî of Sâtavâhana* (Bombay, 1889) [a good commentary]; S. Goldschmidt, *Rāvaṇavaha oder Setubandha* (Strasbourg, 1880–83) [text and translation]; Sivadatta and Parab, *The Setubandha of Pravarasena* (Bombay, 1895); Shaṅkar Pāṇḍurang Pandit, *The Gaüḍavaho, à Historical Poem in Prâkrit, by Vâkpati* (Bombay, 1887); the same editor, *The Kumârapâla-charita* (Bombay, 1900); *Rajaçekhara's Karpūramañjarî,* edited by S. Konow,

translated by C. R. Lanman (1901).

The literature of the Sanskrit drama is given under SANSKRIT LANGUAGE AND LITERATURE.

PRANTL, KARL VON (1820–1888), German philosopher, was born at Landsberg on the Lech on Jan. 28, 1820, and died on Sept. 14, 1888, at Oberstdorf. In 1843 he became doctor of philosophy at Munich observatory, where he was made professor. His best-known work is the *Geschichte der Logik im Abendland* (Leipzig, 1855–70).

PRASEODYMIUM (symbol Pr, atomic number 59, atomic weight 140.92, stable isotope Pr^{141} [100%]) is a metallic element of the rare-earth group. It was discovered by Carl Auer von Welsbach in 1885 when he separated salts of the so-called element didymium into two fractions (praseodymium and neodymium); the name is derived from *praeseodidymium,* meaning "green didymium," reflecting the green colour of its salts. The metal occurs along with the other rare earths in the minerals monazite, cerite and allanite; it is also found among the fission products of uranium, thorium and plutonium. In the past it was usually separated by fractional crystallization employing first a double magnesium nitrate and finally the double ammonium nitrate. Many other procedures have been used but all of them involved long-continued fractional crystallization or fractional precipitation or decomposition. Since 1945 it has been rapidly separated by means of adsorption columns (*see* RARE EARTHS). The oxide is an almost black powder the composition of which varies according to the method of preparation. It is usually considered to be Pr_6O_{11}; it can be reduced in hydrogen to give Pr_2O_3. The higher valency state of the praseodymium is in question, some authorities claiming it to be tetravalent and others pentavalent. The evidence is slightly in favour of the pentavalent state; thus, Pr_6O_{11} would be a double oxide, $2Pr_2O_3.Pr_2O_5$. The black oxide dissolves in acids, with the liberation of oxygen, to give green solutions or green salts such as $Pr_2(SO_4)_3.8H_2O$. Only the trivalent forms are known in solution; they show a strong characteristic absorption spectrum and are paramagnetic.

The metal is prepared by the electrolysis of the fused halides or by thermoreduction of its salts with the alkali metals or alkaline-earth metals. Two allotropic forms are known. The α-form (somewhat distorted hexagonal close packed, $a=3.662$ Å, $c=5.908$ Å) has a calculated density $=6.776$ g. per cubic centimeter. The β-form (cubic close packed, $a=5.151$ Å) has a calculated density $=6.805$ g. per cubic centimeter. The metal melts between 940° C. and 960° C. Alloys of the metal, particularly misch metal (*see* CERIUM), have found various uses. Its salts have found application in the ceramics industry for colouring glass and glazes. (*See* RARE EARTHS.)

(F. H. Sc.)

PRATI, GIOVANNI (1815–1884), Italian poet, was born at Dasindo and studied law at Padua. A partisan of the house of Savoy, in 1862 he was elected a deputy to the Italian parliament, and in 1876 a senator. He died at Rome on May 9, 1884. Prati's work ranged from his romantic narrative *Ermenegarda* (1841) to the 500 sonnets collected in *Psiche* (1875) and the poems entitled *Iside* (1878). His *Opere varie* were published in five volumes in 1875, and a selection in one volume in 1892.

PRATINAS, a tragic poet of Athens, was a native of Phlius in Peloponnesus. About 500 B.C. he competed with Choerilus and Aeschylus, when the latter made his first appearance as a writer for the stage. Pratinas introduced satyric dramas as a species of entertainment distinct from tragedy. Pratinas was also a writer of dithyrambs and the choral odes called *hyporchemata* (a considerable fragment of one of these is preserved in Athenaeus xiv, 617). (*See* SUIDAS.)

PRATINCOLE, a name for the bird *Glareola pratincola,* forming the type of a genus belonging to the order Limicolae. The pratincoles, of which eight or nine species have been described, are small birds, slenderly built and delicately coloured, with a short stout bill, a wide gape, long pointed wings and a forked tail. In some of their habits they are thoroughly plover-like, running swiftly and breeding on the ground, but on the wing they have much the appearance of swallows and, like them, feed, at least partly, while flying. The pratincole of Europe, *G. pratincola,* breeds in many parts of Spain, Barbary and Sicily, along the valley of the Danube and in southern Russia. In the southeast of Europe a second and closely allied species, *G. nordmanni,* which has black instead of chestnut inner wing coverts, accompanies or, farther east, replaces it; other species occur in Asia, Africa and Australia.

PRATO IN TOSCANA, a town and episcopal see of Tuscany, Italy, in the province of Florence, 11 mi. by rail N.W. of Florence, 207 ft. above sea level. Pop. (1936) 28,646, town; 70,206, commune. It is situated on the Bisenzio, and was dominated by a castle built by Frederick II (*c.* 1250). The cathedral was begun in the 12th century; to this period belongs the narrow nave with its wide arches; the raised transepts and the chapels were added by Giovanni Pisano in 1317–20; the campanile dates from 1340, while the façade, also of alternate white sandstone and green serpentine, belongs to 1413. It has a fine doorway with a bas-relief by Andrea della Robbia over it and a lovely open-air pulpit, erected in 1439 by Donatello and Michelozzo for displaying the Virgin's girdle, brought from the Holy Land by a knight of Prato in 1130. The pulpit itself has reliefs of dancing children; beneath it is a splendid bronze capital. The Chapel of the Girdle has a statue of the Virgin by Giovanni Pisano, and a handsome bronze openwork screen. The frescoes in the choir, with scenes from the life of St. John the Baptist and St. Stephen, are by Fra Filippo Lippi (1456–66) and are his best work. The massive old Palazzo Pretorio (13th century) contains a small but good picture gallery. A beautiful Madonna by Filippino Lippi (1498) is in a small street shrine at the corner of the Via Santa Margherita. The Madonna del Buon Consiglio has some good reliefs by Andrea della Robbia, by whom is also the beautiful frieze in the Madonna delle Carceri. This church, by Giuliano da Sangallo (1485–91), is a Greek cross, with barrel vaults over the arms, and a dome; it is a fine work, and the decoration of the exterior in marble of different colours (unfinished) is of a noble simplicity.

PRATT, a city of southern Kansas, U.S., on the headwaters of the Ninnescah river, at an altitude of 1,916 ft.; the county seat of Pratt county; on federal highways 54 and 281; served by the Rock Island and the Santa Fe railways. Pop. (1950) 7,523. Pratt is a well-built, well-kept city, surrounded by a highly developed agricultural region of gently rolling land. It has a commission form of government, a city-planning commission and zoning regulations. Founded in 1884, Pratt became the county seat in 1886. There are farm machinery and steel fabrication industries.

PRAXITELES, of Athens, the son of Cephissodotus, the greatest of the Attic sculptors of the 4th century B.C., who has left an imperishable mark on the history of art.

Though Praxiteles may be considered as in some ways well known to us, yet we have no means for fixing his date accurately. It seems clear that he was no longer working in the time of Alexander the Great, or that king would have employed him. Pliny's date, 364 B.C., is probably that of one of his most noted works. We possess one undisputed original work of Praxiteles, that of the marble statue of Hermes carrying the infant Dionysus (GREEK ART, Plate V, fig. 3). The young child can hardly be regarded as a success; he is not really childlike. But the figure of the Hermes, full and solid without being fleshy, at once strong and active, is a masterpiece, and the play of surface is astonishing. In the head we have a remarkably rounded and intelligent shape, and the face expresses the perfection of health.

This statue is our best evidence for the style of Praxiteles. It altogether confirms and interprets the statements as to Praxiteles made by Pliny and other ancient critics. Gracefulness in repose, and an indefinable charm are also the attributes of works in our museums which appear to be copies of statues by Praxiteles. Perhaps the most notable of these are the Apollo Sauroctonus, or the lizard slayer, a youth leaning against a tree and idly striking with an arrow at a lizard, and the Aphrodite at the bath (GREEK ART, Plate V, figs. 5, 6) of the Vatican, a copy of the statue made by Praxiteles for the people of Cnidus. There is a story that Phryne, who was supposed to have been Praxiteles' model, induced him to name his two finest works by telling him his studio was on fire. He named the Eros and the Satyr. The "Capitoline Faun" at Rome has been identified as a copy of this, and a torso in the Louvre may even be the original.

Excavations at Mantineia in Arcadia have brought to light the basis of a group of Leto, Apollo and Artemis by Praxiteles. This basis was doubtless not the work of the great sculptor himself, but of one of his assistants. Nevertheless it is pleasing and historically valuable. Pausanias (viii, 9, 1) thus describes the base, "on the base which supports the statues there are sculptured the Muses and Marsyas playing the flutes." Three slabs which

have survived represent Apollo, Marsyas, a slave and six of the Muses, the slab which held the other three having disappeared.

Four points of composition may be mentioned, which appear to be in origin Praxitelean: (1) a very flexible line divides the figures if drawn down the midst from top to bottom; they all tend to lounging; (2) they are adapted to front and back view rather than to being seen from one side or the other; (3) trees, drapery and the like are used for supports to the marble figures, and included in the design, instead of being extraneous to it; (4) the faces are presented in three-quarter view.

The subjects chosen by Praxiteles were either human beings or the less elderly and dignified deities. It is Apollo, Hermes and Aphrodite who attract him rather than Zeus, Poseidon or Athena. And in his hands the deities sink to the human level, or, indeed, sometimes almost below it. They have grace and charm in a supreme degree, but the element of awe and reverence is wanting. Between them Scopas with his gift for expressing emotion, and Praxiteles, with his delicacy and grace, changed the whole aspect of such sculpture, and the development of later ages derives largely from these two.

See Klein, *Praxiteles* (Leipzig, 1898); Perrot, *Praxitèle* (Paris, 1905).

PRAYER, a term used generally for any humble petition, but more technically, in religion, for that mode of addressing a divine or sacred power in which there predominates the mood and intention of reverent entreaty (from Lat. *precari,* entreat; Ital. *pregaria;* Fr. *prière*).

Prayer and its Congeners.—Prayer in the latter sense is a characteristic feature of the higher religions, and we might even say that Christianity or Mohammedanism, ritually viewed, is in its inmost essence a service of prayer. At all stages of religious development, however, and more especially in the case of the more primitive types of cult, prayer as thus understood occurs together with, and shades off into, other varieties of observance that bear obvious marks of belonging to the same family.

Confining ourselves for the moment to forms of explicit address, we may group these under three categories according as the power addressed is conceived by the applicant to be on a higher, or on much the same, or on a lower plane of dignity and authority as compared with himself. (1) Only if the deity be regarded as altogether superior is there room for prayer proper, that is, reverent entreaty. Of this we may perhaps roughly distinguish a higher and a lower type, according as there is either complete confidence in the divine benevolence and justice, or a disposition to suppose a certain arbitrariness or, at any rate, conditionality to attach to the granting of requests. In the first case prayer will be accompanied with disinterested homage, praise, and thanksgiving, and tends to lose its distinctive character of entreaty or petition, passing into a mystic communing or converse with God. In the second case it will be supported by pleading, involving on the one hand self-abasement, with confession of sins and promises of repentance and reform, or on the other hand self-justification, in the shape of the expression of faith and recitation of past services, together with reminders of previous favour shown. (2) If the worshipper place his god on a level with himself, so as to make him to some extent dependent on the service man contracts to render him, then genuine prayer tends to be replaced by a mere bargaining, often conjoined with flattery and with insincere promises. This spirit of *do ut des* will be found to go closely with the gift-theory of sacrifice (*q.v.*) and to be especially characteristic of those religions of middle grade that are given over to sacrificial worship as conducted in temples and by means of organized priesthoods. So when the high gods are kind for a consideration, the lower deities will likewise be found addicted to such commerce; thus in India the hedge-priest and his familiar will bandy conditions in spirited dialogue audible to the multitude (*cf.* W. Crooke, *Things Indian, s.v.* "Demonology," pp. 132, 134). (3) Lastly, the degree of dependency on human goodwill attributed to the power addressed may be so great that, instead of diplomatic politeness, there is positive hectoring, with dictation, threats, and abuse. Even the Italian peasant is said occasionally to offer both abuse and physical violence to the image of a recalcitrant saint; and antiquity wondered at the bullying manner of the Egyptians towards their gods (*cf.* Iamblichus, *De mysteriis,* vi. 5–7). Westermarck supplies many instances from Morocco of *'âr* the "conditional curse," applied to saints in order to make them attend, on pain of disaster if they are recalcitrant (*History and Development of the Moral Ideas,* passim). This frame of mind, however, is mainly symptomatic of the lower levels of cult. Thus the Zulu says to the ancestral ghost, "Help me or you will feed on nettles"; whilst the still more primitive Australian exclaims to the "dead hand" that he carries about with him as a kind of divining-rod, "Guide me aright, or I throw you to the dogs."

So far the forms of address are explicitly directed towards a power that, one might naturally conclude, has personality, since it is apparently expected to hear and answer. At the primitive stage, however, the degree of personification is, probably, often far slighter than the words used would seem to suggest. The verbal employment of vocatives and of the second person may have little or no personifying force, serving primarily but to make the speaker's wish and idea intelligible to himself. When the rustic talks in the vernacular to his horse he is not much concerned to know whether he is heard and understood; still less when he mutters threats against an absent rival, or kicks the stool that has tripped him up with a vicious "Take that!"

These considerations may help towards the understanding of a second class of cases, namely, forms of implicit address shading off into unaddressed formulas. Wishings, blessings, cursings, oaths, vows, exorcisms, and so on, are uttered aloud, partly that they may be heard by the human parties to the rite, but in many cases that they may be heard, or at least overheard, by a consentient deity, perhaps represented visibly by an idol or other cult-object.

From Suggestion to Prayer.—To address and entreat a fellow-being is a faculty as old as that of speech, and, as soon as it occurred to man to treat sacred powers as fellow-beings, assuredly there was a beginning of prayer. We are not likely to know how religion first arose, and the probability is that many springs went to feed that immense river. Thus care for the dead may well have been one amongst such separate sources. It is natural for sorrow to cry to the newly dead "Come back!" and for bereavement to add "Come back and help!" Another source is mythologic fancy, which, in answer to child-like questions: "Who made the world?" "Who made our laws?" and so on, creates "magnified non-natural men," who presently made their appearance in ritual (for to think a thing the savage must dance it); whereupon personal intercourse becomes possible between such a being and the tribesmen, the more so because the supporters of law and order, the elders, associate themselves as closely as possible with the supreme law-giver. From Australia comes a certain amount of evidence showing that, in the two ways just mentioned, some inchoate prayer is being evolved. On the whole, the absence of prayer from the magico-religious ritual of the Australians is conspicuous. Uttered formulas abound; yet they are not forms of address, but rather self-sufficient pronouncements charged with *mana* (*q.v.*). They involve a wonder-working recognized as such, the core of the mystery consisting in the supposed transformation of suggested idea into accomplished fact by means of that suggestion itself. To the man endowed in the opinion of his fellows (and doubtless of himself) with this wonderful power of effective suggestion, the output of such power naturally represents itself as a kind of unconditional willing. When he cries "Rain, rain," or otherwise makes vivid to himself and his hearers the idea of rain, expecting that the rain will thereby be forced to come, it is as if he had said "Rain, now you must come," or simply "Rain, come!" and we find that suggestional formulas mostly assume the tone of an actual or virtual imperative, "As I do this, so let the like happen," "I do this in order that the like may happen," and so on. Now it is easy to "call spirits from the vasty deep," but they do not always come. Hence such imperatives have a tendency to dwindle into optatives. "Let the demon of small-pox depart!" is replaced by the more humble "Grandfather Smallpox, go away!" where the affectionate appellative (employed, however, in all likelihood merely to cajole) signalizes an approach to the genuine spirit of prayer. Again, the user of suggestion conscious

of his limitations will seek to supplement his *mana* by tapping, so to speak, whatever sources of similar power lie round about him. A notable method of borrowing power from another agency involving *mana* is simply to breathe its name in connection with the spell that stands in need of reinforcement; as the name suggests its owner, so it comes to stand for his real presence. Even the more highly developed forms of liturgical prayer tend, in the recitation of divine titles, attributes and the like to present a survival of this formalist use of potent names. (*See* NAME.)

Prayer as a Part of Ritual.—By an exactly converse process prayer actually generates formalism, instead of growing out of it. In advanced religion, indeed, prayer is the chosen vehicle of the free spirit of worship. Its mechanism is not unduly rigid, and it is largely autonomous, being rid of subservience to other ritual factors. In more primitive ritual, however, set forms of prayer are the rule, and their function is mainly to accompany and support a ceremony the nerve of which consists in action rather than speech. Hence, suppose genuine prayer to have come into being, it is apt to degenerate into a mere piece of formalism; and yet, whereas its intrinsic meaning is dulled by repetition according to a well-known psychological law, its virtue is thereby hardly lessened for the undeveloped religious consciousness, which holds the saving grace to lie mainly in the repetition itself. But a formula that depends for its efficacy on being uttered rather than on being heard is virtually indistinguishable from the purely suggestional type of utterance, though its origin is different. A good example of a degenerated prayer-ritual comes from the Todas (*see* W. H. R. Rivers, *The Todas,* ch. x.). The prayer itself tends to be slurred over, or even omitted. On the other hand, great stress is laid on a preliminary citation of names of power followed by the word *idith.* This at one time seems to have meant "for the sake of," carrying with it some idea of supplication; but it has now lost this connotation, seeing that it can be used not merely after the name of a god, but after that of any sacred object or incident held capable of imparting efficacy to the formula. Even the higher religions have to fight against the tendency to "vain repetitions" (often embodying a certain sacred number, *e.g.* three), as well as to the use of prayers as amulets, medicinal charms, and so on. Throughout we must carefully distinguish in theory, though hard in practice, between legitimate ritual understood as such, whether integral to prayer, such as its verbal forms, or accessory, such as gestures, postures, incense, oil or what not, and the formalism of religious decay, such as generally betrays itself by its meaninglessness, by its gibberish phrases, sing-song intonation and so forth.

Silent Prayer.—A small point in the history of prayer, bearing on the subject of its relation to magic, is concerned with the custom of praying silently. Charms and words of power being supposed to possess efficacy in themselves are guarded with great secrecy by their owners, and hence, in so far as prayer verges on spell, there will be a disposition to mutter or otherwise conceal the sacred formula. Thus the prayers of the Todas already alluded to are in all cases uttered "in the throat," although these are public prayers, each village having a form of its own. At a later stage, when the distinction between magic and religion is more clearly recognized and an anti-social character definitely assigned to the former, on the ground that it subserves the sinister interests of individuals, the overt and, as it were, congregational nature of the praying comes to be insisted on as a guarantee that no magic is being employed, a notion that suffers easy translation into the view that there are more or less disreputable gods with whom private trafficking may be done on the sly. Thus, in accordance with the outlook of the classical period, Plato in his *Laws* (909–910) prohibits all possession of private shrines or performance of private rites; "Let a man go to a temple to pray, and let anyone who pleases join with him in the prayer." Nevertheless, instances are not wanting amongst the Greeks of private prayers of the loftiest and the most disinterested tone (*cf.* L. R. Farnell, *The Evolution of Religion,* p. 202 *seq.*). Finally, in advanced religion, at the point at which prayer is coming to be conceived as communion, silent adoration is sometimes thought to bring man nearest to God.

The Moralization of Prayer.—As to the moral quality of the act of prayer, this contrast between the spirit of public and private religion is fundamental for all but the most advanced forms of cult. In its public rites the community becomes conscious of common ends and a common edification. Even a very primitive people such as the Arunta of Australia behaves with the greatest solemnity at its ceremonies, and professes to be made "glad" and "strong" thereby. Of his countrymen, whom he would not trust to pray in private, Plato testifies that in the temples during the sacrificial prayers "they show an intense earnestness and with eager interest talk to the gods and beseech them" (*Laws,* 887). In acts of public worship at any rate, therefore, prayer and its magico-religious congeners are at all stages resorted to as a "means of grace," even though such grace does not constitute the expressed object of petition. Poverty of expression is apt to cloak the real spirit of primitive prayer, and the formula under which its aspirations may be summed up, namely, "Blessings come, evils go," covers all sorts of confused notions about a grace to be acquired and an impurity to be wiped away, which, as far back as our clues take us, invite interpretations of a decidedly spiritualistic and ethical order. To explicate, however, and purge the meaning of that "strong heart" and "clean" which the savage after his fashion can wish and ask for, remained the task of the higher and more self-conscious types of religion. A favourite contrast for which there is more to be said is that drawn between the magico-religious spell-ritual, that says in effect, "My will be done," and the spirit of "Thy will be done" that breathes through the highest forms of worship. Such resignation in the face of the divine will and providence is, however, not altogether beyond the horizon of primitive faith, as witness the following prayer of the Khonds of Orissa: "We are ignorant of what it is good to ask for. You know what is good for us. Give it to us." (Tylor, *Prim. Culture,* 4. 369). At this point prayer by a supreme paradox virtually extinguishes itself, since in becoming an end in itself, a means of contemplative devotion and of mystic communing with God, it ceases to have logical need for the petitionary form. Thus on the face of it there is something like a return to the self-sufficient utterance of antique religion; but, in reality, there is all the difference in the world between a suggestion directed outwardly in the fruitless attempt to conjure nature without first obeying her, and one directed towards the inner man so as to establish the peace of God within the heart.

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PRAYER, BOOK OF COMMON, the title of the official service book of the Church of England. One of the most important steps taken at the Reformation was the compilation and provision of a comprehensive service book for general and compulsory use in public worship throughout the Church of England. The following main advantages were achieved.

(1) The substitution of the English language for the Latin language, in which all the old service books were written.

(2) Unification and simplification. The Prayer Book represents in a much condensed and abbreviated form the four chief ancient service books, viz.: the Missal, Breviary, Manual and Pontifical. In addition to a multiplicity of books there was much variety of use. Although the Sarum Use prevailed far the most widely, yet there were separate Uses of York and Hereford, and also to a less degree of other dioceses and cathedral churches as well. Cranmer's preface "Concerning the Service of the Church" expressly mentions the abolition of this variety as one of the things to be achieved by a book of Common Prayer. It says: "And whereas heretofore there hath been great diversity in saying and singing in Churches within this Realm; some following Salisbury Use, some Hereford Use, and some the Use of Bangor, some of York, some of Lincoln; now from henceforth all the whole Realm shall have but one Use." On the sources from which the Prayer Book was compiled, *see* F. Procter and W. H. Frere, *New History of the Book of Common Prayer* (2nd ed. 1902), and the works mentioned below.

Of changes preceding the first Prayer Book we may note: (*a*) The compiling and publishing of the Litany in English by Cranmer in 1544. (*b*) Royal injunctions in Aug. 1547 ordering the Epistle and Gospel to be read in English at High Mass. (*c*) A royal proclamation, dated March 8, 1548, imposing for use at the coming Easter *The Order of the Communion.* This was an order or form of service in English for the communion of the people in both kinds. It was to be inserted into the service after the communion of the priest, without making any other alteration in the Latin Mass. It comprised the long exhortation or notice to be given on Sunday, or on some other day, previous to the Communion, the longer exhortation, and the shorter invitation, the confession, absolution, comfortable words, prayer of humble access, formulae of administration and the concluding peace, much as they exist at present.

The First Complete Prayer Book.—The first complete vernacular Book of Common Prayer was issued in Jan. 1549. An Act of Uniformity made its use compulsory on and after the following Whit-Sunday. Some of the chief points of difference between this and subsequent Prayer Books were the following: Matins and Evensong began with the Lord's Prayer, and ended with the third collect; the Athanasian Creed was introduced after the Benedictus on six festivals only, and in addition to the Apostles' Creed; to the Communion service an alternative title was given, viz.: "commonly called the Mass." Introits were provided for use on every Sunday and Holy-Day; in the prayer for the whole state of Christ's church, the blessed Virgin Mary was commemorated by name; prayer for the dead was explicitly retained; also an invocation of the Holy Spirit before the words of institution, the prayer of oblation immediately following them; the mixed chalice was ordered to be used, and the Agnus Dei to be sung during the Communion of the people; unleavened bread was to be used and placed in the mouth of the communicant; the sign of the cross was frequently to be made; reservation for the sick and unction of the sick were retained; and exorcism, unction, trine immersion and the chrisom were included in the baptismal service. As to vestments, at Holy Communion the officiating priest was to wear "a white albe plain with a vestment or cope," and the assistant clergy were to wear "albes with tunicles." Whenever a bishop was celebrant he was to wear, "beside his rochette, a surplice or albe, and a cope or vestment"; the mitre was not mentioned.

The ordinal was added to this Prayer Book in 1550 by another act of parliament. It included the deliverance to the newly ordained priest of the chalice or cup, with the bread.

Second Prayer Book.—In 1552 a new and revised edition was introduced by an act of parliament which ordered that it should come into use on All Saints' Day (Nov. 1). This represents the most Protestant position ever reached in the Prayer Book. The chief alterations were: (1) the introductory sentences, exhortation, confession and absolution were to be read at the beginning of the order for morning and evening prayer; (2) in the order for Holy Communion the alternative title "commonly called the Mass" was left out; the introits were omitted, the Gloria in Excelsis was transferred from near the beginning to near the end of the service; the ten commandments with an expanded Kyrie eleison were introduced; the long new English canon of 1549 was split up into three parts—the prayer for the church militant, the prayer of consecration and prayer of oblation, becoming a post-Communion collect; the epiklesis or invocation of the Holy Ghost upon the elements was entirely omitted; the mixed chalice, the use of the sign of the cross in the consecration prayer; the commemoration of the blessed Virgin Mary and of various classes of saints were omitted; the words of administration in the 1549 book were abolished, viz.: "The body of our Lord Jesus Christ which was given for thee, preserve thy body and soul unto everlasting life," and "The blood of our Lord Jesus Christ which was shed for thee preserve thy body and soul unto everlasting life," and the following words were substituted: "Take and eat this in remembrance that Christ died for thee, and feed on him in thy heart by faith, with thanksgiving," and "Drink this in remembrance that Christ's blood was shed for thee, and be thankful;" a long rubric was added at the end of the service explanatory of the attitude of kneeling at the reception of Holy Communion, in which it was stated that "it is not meant hereby that any adoration is done, or ought to be done, either unto the sacramental bread and wine there bodily received, or to any real and essential presence there being of Christ's natural flesh and blood," etc.; exorcism, unction, trine immersion and the chrisom were omitted from the baptismal service; unction and communion with the reserved sacrament were removed from the services for the visitation and the communion of the sick; prayers for the dead and provision for a celebration of Holy Communion at a funeral were removed from the burial service; the vestments retained and ordered under the Prayer Book of 1549 were abolished by a new rubric which directed that both at the time of Communion and at all other times of ministration a bishop should wear a rochet and that a priest or deacon should have and wear a surplice only; on the other hand, the directions as to daily service were extended to all clergy and made much stricter, and the number of days on which the Athanasian Creed was to be used was raised from six to thirteen.

The main objects of these drastic alterations have been thought to have been two-fold: to abolish all ritual for which there was not scriptural warrant; and to make the services as unlike the pre-Reformation services as possible. The alterations were violent enough to alarm and offend the Catholic party, but they were not violent enough to satisfy the extreme Puritan party, who would no doubt have agitated for and would probably have obtained still further reformation and revision. This Prayer Book only lived for eight months. It came into use on All Saints' Day (Nov. 1) 1552, and on July 6, 1553, Edward VI. died and was succeeded by his sister Mary, under whom the Prayer Book was abolished and the old Latin services and service books resumed their place.

Act of Uniformity.—On the death of Queen Mary and the accession of her sister Elizabeth (Nov. 17, 1558) all was reversed, and the Book of Common Prayer was restored into use again. The Act of Uniformity, which obtained final parliamentary authority on April 28, 1559, ordered that the Prayer Book should come again into use on St. John the Baptist's Day (June 24, 1559). This was the second Prayer Book of King Edward VI., with few but important alterations, which, like all the alterations introduced at subsequent dates into the Prayer Book, were in a Catholic rather than in a Protestant direction. Morning and Evening Prayer were directed to be "used in the accustomed place of the church, chapel or chancel," instead of "in such place as the people may best hear"; the eucharistic vestments ordered in the first Prayer Book of Edward VI. were brought back by a new rubric which directed that "the minister at the time of the communion and at all other times in his ministration, shall use such vestments in the church as were in use by authority of parliament in the second year of the reign of King Edward the VI. according to the act of parliament set in the beginning of this book; in the Litany the following petition found in both the Edwardian Prayer Books was omitted "from the tyranny of the bishop of Rome and all his detestable enormities, good Lord deliver us;" in the Communion service the two clauses of administration found in the first and

second Prayer Books of King Edward's reign were combined; the rubric explanatory of "kneeling for reception," commonly known as "the Black Rubric" was omitted; in the Ordinal in the rubric before the oath of the queen's sovereignty the words "against the power and authority of all foreign potentates" were substituted for "against the usurped power and authority of the Bishop of Rome," and in the oath itself four references to the bishop of Rome, by name, were omitted.

A smouldering and growing Puritan discontent with the Prayer Book, suppressed with a firm hand under Queen Elizabeth, burst out into a flame on the accession of King James I. in 1603. A petition called the millenary petition, because signed by no less than 1,000 ministers, was soon presented to him, asking, among other things, for various alterations in the Prayer Book and specifying the alterations desired. As a result the king summoned a conference of leading Puritan divines, and of bishops and other leading Anglican divines, which met under his presidency at Hampton Court in Jan. 1604. After both sides had been heard, certain alterations were determined upon and were ordered by royal authority, with the general assent of Convocation. These alterations were not very numerous nor of great importance, but such as they were they all went in the direction of catholicizing rather than of puritanizing the Prayer Book; the one exception being the substitution of some chapters of the canonical scriptures for some chapters of the Apocrypha, especially of the book of Tobit. Alterations were introduced into the service for the private baptism of children in houses, with the object of doing away with lay baptism and securing the administration by the minister of the parish, or some other lawful minister; and the concluding portion of the Catechism, consisting of 11 questions on the sacraments, was now added.

The next important stage in the history of the Prayer Book was its total suppression in 1645 for a period of 15 years, "the Directory for the Public Worship of God in the Three Kingdoms" being established in its place. The restoration of King Charles II. in 1660 brought with it toleration at once. Nonconformists pressed upon the king, either that the Prayer Book should not be re-introduced, or that if it were re-introduced, features which they objected to might be removed. The result was that a conference was held in 1661, known from its place of meeting as the Savoy Conference. The objections raised from the Nonconformist point of view were numerous and varied, but they were thoroughly discussed between the first meeting on April 15 and the last on July 24, 1661; the bishops agreeing to meet the Puritan wishes on a few minor points but on none of fundamental importance. Later in the year, between Nov. 20 and Dec. 20, Convocation assembled and undertook the revision of the Prayer Book. In the earlier part of the following year the book so revised came before parliament. No amendment was made in it in either house and it finally received the royal assent on May 19, 1662, being annexed to an Act of Uniformity which provided for its coming into general and compulsory use on St. Bartholomew's Day (Aug. 24).

The alterations thus introduced were very numerous, amounting to many hundreds and many of them were more important than any which had been introduced into the Prayer Book since 1552. Their general tendency was distinctly in a Catholic as opposed to a Puritan direction, and the 2,000 Puritan incumbents who vacated their benefices on St. Bartholomew's Day rather than accept the altered Prayer Book bear eloquent testimony to that fact. Among the important alterations, the following may be named as of special interest.

(*a*) The preface "It hath been the wisdom of the Church of England," etc., composed by Sanderson, bishop of Lincoln, was prefixed to the Prayer Book. (*b*) The authorized version of the Bible of 1611 was taken into use, except in the case of the Psalms, where the great Bible of 1539–1540 was retained as much smoother for singing, and in parts of the Communion service. (*c*) The rubric preceding the absolution in Morning and Evening Prayer, viz.: "The absolution to be pronounced by the minister alone," was altered into "The Absolution, or Remission of Sins, to be pronounced by the priest alone, standing; the people still kneeling." (*d*) In the Litany the phrase "Bishops, Pastors and Ministers of the Church," was altered into "Bishops, Priests and Deacons," and in the clause commencing "From all sedition and privy conspiracy," etc., the words "rebellion" and "schism" were added. (*e*) In the Communion service two rubrics were prefixed to the prayer "for the whole state of Christ's Church militant here in earth" ordering the humble presentation and placing of the alms upon the Holy Table, and the placing thereon then of so much Bread and Wine as the priest shall think sufficient; and the commemoration of the departed was added to the prayer itself. (*f*) The rubric explanatory of the posture of kneeling for reception, known as the Black Rubric, which had been added in 1562, but omitted in 1559 and 1604, was re-introduced; but the words "to any real and essential presence there being of Christ's natural flesh and blood" were altered to "unto any Corporal Presence of Christ's natural Flesh and Blood"—a very important and significant alteration which affected the meaning of the whole rubric. (*g*) A new office was added for the Ministration of Baptism to such as are of riper years. (*h*) A rubric was prefixed to the Order for the Burial of the Dead, forbidding that order to be used "for any that die unbaptized, or excommunicate, or have laid violent hands upon themselves." (*i*) In the "Ordering of Priests," and "the Consecration of Bishops," in the formula for ordination, after the words, "Receive the Holy Ghost," these words were added "for the Office and Work of a Priest (or Bishop) in the Church of God, now committed unto thee by the Imposition of our hands."

No substantial alteration has been made in the Prayer Book since 1662. But in 1859 the special services prescribed for Nov. 5, Jan. 30 and May 29 (which had an essential political significance) were abolished by royal warrant, chronicled as having obtained the sanction of the Convocations of Canterbury and York, and also legal force by act of parliament. In 1871 a revised Lectionary was substituted for the previously existing one, into the merits and demerits of which it is not possible to enter here; and in 1872, by the Act of Uniformity Amendment Act, a shortened form of service was provided instead of the present form of Morning and Evening Prayer for optional use in other than cathedral churches on all days except Sunday, Christmas Day, Ash Wednesday, Good Friday and Ascension Day; provision was also statutably made for the separation of services, and for additional services, to be taken, however, except so far as anthems and hymns are concerned, entirely out of the Bible and the Book of Common Prayer. In 1901 new forms of prayer, with Thanksgiving, were prepared by Convocation and authorized by royal warrant, and in 1922 a new Lectionary was issued for use in morning and evening prayer throughout the year.

Movements for Revision.—Since 1910 there has been a great movement for the revision of the Prayer Book in almost all branches of the Anglican Church. In *Scotland* some suggestions were made in the Synod of 1911, when a schedule of permissible variations to, and deviations from, the Prayer Book was drawn up, and a revised text of the Scottish liturgy was authorized. In 1919 a more complete revision was undertaken by the consultative council on Church legislation, a body consisting of bishops, clergy and laity sitting together without legislative power. The result of its labours from 1919 to 1924 was contained in a series of reports. In *America* revision was inaugurated in 1913 by the appointment of a Revision Commission of the General Convention, consisting of seven bishops, seven presbyters and seven laymen. The work had been going on continuously since then until, in 1925, the last stages were reached. A considerable number of the changes have been already ratified, and, after the ratification of the changes, approved in Oct. 1925, at New Orleans by the General Convention, in 1928 a Prayer Book according to the standard of 1928 will be published. In *South Africa* two tentative alternative uses for the Communion Office were put forward. This was followed by the definite issue of an alternative liturgy, which was sanctioned for use in the province at a provincial synod held in 1924, to be used when desired by the priest and people in the parish. In *Canada* a new Prayer Book has been issued. It carefully avoids making any changes in the Communion Office or

any changes involving doctrine, but adds a large number of services adapting the worship of the Church to the needs of the day. In *Ireland* a new revision is being undertaken for which a committee was appointed in 1909.

Proposals were made for a revision of the English Prayer Book on the accession of William III. in 1689, but they came to nothing. The subject was much to the fore between 1857 and 1863. Revision proposals were made in 1879, but came to nothing. The later movement for revision dates from the Royal Commission which was appointed on April 23, 1904, to inquire into "the alleged prevalence of breaches or neglect of the law relating to the conduct of Divine Service in the Church of England." This reference inevitably led to the consideration of a general revision of the book; and Convocation took up this task in 1906, though it was stated that it is not desirable at present to introduce into the text of the Prayer Book any changes, but they should be embodied in another volume to be sanctioned for optional use for a determined period. The work of revision went on for many years. The whole matter went through the hands of each House of Convocation separately, of the Joint Committee of both Provinces and then of each House again.

The result of this work was taken up by the Church Assembly when it was formed. A committee was appointed and the report of the Assembly on the revision of the Prayer Book was ultimately published under the auspices of the National Assembly (N.A.84). But when the moderate and somewhat conservative proposals which had been put forward by Convocation appeared in the fuller light of the Assembly many new factors came into consideration and different groups or parties in the Church took the matter of revision up with great keenness, so there was issued a series of new proposals. These were contained in the Green Book, issued by the English Church Union, the Grey Book, issued by a committee which was supposed to represent the Life and Liberty Movement, the Yellow Book, issued under the auspices of the Alcuin Club, an attempt to embody these suggestions in one book, and some white papers, representing a still more extreme view.

Reasons for Revision.—It may be convenient to sum up the reasons for the amendment of the Prayer Book. Speaking generally, they are the desire to adapt a book which dates from 1662 to the needs of the time. (1) A desire to do away with old-fashioned expressions, phrases unsuitable to the taste of the time, and statements inconsistent with modern thought. On this point there is considerable variation of opinion, many being attached even to the archaisms of the Prayer Book, others finding them difficult or even offensive. (2) A desire to adapt the Prayer Book to the changed usages of the Church which have gradually grown up, to accommodate law to custom. (3) Some desire that the Prayer Book should be revised so as to make the restoration of law and order in the Church possible. It is recognized that the existing Prayer Book cannot reasonably be obeyed in various points. It is proposed that there should be a rule of worship adapted to the present time with a reasonable latitude in the way of variations allowed, and that this should be enforced on the clergy. (4) There is a great desire to adapt the Prayer Book to the far wider religious and social aspirations of the present day. There is a great demand that religious worship should be brought much more closely into touch with the life of the people. (5) A desire felt, particularly by one party in the Church, arising from the great growth among them of sacramental ideas of worship. It is desired to give far greater opportunity for this in the new Prayer Book, and to accommodate it more closely to the traditional liturgical customs of the Church.

The final proposals embodied in the revised Prayer Books submitted to parliament in 1927 and 1928, and the events which ensued, are dealt with in ENGLAND, CHURCH OF: *Prayer Book Revision.*

BIBLIOGRAPHY.—The following additional references, on the history of the Book of Common Prayer to the end of the 19th century, may be given here. W. Palmer, *Originès Liturgicae*, 4th ed. (1845); J. H. Blunt, *Annotated Book of Common Prayer* (1866); H. B. Swete, *Church Services and Service Books before the Reformation* (1896); L. Pullan, *History of the Book of Common Prayer* (1900); F. E. Brightman, *The English Rite* (1915); and *The Prayer Book Dictionary* (1912). (F. E. WA.; A. C. HE.; X.)

PRAYERS FOR THE DEAD. Wherever there is a belief in continued existence through and after death, religion naturally concerns itself with the relations between the living and the dead. In the ancient practices and doctrines of the Judaeo-Christian tradition prayers for the dead have an important place. The practice of the Old Testament Jews is expressed in II Mac. xii:43–44, where it is related that Judas sent "twelve thousand drachmas of silver to Jerusalem for sacrifice to be offered for the sins of the dead. . . . It is a holy and a wholesome thing to pray for the dead that they may be loosed from sin." The Gospels are not explicit in the matter but indications of early Christian practice are found in the letters of St. Paul. In I Cor. xv:29, he refers to the custom of Christians being baptized for those who had died without baptism. This at least bears witness to their belief in the efficacy of works for the dead. In II Tim. i:16–18 Paul seems to pray for Onesiphorus, then dead. Outside the Bible, early use of prayers for the dead is found in the inscription on the tomb of Abercius of Hieropolis in Phrygia (*see* Lightfoot, *Apostolic Fathers*, vol. i): "Let every friend who observeth this pray for me," *i.e.*, *Abercius*, who died in the latter part of the second century. The inscriptions in the Roman catacombs bear similar witness to the practice, by the occurrence of such phrases as "Mayest thou live amongst the saints" (3rd century); "May God refresh the soul of . . ."; "Peace be with them." Among Church writers Tertullian is the first to mention prayers for the dead: "The widow who does not pray for her dead husband has as good as divorced him" (beginning of the 3rd century). Subsequent writers similarly make incidental mention of the practice as prevalent, but not as unlawful or even as disputed (until Aerius challenged it towards the end of the 4th century). The most famous instance is St. Augustine's prayer for his mother, Monnica, *Confessions* (Bk. ix).

An important element in the liturgies of the various churches consisted of the diptychs or lists of names of living and dead who were to be commemorated at the Eucharist. To be inserted in these lists was an honour, and it was out of this practice that the canonization of saints grew. In the third century we find Cyprian enjoining that there should be no oblation or public prayer made for a deceased layman who had broken a Church rule by appointing a cleric trustee under his will: "He ought not to be named in the priest's prayer who has done his best to detain the clergy from the altar." The universal occurrence of these diptychs and of definite prayers for the dead in all parts of the Church in the 4th and 5th centuries tend to show how primitive such prayers were. The language used in the prayers reflects the Old Testament, suggesting the continuance of an ancient Jewish tradition. We may cite from the so-called liturgy of St. James:—

"Remember, O Lord, the God of spirits and of all flesh, those whom we have remembered and those whom we have not remembered, men of the true faith, from righteous Abel unto to-day; do thou thyself give them rest there in the land of the living, in thy kingdom, in the delight of Paradise, in the bosom of Abraham, Isaac and Jacob, our holy fathers, from whence pain and sorrow and sighing have fled away, where the light of thy countenance visiteth them and always shineth upon them."

Public prayers were offered only for those who were believed to have died as faithful members of Christ. This restriction on public prayers is still enforced by the laws of the Roman Catholic Church. But where there is no danger of scandal, permission is explicitly given to offer prayers and the sacrifice of the mass privately for heretics and schismatics (*Codex Juris Canonici*, 809; 2262). Theologians commonly teach that this permission extends also to the case of mass, and *a fortiori* prayers, offered for infidels (*cf.* Cappello, *De Sacramentis* (1928), vol. i, n. 619).

With the development of doctrine in the Catholic Church the foundations for the practice of prayers for the dead became more clearly defined. It is seen as the consequence of (a) the doctrine that purification from sin requires, beyond divine forgiveness, a satisfaction on man's part that is offered by good works in life or by a period of suffering after death; and (b) the doctrine that the prayers and good works of the living can benefit the souls of the dead who have not offered complete satisfaction for the sins

whose guilt has been remitted. The authoritative statement of the Catholic Church's doctrine is in the *Decree for the Greeks* from the Council of Florence: "Likewise, if those who have truly repented of their sins have died in the charity of God before they have satisfied with fruits worthy of penance for their sins . . . , their souls are cleansed after death by purifying pains; of great benefit to them for relief from these pains are the suffrages of the faithful still alive, *i.e.*, the sacrifice of the mass, prayers and alms-deeds and other good works. . . ." (Denzinger, *Enchiridion Symbolorum*, 693). These doctrines on the existence of purgatory and the related doctrine on indulgences (*q.v.*) were opposed by the leaders of the Protestant reformation; consequently, they were inclined to disuse all prayers for the dead.

In the English communion service of 1549, after the offering of praise and thanks for all the saints, came the following: "We commend into thy mercy all other thy servants, which are departed hence from us with the sign of faith and now do rest in the sleep of peace: grant unto them, we beseech thee, thy mercy and everlasting peace." The burial service of the same date also contained explicit prayers for the deceased. In 1552 all mention of the dead, whether commemorative or intercessory, was cut out of the Eucharist; the prayers in the burial service were brought into their present form; and the provision for holy communion at a burial was omitted. The thankful commemoration of the dead in the Eucharist was restored in 1662, but prayers for them remained, if they remained at all, veiled in ambiguous phrases.

The Church of England has, however, never forbidden prayers for the dead. It was proposed in 1552 to condemn the Roman doctrine *de precatione pro defunctis* in what is now the 22nd of the Thirty-Nine articles, but the proposal was rejected. And these intercessions have been used in private by a long list of English divines, *e.g.*, Andrewes, Cosin, Ken, Wesley and Keble. In a suit (1838) as to the lawfulness of an inscription "Pray for the soul of . . .," the Court held that "no authority or canon has been pointed out by which the practice of praying for the dead has been expressly prohibited."

See H. M. Luckock, *After Death* (1886); E. H. Plumptre, *The Spirits in Prison* (1886); H. B. Swete, "Prayers for the Departed in the First Four Centuries," *Jour. Theol. Stud.* viii.; Arts. "Prayers for the Departed" in Hastings' *Encyc. Rel. Eth.* and "Dead, Prayers for the" in *Cath. Encyc.*

PRAYING WHEEL, used by the Buddhists of Tibet as a means of offering invocations. The smallest kind consists of a cylinder of metal or other substance turning on a handle as pivot. Outside it and on strips of paper within is inscribed the invocation to Avalokiteśvara or his consort, *Oṃ Maṇipadme hūṃ*. A weight hangs at the side, and with a slight movement of the hand the cylinder revolves. Larger wheels are made to revolve by means of wind or water.

PREACHING, the proclamation of a Divine message, and the regular instruction of the converted in the doctrines and duties of the faith, is a distinctive though not a peculiar feature of the Christian religion. The Mohammedans exercise it freely, and it is not unknown among the Buddhists. The history of Christian preaching with which alone this article is concerned has its roots (1) in the activity of the Hebrew prophets and scribes, the former representing the broader appeal, the latter the edification of the faithful, (2) in the ministry of Jesus Christ and His apostles, where again we have both the evangelical invitation and the teaching of truth and duty. Whichever element is emphasized in preaching, the preacher is one who believes himself to be the ambassador of God, charged with a message which it is his duty to deliver.

The Patristic Age, to the Death of St. Augustine, 430.—From the Acts of the Apostles we gather something as to the methods adopted by St. Peter and St. Paul, and these we may believe were more or less general. The Apostles who had known the Lord would naturally recall the facts of His life, and the story of His words and works would form a great deal of their preaching. It is not until we come to Origen (d. 254) that we find preaching as an explanation and application of definite texts, a usage that Christianity adopted from Greek rhetoricians. The fourth century marks the culmination of early Christian preaching. In an age of doctrinal controversy, the intellectual presentation of the Christian position was thus developed. Preaching flourished chiefly in the East; especially noteworthy are the three Cappadocians, Basil (*q.v.*) of Caesarea, cultured, devout and practical; his brother Gregory (*q.v.*) of Nyssa, more inclined to the speculative and metaphysical; and Gregory (*q.v.*) of Nazianzus, richly endowed with poetic and oratorical gifts, the finest preacher of the three. Foremost of all stands John of Antioch, Chrysostom (*q.v.*), who in 386 began his 12 years' ministry in his native city, and in 398 the six memorable years in Constantinople, where he loved the poor, withstood tyranny and preached with amazing power. In the West the allegorical method of Alexandria had more influence than the historical exegesis cultivated at Antioch. This is seen in Ambrose of Milan and in Hilary of Poitiers. But the only name of first rank in preaching is that of Augustine, and even he is curiously unequal. His fondness for the allegorical and his manifest carelessness of preparation disappoint as often as his profundity, his devout mysticism and his practical application attract and satisfy. Augustine's *De doctrina Christiana*, bk. iv., is the first attempt to formulate the principles of homiletics.

The Middle Ages.—After the days of Chrysostom and Augustine there was a great decline of preaching. The West did better than the East: at Rome Leo the Great and Gregory the Great could preach, and the missionaries Patrick, Columba, Columbanus, Augustine, Wilfrid, Willibrord, Gall and Boniface are known by their fruits. Then came the age when the papacy was growing out of the ruins of the old Roman empire, and the best talents were devoted to the organization of ecclesiasticism rather than to the preaching of the Word. But certain forces were at work which were destined to bring about a great revival, *e.g.*, the rise of the scholastic theology, the reforms of Pope Hildebrand and the preaching of the First Crusade by Pope Urban II. (d. 1099) and Peter the Hermit. In the 12th century the significant feature is the growing use of the various national languages in competition with the hitherto universal Latin. The most eminent preachers of the century were Bernard of Clairvaux (1091–1153), the two mystics of St. Victor, Hugo and Richard, and Peter Waldo of Lyons, who preached a plain message to the poor and lowly. The 13th century saw the culmination of mediaeval preaching, especially in the rise of the two great mendicant orders of Francis and Dominic. Representative Franciscan names are Antony of Padua (d. 1231), who travelled and preached through southern Europe; Berthold of Regensburg (d. 1272), who, with his wit and pathos, imagination and insight, drew huge crowds all over Germany; and Francis Bonaventura, the schoolman and mystic, who wrote a little book on *The Art of Preaching*. Of the Dominicans Thomas Aquinas (d. 1274), the theologian, was perhaps also the greatest preacher. With the 14th century a new note, that of reformation, is struck; but on the whole there was a drop from the high level of the 13th. Among the popular preachers vigour was often blended with coarseness and vulgarity. Mysticism is represented by Suso, Meister Eckhart, above all Johann Tauler (*q.v.*) of Strasbourg (d. 1461), a true prophet in an age of degeneration. Towards the close of the century comes John Wycliffe (*q.v.*) and his English travelling preachers, who passed the torch to Hus and the Bohemians, and in the next age Savonarola.

The Reformation Period, 1500–1700.—The Reformers gave the sermon a higher place in the ordinary service than it had previously held, and they laid special stress upon the interpretation and application of scripture. The controversy with Rome, and the appeal to the reason and conscience of the individual, together with the spread of the New Learning, gave preaching a new force and influence which reacted upon the old faith. Most of the Reformation preachers read their sermons, in contrast to the practice of earlier ages. The English Book of Homilies (*see* HOMILY) was compiled because competent preachers were comparatively rare.

The 17th-century preaching was, generally speaking, a continuation of that of the 16th century, the pattern having been set by the Council of Trent and by the principles and practice of the Reformers. In Spain and Germany, however, there was a decline of power, in marked contrast to the vigour manifested in France

and England. In France, indeed, the Catholic pulpit now came to its perfection, stimulated, no doubt, by the toleration accorded to the Huguenots up to 1685 and by the patronage of Louis XIV. The names of Bossuet, Fléchier, Bourdaloue, Fénelon and Massillon, all supreme preachers, despite a certain artificial pompousness, belong here, and on the reformed side are Jean Claude (d. 1687) and Jacques Saurin (d. 1730). In England, among Anglicans, are Andrewes, Hall, Chillingworth, Jeremy Taylor, Barrow and South; among Puritans and Nonconformists, Baxter, Calamy, the Goodwins, Howe, Owen and Bunyan. The sermons of these men were largely scriptural, the cardinal evangelical truths being emphasized with reality and vigour, but with a tendency to abstract theology rather than concrete religion.

The early years of the 18th century were a time of torpor as regards preaching. Generally speaking, sermons were unimpassioned, stilted and formal presentations of ethics and apologetics, seldom delivered extempore.

The Modern Period.—This dates from 1738, the year in which John Wesley began his memorable work. The example and stimulus given by him and by Whitefield were almost immeasurably productive. In their train came the great field preachers of Wales, like John Elias and Christmas Evans, and later the Primitive Methodists, who by their camp meetings and itinerancies kept religious enthusiasm alive when Wesleyan Methodism was in peril of hardening. Meanwhile, in America the Puritan tradition, adapted to the new conditions, is represented by Cotton Mather, and later by Jonathan Edwards, the greatest preacher of his time and country. Whitefield's visits raised a band of pioneer preachers, cultured and uncultured, men who knew their Bibles but often interpreted them awry.

Preaching, in modern times, has been so varied, depending, as it largely does, on the personality of the preacher, that it is not possible to speak of its characteristics. Nor can one do more than enumerate a few outstanding modern names, exclusive of living preachers. In the Roman Catholic Church are the Italians Ventura and Curci, the Germans Diepenbrock and Foerster, the French Lacordaire, Dupanloup, Loyson (Père Hyacinthe) and Henri Didon. Of Protestants, Germany produced Schleiermacher, Claus Harms, Tholuck and F. W. Krummacher; France, Vinet and the Monods. In England representative Anglican preachers were: Newman (whose best preaching preceded his obedience to Rome), T. Arnold, F. W. Robertson, Liddon, Farrar, Magee; of Free Churchmen, T. Binney, R. W. Dale, Joseph Parker and J. H. Jowett (Congregationalist); Robert Hall, C. H. Spurgeon, Alexander Maclaren and John Clifford (Baptists); W. M. Punshon, Hugh Price Hughes, Peter Mackenzie and W. L. Watkinson (Wesleyan); James Martineau (Unitarian). The Scottish churches gave Edward Irving, Thomas Chalmers, R. S. Candlish, R. M. McCheyne and John Caird. In America, honoured names are those of W. E. Channing, Henry Ward Beecher, Horace Bushnell, Phillips Brooks, to mention only a few.

See A. E. Garvie, *The Christian Preacher* (1920), a comprehensive survey with full bibliography. (A. J. G.)

PREADAMITES, a term signifying either (1) human races existent before Adam or (2) a 17th century Christian sect that professed belief in such races. The sect was inspired by Isaac La Peyrère's *Prae-Adamitae* (1655), which interpreted Paul's *Epistle to the Romans* (v. 12–14) to mean that, since "sin was in the world" before the law (that given to Adam), then there must have been human beings to sin. These were the Gentiles, whose creation is described in *Genesis* i., while Adam ("man") the first of the Jews, is not mentioned until *Genesis* ii.

PREAMBLE, a term particularly applied to the opening paragraph of a statute which summarizes the intention of the legislature in passing the measure. The procedure in the British parliament differs in regard to the preambles of public and private bills. The second reading of a public bill affirms the principle, and therefore in committee the preamble stands postponed till after the consideration of the clauses, when it is considered in reference to those clauses as amended and altered if need be (Standing Order 35). On the other hand, the preamble of a private bill, if opposed, is considered first in committee, and counsel for the bill deals with the expediency of the bill, calls witnesses for the allegation in the preamble, and petitions against the bill are then heard; if the preamble is negatived the bill is dropped, if affirmed it is gone through clause by clause. On unopposed private bills the preamble has also to be proved, more especially with regard to whether the clauses required by the standing orders are inserted (*see* May, *Parliamentary Practice*).

PREANGER (Priangan), a district in the southwest of Java, Netherlands Indies, part of the province of West Java. Formerly one residency—the Preanger Regencies—it was divided into two residencies, Buitenzorg and Preanger. They are bounded north by Cheribon and Batavia, west by Bantam, east by Banjumas and Cheribon and south by the Indian ocean. Pop. (1930): Buitenzorg 2,212,997, Preanger 3,448,796. The natives are Sundanese. The whole district is mountainous, and contains a large number of both active and inactive volcanoes, including the well-known Salak and Gedeh in the north, and bunched together at the eastern end the Chikorai, Papandayan, Wayang, Malabar, Guntur, etc., ranging from 6,000 to 10,000 ft.

The greatest rivers are the Chi Manuk and the Chi Tarum, both rising in the eastern end of the province and flowing northeast and northwest respectively to the Java sea, and the Chi Tandui, flowing southeast to the Indian ocean. Crater lakes are Telaga (lake) Budas, in the crater of the volcano of the same name in the southeast, and Telaga Warna, on the slopes of the Gedeh, famous for its beautiful tinting. There are also other small lakes—Bagendit, Leles, Penjalee, etc. On the side of the Gedeh is the health resort of Sindanglaya (3,500 ft.), with a mineral spring containing salt.

Numerous warm springs are scattered about this volcanic region. The soil is in general very fertile, the principal products being rice, maize, cassava and pulse (*kachang*) and rubber in the lower grounds, and cinchona, coffee and tea, as well as cocoa, coca, tobacco and fibrous plants in the hills. The coffee cultivation has, however, diminished considerably. Irrigation works have been carried out in various parts. The principal towns are Bandung, the capital of Preanger; Buitenzorg, the site of world-famous botanical gardens; Sukabumi (34,191); Tasikmalaja (25,605) with its native wicker industry and Chianjur (20,812), Sumedang, Chibatu, Chichalengka, Garut and Manon Java; all with the exception of Sumedang connected by railway. The Preanger became Dutch in 1704, after the trouble with Susuhunan, Amangku Rat II. From the time of the British reform of the administration in Java by Sir Stamford Raffles (1811–16), it was known generally as the Preanger Regencies.

The district of Preanger was occupied by the Japanese in March 1942.

PRE-CAMBRIAN. The Pre-Cambrian, as the name implies, includes all rock formations older than the basal beds of the Cambrian, the earliest period of the Palaeozoic era. Throughout most of the world where the contact of the Cambrian and Pre-Cambrian is exposed, a great unconformity or gap in the succession of formations separates the Cambrian from the Pre-Cambrian. In a few regions, however, there seems to be no unconformity, the Cambrian beds passing without interruption downward into strata believed to be of Pre-Cambrian Age. Most of the Cambrian and later strata of the Palaeozoic contain numerous fossils—evidence of varied and abundant life—in contrast with this there are almost no fossils in the Pre-Cambrian.

Wherever erosion has removed the Palaeozoic and later formations, Pre-Cambrian rocks are usually present. They are exposed over one-fifth of the land surface of the earth but, except where intruded by igneous rocks of later age, exist everywhere at depth beneath Palaeozoic and later strata. They occur in areas of two kinds: (1) the deeply denuded interior parts of mountain chains where they have been uplifted by mountain building, and (2) in the widely extended areas of relatively low elevation called shields because of their regional gentle slopes resembling roughly the surface of a shield. The occurrences is mountain chains are much more restricted in extent than in the shield areas.

The formations of the Pre-Cambrian are, for the most part, highly folded and intruded by masses of granite, granite gneiss,

and other igneous rocks, most of which came in at depth as the Pre-Cambrian mountain-building folding was in progress. On the margins of the Pre-Cambrian shield areas, Cambrian and later beds in many places lie on the upturned edges of Pre-Cambrian strata. This relationship shows that prior to the Cambrian, the Pre-Cambrian mountains were worn down to a relatively low land area over which the Cambrian sea advanced.

Although most of the Pre-Cambrian rocks have been subjected to the deformation and alteration that accompanies mountain building, many of the shield areas have suffered little change through all the later eras, and original structures even of the earliest Pre-Cambrian have been remarkably well preserved. It has been found possible in many Pre-Cambrian regions, by means of detailed mapping, to determine the structural succession of formations over considerable areas, but only a relatively small part of the Pre-Cambrian has been mapped in this way, and because of the absence of fossils, much intensive geological work will be necessary before the rocks can be correlated extensively with certainty even within most of the separate Pre-Cambrian areas.

The discovery that radioactive elements slowly disintegrate into helium and lead affords a way in which the approximate age of Pre-Cambrian rocks can be determined. From the time a uranium-bearing mineral is formed, its uranium slowly breaks up and a residue of lead is left behind. As the rate of disintegration of uranium is known, it is possible to determine the age of the mineral from the amount of lead relative to uranium present. Many pegmatites and other igneous rocks of the Pre-Cambrian contain uranium-bearing minerals, the oldest of which was determined in 1931 to have an age of about 1,800,000,000 years. The rocks in which these occur, however, are intrusive into older rocks, and it has been estimated that the oldest Pre-Cambrian rocks on the earth's surface have an age of at least 2,000,000,000 years.

For all of Pre-Cambrian time of which there is a geological record, conditions on the surface of the earth appear to have been similar in most respects to those of later eras. Mountain building and volcanic activity recurred as in the later periods of the earth's history; water played the same role then as it does today; rocks were deeply eroded and conglomerates, sandstones and other sediments were deposited in the same manner as at the present time. There is evidence also that ice sheets similar to the one now covering most of Greenland occurred in Canada, India, South Africa, Australia and elsewhere.

Economic Importance.—Because most valuable mineral deposits are found in association with the igneous rocks of deeply denuded mountainous or formerly mountainous regions, the Pre-Cambrian parts of the earth's surface are of special economic importance. Most of the world's largest gold mines, those of the Transvaal and Southern Rhodesia in Africa, South Dakota in the United States, northern Ontario and Quebec in Canada, Brazil and Western Australia, are all in Pre-Cambrian rocks. The important iron deposits of the Lake Superior region in the U.S., the iron deposits of Labrador, the iron ores of Brazil and northern Sweden, the great nickel-copper ore masses of Sudbury, Ont., the silver-bearing cobalt-nickel veins of Cobalt, Ont., and many important copper deposits belong to the Pre-Cambrian. It also includes a great variety of useful nonmetallic minerals. Among these are garnet, talc, mica, graphite, feldspar, and magnesite.

North America.—Pre-Cambrian rocks occur in North America mainly in the Canadian Pre-Cambrian shield that occupies most of the northeastern part of the continent. They also occur, however, in scattered areas in the western or cordilleran part and in places in the eastern belt of folded rocks that extends from Alabama to Newfoundland.

The Canadian shield is the world's largest area underlain by Pre-Cambrian rocks. It includes most of northeastern Canada, the greater part of Greenland and extensions into the United States west and south of Lake Superior, and in northern New York state. It has a total area of about 2,780,000 sq.mi., of which about 800,000 are in Greenland, 1,905,000 in Canada, and 75,000 in the U.S.

The limitations of the shield are sharply defined on the east, except in east Greenland, by the Atlantic ocean, and on the south and west by south- and southwestward-dipping sediments of later, chiefly Palaeozoic, age that outcrop in a succession of alternating lowland and north- or northeast-facing scarp belts, but on the north the boundary is less definite, the Pre-Cambrian surface disappearing first beneath scattered remnants and finally beneath a most irregular border of Palaeozoic or later sediments.

Only a very small part of the shield had been mapped geologically in detail by mid-20th century, but in its southern part the formations belong definitely to two major groups, the Archaean or Early Pre-Cambrian and the Proterozoic or Late Pre-Cambrian. The major break in deposition, or unconformity, that separates the Archaean from the Proterozoic was originally observed in 1845 on Lake Timiskaming by Sir William Logan, first director of the Canadian Geological survey, and was later found to extend with reasonable certainty from Lake Mistassini in northern Quebec to the region south of Lake Superior, a distance of more than 900 mi. The northern parts of the shield were originally mapped largely as Archaean, but in places there are bands or areas of rock that because of their less deformed condition and lithological character are now believed to be of late Pre-Cambrian Age.

Archaean.—The Archaean formations of the Canadian shield, classified according to their lithological character and mode of origin, occur in two separate geographical parts. In the territory extending from the north end of Lake Huron to the Straits of Belle Isle, the Adirondack region in New York state, Baffin Island and Greenland, the surficial bedrock formations are limestone and associated sediments of the type laid down in the sea, whereas limestone is absent elsewhere in the shield and the predominant formations are lava flows and clastic sediments characterized by features that suggest continental deposition.

Information was still far too incomplete at mid-20th century for the preparation of a single tabular classification of the Archaean rocks of the shield that would hold for its entire area, but in the Timiskaming region of northeastern Ontario and western Quebec, where the geological mapping had been most detailed, the succession in descending order was believed to be as follows:

Classification of Archaean Rocks in Timiskaming Region

	GREAT UNCONFORMITY
Archaean	Batholithic intrusives Granite and related rocks Intrusive masses, dykes and sills Diorite, gabbro, peridotite and related rocks Timiskaming Conglomerate, graywacke and volcanic rocks
	UNCONFORMITY
Archaean	Pre-Timiskaming batholithic intrusives (represented only by pebbles in Timiskaming conglomerate) Pontiac and Hoyle groups Graywacke, mainly lava and fine-grained volcanic ejectamenta (tuff) Keewatin Lavas, volcanic fragmental rocks (agglomerate) and tuff

In the region northwest of Lake Superior the Archaean succession from youngest to oldest is the following:

Classification of Archaean Rocks Northwest of Lake Superior

	Algoman batholithic intrusives Granite and related rocks Knife Lake, Steeprock, and Seine sediments
	UNCONFORMITY
Archaean	Laurentian batholithic intrusives Granite and related rocks Keewatin Lavas Coutchiching * mica schist and gneiss of sedimentary origin (paragneiss)

* Relationship of the Coutchiching to the Keewatin uncertain

Although the above tabulation of formations is from localities more than 600 mi. apart, there is apparently considerable similarity in the successions in the two regions and, for this reason, some correlations have been attempted between them. For example the name Keewatin, first proposed for volcanic rocks occurring in the Lake of the Woods district northwest of Lake Superior by A. C. Lawson in 1885, has been used by almost all geologists for similar rocks occurring in northern Ontario and eastward into western Quebec. Some geologists have also assumed that the post-Timiskaming granites of the Timiskaming region are of the same age as the Algoman granites of the region northwest of Lake Superior and that the pebbles of granite occurring in the Timiskaming conglomerate are derived from granite of the same age as the Laurentian granite of the region northwest of Lake Superior. According to these assumptions two separate mountain-building uplifts extended across the whole southern part of the Canadian shield during the Archaean era. It is possible that detailed geological mapping in northern Ontario might prove this hypothesis true, but much geological work would be required to establish it.

In the southeastern part of the Canadian shield, where the Grenville sediments, believed to be of marine origin, occur, the most complete succession of formations is in southeastern Ontario. A tabular statement of the sequence of formations in this region commencing with the youngest is as follows:

Classification of Archaean Rocks in Southeastern Ontario

Archaean
- Batholithic intrusives
  - Granite, granite gneiss, syenite and related rocks
  - Diorite, gabbro and related rocks
- Hastings series
  - Limestone, dolomite, graywacke and conglomerate

UNCONFORMITY

Grenville series
- Crystalline limestone, dolomite, garnet gneiss, quartzite, mica schist and lava flows

Except for the presence of the Hastings series and the Grenville lavas, which are restricted to southeastern Ontario, the above succession of sediments and intrusives is similar to that throughout the whole of the Grenville region or subprovince that extends from the north end of Lake Huron and the Adirondack region northeast to the Straits of Belle Isle.

Proterozoic.—Late Pre-Cambrian rocks occur extensively in the southern part of the Canadian shield south and northwest of Lake Superior and in the territory extending northeast from the north shore of Lake Huron northeast to Lake Timiskaming. In the Lake Superior region of the United States they were classified in 1935 by C. K. Leith, R. J. Lund and A. Leith in descending order as follows:

Keweenawan
- Acid intrusives
- Basic intrusives
- Sandstone, shale, conglomerate and lava flows

UNCONFORMITY

Upper Huronian (Animikie)
- Sediments, iron formation, volcanics

UNCONFORMITY

Middle Huronian
- Basic intrusives, iron formation and sediments

UNCONFORMITY

Lower Huronian
- Dolomite and quartzite

UNCONFORMITY

In 1952 S. A. Tyler and W. H. Twenhofel, following a study of the Late Pre-Cambrian formations of the Marquette district in northern Michigan, reported that they could not recognize the unconformity between the Lower and middle Huronian and believed it not to exist. According to this conclusion the rocks of the so-called middle Huronian belong to the Lower Huronian and the name middle Huronian is no longer required.

In the Lake Huron-Lake Timiskaming region in northern Ontario the late Pre-Cambrian or Proterozoic rocks are classified as follows:

Igneous intrusives
- Killarney granite and related igneous rocks

Whitewater series

UNCONFORMITY

Cobalt series

UNCONFORMITY

Bruce series

UNCONFORMITY

Of the above, the Bruce series is lithologically similar and is almost certainly the eastward continuation of the Lower Huronian of the region south of Lake Superior. The Cobalt series, although believed to be in part of glacial origin, is usually classified as middle Huronian. The correlation of the Whitewater series is in doubt. It has been called both Upper Huronian (Animikie) and Keweenawan.

In the vast northern part of the shield, extending from the Straits of Belle Isle to Great Bear lake and beyond to the Arctic ocean, areas of late Pre-Cambrian rocks, some of them of considerable extent, occur in the Great Slave lake-Great Bear lake-Coronation gulf region; south of Lake Athabaska; west of Chesterfield inlet; on the Belcher Islands near the east coast of Hudson bay and on the mainland adjacent; in Labrador both on the Atlantic coast and in the interior; and along the headwaters of the Koksoak river northwest of Labrador. Two of these areas of Proterozoic rocks—the Coppermine river and the Athabaska series—resemble the Keweenawan rocks south of Lake Superior. The other areas of Proterozoic formations in the northern part of the shield resemble the Huronian of the Lake Superior region.

In the western or cordilleran part of North America, the best known section of Pre-Cambrian rocks is that exposed in the Grand Canyon of the Colorado river in Arizona. The most extensive occurrence, however, is that of the Proterozoic Beltian formations. These occupy an area 300 mi. wide in northern Idaho, Montana and Washington, and extend discontinuously northwest with a maximum width of about 100 mi. through British Columbia to the Yukon in Canada.

Pre-Cambrian rocks occur in Arizona in the Grand Canyon area and widely scattered in southern, southwestern and western parts of the state. In the Grand Canyon gorge the oldest rocks, known as the Vishnu schists, are classed as older Pre-Cambrian. They consist of igneous gneisses and altered sediments cut by dikes of granite and pegmatite. A younger group of Pre-Cambrian rocks 12,000 ft. thick, the Grand Canyon series, composed mainly of sediments, rests unconformably on the Vishnu schists.

The rocks of the Beltian system include argillite, impure limestone, quartzite and other sediments. They are estimated to have a thickness up to 35,000 ft. in the United States. In Canada, according to H. M. A. Rice, they have a total thickness of 67,000 ft. and occur in two series separated by an important unconformity.

In the belt of folded rocks that lies parallel with the east coast of North America, there are Pre-Cambrian rocks in Newfoundland, in southeastern Nova Scotia, along the northwest shore of the Bay of Fundy in New Brunswick, and in zones within the Appalachian mountains from the Canadian border to Georgia. In southeastern Pennsylvania and adjacent parts of New York, New Jersey and Maryland the Pre-Cambrian includes sedimentary and igneous gneisses overlain unconformably by crystalline limestone, dolomite, quartzite, sedimentary gneisses and schists. The older group of rocks is known as the Baltimore gneiss; the younger as the Glenarm series.

South America.—Pre-Cambrian formations outcrop in South America mainly in two regions: (1) in elongated zones here and there in the western Cordilleran belt of mountains extending from Venezuela to Chile, and (2) in broad masses here and there in the eastern part of the continent but most extensively in Brazil and the adjacent parts of Venezuela, Surinam and British and French Guiana. The zones of the cordilleran region consist mainly of granite, schists and gneisses, which because of their highly altered condition, have been largely classed as Archaean. The Pre-Cambrian rocks underlying most of Brazil and adjacent territory are overlain thinly in places in the southeast-central areas and continuously along the Amazon river by sediments of Permian and later age. Because of their division geographically by the sediments of the Amazon river basin, the area south of the Amazon river has been called Amazonia and that to the north Guiania, but in a general way they all belong to a single mass. The rocks of this Brazilian shield are chiefly Archaean gneisses, schists, crystalline limestone, granite and other igneous intrusives but numerous areas and bands of folded and faulted late Pre-Cambrian quartzite, mica schist, and iron formation rest on the eroded surface of the Archaean complex in places. Numerous mineral deposits occur in the Brazilian shield. Some of the most important of these are those of haematite iron ore, manganese, gold and mica. The Morro Velho mine of the St. John Del Rey Mining company in the state of Baía is one of the world's deepest gold mines. The iron ore is associated with sediments believed to be of Proterozoic Age.

Europe.—Small areas or zones of Pre-Cambrian rocks occur widely scattered in Europe wherever deeply denuded mountains are present, but by far the largest area underlain by Pre-Cambrian formations is that known as the Baltic shield, Baltica or Fennoscandia, which occupies a large part of Norway and most of Sweden, Finland and northwestern U.S.S.R. west of the White sea. There are also considerable areas of Pre-Cambrian in the highlands of Scotland and northeastern Ireland that may be parts of a western extension of the Baltic mass.

The Pre-Cambrian area of Fennoscandia or the Baltic shield extends from the Arctic ocean to the island of Bornholm in the Baltic sea and from the eastern extremity of Kola peninsula in the U.S.S.R. to the westernmost tip of Norway. J. J. Sederholm classified the Pre-Cambrian rocks of this region into four divisions separated by great unconformities. The periods of erosion represented by these unconformities in every case but the last were preceded by mountain building and batholithic intrusion of granitic rocks which were laid bare by denudation before the succeeding formations were deposited. The oldest rocks are metamorphosed sediments (including crystalline limestone) and lavas, known as Sivonian. They were called early Archaean (Katarchaean) by Sederholm and are intruded by granite. The Sivonian formations and the post-Sivonian granite are overlain unconformably by the Bothnian consisting mainly of conglomerate and other clastic sediments interbedded with lava flows and tuffs. These are intruded by basic igneous rocks and a post-Bothnian granite. The third division, the Jatulian-Kalevian, is composed of conglomerate, ripple-marked sandstone, dolomite and greenstones that rest unconformably on the Bothnian formations and post-Bothnian granite and are intruded and metamorphosed by (post-Jatulian and post-Kalevian) granite. During the late Pre-Cambrian the peculiar rapakivi granite was intruded after which the Jotnian sandstone was deposited. Certain similarities between the Pre-Cambrian rocks of Fennoscandia and those of North America and Scotland have been noted. The Bothnian is lithologically similar to the Timiskaming series of the Timiskaming region in Canada and is classified as late Archaean by Sederholm. Similarly the Jotnian-Kalevian sediments and volcanics resemble the Huronian of the Lake Superior-Lake Timiskaming region of the Canadian shield and the Jotnian sandstone is similar in many respects to both the Torridonian of the northern Highlands of Scotland and the Keweenawan of the Lake Superior region of North America.

The Pre-Cambrian of Scotland lies north of the great fault that marks the southern border of its Highlands. In this region there are four main rock groups of Pre-Cambrian or possible Pre-Cambrian Age. These are: (1) The Lewisian complex, consisting of sediments that have been transformed into gneisses and schists and intruded by granite, igneous gneisses, pegmatite and ultrabasic rocks. It occurs in the northwest Highlands and in the Hebrides Islands. (2) The Moine series, composed of metamorphosed sediments, ultrabasic and basic intrusives, and banded gneisses formed by the injection of granite into schists. The series underlies a large part of the middle Highlands. (3) The Dalradian series, a metamorphic group of rocks mainly of sedimentary origin. It occurs in the southeast Highlands north of the Highland Boundary fault. (4) Unaltered conglomerate, sandstone, grit and shale—the Torridonian sediments. These are only gently folded

and faulted. They rest unconformably on Lewisian gneiss in the northwest Highlands, in the Hebrides and in other adjacent islands, and are overlain with structural unconformity by Cambrian sediments. The Lewisian presumably belongs to the early and Torridonian to the late Pre-Cambrian. The Moine sediments have variously classified as Lewisian, post-Lewisian but pre-Torridonian, Torridonian or early Palaeozoic metamorphosed by Caledonian mountain-building. According to James Phemister the post-Lewisian pre-Torridorian Age is probably the most generally accepted hypothesis. The Dalradian rock group is of uncertain age. Some geologists have thought it to be pre-Cambrian but others maintain that it belongs wholly or in part to the Cambrian.

Asia.—Rocks that are positively known to be Pre-Cambrian, or are probably Pre-Cambrian, are widespread in Asia wherever eroded mountains occur. The most extensive areas, however, are in eastern Siberia, northeastern China, India, and Arabia adjacent to the Red sea. That of Arabia is an eastward extension of similar rocks in Africa west of the Red sea and can best be described with the Pre-Cambrian of Africa. The Pre-Cambrian of eastern Siberia occupies a large area mainly in the headwater parts of the Yenisei and Lena river basins. This is divided, however, by a wide belt of early Palaeozoic (Caledonian) mountain-building into the North, or Anabar, shield and the Southeast, or Aldan, massif. The rocks in the central parts of these ancient land masses are called Archaean and include crystalline limestone, quartzites and other metamorphosed sediments, schists, gneisses and intrusions of granite. In their border zones, notably in the Lake Baikal region, the Archaean complex is overlain unconformably by a folded succession of two Proterozoic structurally unconformable metamorphic series. The lower of these consists of schists, conglomerate and quartzites, and the upper of phyllites, sandstone and interbedded lava flows. In parts of the region Cambrian strata rest on the early Pre-Cambrian complex and Proterozoic strata are absent.

In China Pre-Cambrian rocks occur widely from Mongolia southeast, east and northeast to the Siberian border. They belong to three unconformably separate groups: (1) the Tai-Shan or Archaean complex of gneisses, schists and altered sediments, intruded by both granite and basic igneous rocks; (2) the Wu-T'ai system composed of dolomite, conglomerate and other sediments metamorphosed to schists, interbedded greenstones, probably altered volcanics, and gneisses intruded by granite; and (3) the Sinian system composed of limestone, quartzite, shale and other sediments. The Wu-T'ai is compared by some authors with the Huronian of North America. The Sinian is similar in many respects to the Beltian sediments of western United States and Canada. In Manchuria and Korea the names Lia-ho and Keirin have been given by Shintaro Nakamura to rocks believed to be the equivalent of the Wu-T'ai and Tai-Shan systems.

The bedrock surface of peninsular India and the adjacent island of Ceylon is composed mainly of highly folded, crystalline schists and gneisses intruded by granite and granite gneiss; a widespread group of igneous rocks containing the mineral hypersthene known as the Charnockite series; and other intrusives. This complex was called Vedic and correlated with the Archaean by Sir T. H. Holland. It includes an abundance of crystalline limestone, and other highly altered sediments, which, as noted by F. D. Adams in Ceylon, resemble the Grenville series occurring in the southeast part of the Canadian shield. It also includes some lava flows. In parts of the peninsula the sediments and schists of sedimentary origin within the complex are known as the Dharwar system. These early Pre-Cambrian rocks are overlain unconformably by great thicknesses of little-disturbed sediments called Purana. They contain no fossils and are believed to be of late Pre-Cambrian age. The Purana sediments have been variously named in different parts of the peninsula. In central India they are divided into two series separated by an unconformity, the Gwalior and Vindhyan. The gold-bearing veins of the important Kolar gold fields in Mysore intersect the schists of the Dharwar system. Deposits of white mica (muscovite) occur in pegmatite dikes cutting the Dharwar or similar rocks in several provinces of peninsular India. The graphite of Ceylon occurs in veins cutting the older gneisses.

Africa.—Pre-Cambrian rocks are present in many places in Africa, but are most widespread in a very irregular zone extending longitudinally from Arabia and Egypt to Cape province of the Union of South Africa and transversely from the Gulf of Aden almost to the western extremity of the continent. They also underlie most of the island of Madagascar and occur discontinuously in a narrow belt adjoining the west coast from the Gulf of Guinea southward. In most of these regions they are not in contact with Cambrian formations but are overlain with great unconformity by Devonian, Permo-Carboniferous, or later strata. Their classification as Pre-Cambrian is, therefore, based largely on their metamorphic condition and lithological character. In most of north and central Africa the formations classified as Pre-Cambrian belong to two groups: an older Archaeanlike rock assemblage consisting of quartzites, mica and other schists; mixed rocks; amphibolites; granites; orthogneisses; pegmatites; and injection gneisses; and a younger Algonkianlike or Proterozoiclike sedimentary series composed of limestone, slate and quartzite highly folded and intruded by granite. In the Union of South Africa, Northern and Southern Rhodesia, Tanganyika and Kenya the rocks of the early Pre-Cambrian complex occur in scattered areas and, for this reason, are known under various local names. They have been tentatively grouped together as the basement complex, schists or system. They include an abundance of pillowed lavas largely altered to greenstone, fragmental sediments, banded ironstones and intrusive "older" granite.

In the Transvaal the basement complex is overlain unconformably by the following succession:

Waterberg system	
	Sediments
Rooiberg series	Lavas and sediments
Transvaal system	
Pretoria series	Lavas and sediments (tillite)
Dolomite series	Dolomite and shale
Black Reef series	Conglomerate, sandstone and shale
Ventersdorp system	Lavas and sediments
Witwatersrand system, lower and upper	Sediments (lavas in upper)

The Witwatersrand rocks are of special interest because they contain the world's largest known deposits of gold. They form a conformable succession of conglomerate, quartzites, shales and in its upper part, lava flows. They have a total thickness of more than 24,000 ft. The gold occurs in conglomerate beds known as "bankets" or "reefs." In South West Africa and western South Africa there is a succession of sediments and subordinate lava known as the Nama system. This group, for lithological reasons, is correlated with the Transvaal system. One of the outstanding features of the South African Pre-Cambrian is the widely extended assemblage of volcanics and intrusive igneous rocks known as the Bushveld complex that occurs throughout an area of 57,000 sq.mi. in central Transvaal. This igneous activity occurred mainly during and after the deposition of the Rooiberg sediments but before the Waterberg sediments were laid down.

Australia and New Zealand.—The Pre-Cambrian formations of Australia and New Zealand occur in either (1) relatively small scattered areas and zones in the cores of the mountains or highlands of southwestern New Zealand, western Tasmania, South Australia, New South Wales and northern Queensland; or (2) the widely extended shield area of west, central, and north-central Australia. In the occurrences of the first group there is in every case a complex of sediments and lavas metamorphosed to gneisses and schists and intruded by granite and other igneous rocks, usually called Archaean. In South Australia and Queensland, rocks classed as Proterozoic are also present. In the Mount Isa region of northern Queensland the Pre-Cambrian is represented by four groups of rocks separated by unconformities. The two older of these, the Kalkadoon-Argylla and Soldier's Cap series, are believed to belong to the Archaean and the two younger, the Mount Isa and the Mount Quamby series, to the Proterozoic. The Mount Quamby rocks, in contrast with the underlying formations, are only gently dipping. In the central gold-bearing area of West Australia, a region within the Australian Pre-Cambrian shield that has been studied with some intensity, there are three unconformable groups of rocks: (1) lavas with some interbedded sediments (the Kalgoorlie series); (2) sandstone, shale conglomerate, lavas and pyroclastic volcanics; and (3) the late Pre-Cambrian Nullagine series composed of gently folded, unmetamorphosed conglomerate and other sediments, lavas and pyroclastic volcanics. All of these rocks except the Nullagine series are intruded by granite and other igneous rocks. A considerable part of the gold of Australia has been obtained from lodes and veins occurring in the Pre-Cambrian shield of western and middle Australia. The silver-lead-zinc ores of Broken Hill in New South Wales are in the intensely metamorphosed Pre-Cambrian rocks; and tin with tantalum occurs in association with pegmatite dikes of the shield in southwest Australia.

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PRECEDENCE. This word in the sense in which it is here employed means priority of place, or superiority of rank. In Great Britain the crown is the fountain of honour, and has the undoubted prerogative to confer such rank and place as to it may seem convenient. In the old time all questions of precedence came in the ordinary course of things within the jurisdiction of the court of chivalry.

In 1539 an Act "for the placing of the Lords in Parliament" (31 Hen. VIII. c. 10) was passed at the instance of the king, and by it the relative rank of the members of the royal family, of the great officers of State and the household, and of the hierarchy and the peerage was definitely and definitively ascertained. Subsequent modifications were enacted in 1563 (5 Eliz. c. 18), and in 1689 (1 Will. and Mary c. 21). The Acts of Union with Scotland (1707) and Ireland (1800) laid down rules of precedence for the Scottish and Irish peers. At different times too, statutes for the reform and extension of the judicial organization have affected the precedence of the judges, more especially the Judicature Act of 1873. But the statute of Henry VIII. "for the placing of the Lords" remains the only measure dealing with any large section of the scale of general precedence; and the law, so far as it relates to the ranking of the sovereign's immediate kindred, the principal ministers of the Crown and court, and both the spiritual and temporal members of the House of Lords, is to all practical intents what it was made by that statute.

General Precedence of Men.—The sovereign; (1) prince of Wales; (2) younger sons of the sovereign; (3) grandsons of the sovereign; (4) brothers of the sovereign; (5) uncles of the sovereign; (6) nephews of the sovereign; (7) archbishop of Canterbury, primate of all England; (8) lord high chancellor of Great Britain or lord keeper of the great seal; (9) archbishop of York, primate of England; (10) prime minister; (11) lord high treasurer of Great Britain; (12) lord president of the privy council; (13) speaker of the House of Commons; (14) lord keeper of the privy seal; (15) lord great chamberlain of England, (16) lord high constable of England, (17) earl marshal, (18) lord high admiral, (19) lord steward of the household, (20) lord chamberlain of the household, (21) master of the horse, above peers of their own degree; (22) dukes; (23) eldest sons of dukes of the blood royal; (24) marquesses; (25) dukes' eldest sons; (26) earls; (27) younger sons of dukes of the blood royal; (28) marquesses' eldest sons; (29) dukes' younger sons; (30) viscounts; (31) earls' eldest sons; (32) marquesses' younger sons; (33) bishops; (34) secretaries of State of baronial rank; (35) barons; (36) lords commissioners of the great seal; (37) treasurer of the household; (38) comptroller of the household; (39) vice-chamberlain of the household; (40) secretaries of State; (41) high commissioners in London; (42) viscounts' eldest sons; (43) earls' younger sons; (44) barons' eldest sons; (45) knights of the Garter; (46) privy councillors; (47) chancellor of the Exchequer; (48) chancellor of the duchy of Lancaster; (49) lord chief justice of England; (50) master of the rolls; (51) president of the probate, divorce and admiralty division; (52) lords justices of appeal; (53) judges of the High Court of Justice; (54) viscounts' younger sons; (55) barons' younger sons; (56) sons of lords of appeal; (57) baronets; (58) knights grand cross of the Bath, Grand Commanders of the Star of India, grand cross of St. Michael and St. George, grand commanders of the Indian Empire, grand cross of the Royal Victorian Order, and of the Order of the British Empire; (59) knights commanders of the Bath, the Star of India, etc.; (60) knights bachelors; (61) judges of the county court direct; (62) serjeants-at-law; (63) masters in chancery; (64) masters in lunacy; (65) companions of the Bath, of the Star of India, of St. Michael and St. George, of the Indian Empire, commanders of the Royal Victorian Order, and of the Order of the British Empire; (66) companions of the Distinguished Service Order; (67) members of the Royal Victorian Order (4th class); (68) officers of the Order of the British Empire; (69) companions of the Imperial Service Order; (70) gentlemen of the privy chamber; (71) eldest sons of the younger sons of peers; (72) eldest sons of the baronets; (73) eldest sons of the knights of the Garter; (74) eldest sons of the knights of the Bath, of the Star of India, etc., (eldest sons of the knights grand cross taking precedence of eldest sons of knights of the second degree); (75) members of the Royal Victorian Order (5th class); (76) members of the Order of the British Empire; (77) younger sons of baronets; (78) younger sons of knights; (79) esquires; (80) gentlemen.

General Precedence of Women.—The Queen; (1) the queen dowager; (2) the princess of Wales; (3) daughters of the sovereign; (4) wives of the sovereign's younger sons; (5) granddaughters of the sovereign (with style of Royal Highness); (6) wives of the sovereign's grandsons; (7) sisters of the sovereign; (8) wives of the sovereign's brothers; (9) aunts of the sovereign; (10) wives of the sovereign's uncles; (11) nieces of the sovereign; (12) wives of the sovereign's nephews; (13) granddaughters of the sovereign (without style of Royal Highness); (14) wives of dukes of the blood royal; (15) duchesses; (16) wives of sons of dukes of the blood royal; (17) marchionesses; (18) wives of the eldest sons of dukes; (19) dukes' daughters; (20) countesses; (21) wives of the younger sons of dukes of the blood royal; (22) wives of the eldest sons of marquesses; (23) marquesses' daughters; (24) wives of the younger sons of dukes; (25) viscountesses; (26) wives of the eldest sons of earls; (27) earls' daughters; (28) wives of the younger sons of marquesses; (29) baronesses; (30) wives of the eldest sons of viscounts; (31) viscounts' daughters; (32) wives of the younger sons of earls; (33) wives of the eldest sons of barons; (34) baron's daughters; (35) maids of honor to the Queen; (36) wives of knights of the Garter; (37) wives of the younger sons of viscounts; (38) wives of younger sons of barons; (39) daughters of life barons; (40) wives of the sons of life barons; (41) baronets' wives; (42) dames grand cross of the Order of the British Empire; (43) wives of the knights grand crosses of the Bath, grand commanders of the Star of India, grand crosses of St. Michael and St. George, grand commanders of the Indian Empire, grand crosses of the Royal Victorian Order, and of the order of the British Empire; (44) dames commanders of the Order of the British Empire; (45) wives of knights commanders of the Bath, Star of India, etc.; (46) wives of knights bachelors; (47) commanders of the Order of the British Empire; (48) wives of the companions of the Bath, of the Star of India, of St. Michael and St. George, of the Indian Empire, of commanders of the Royal Victorian Order, and commanders of the Order of the British Empire; (49) wives of companions of the Distinguished Service Order; (50) wives of serjeants-at-law; (51) officers of the Order of the British Empire; (52) wives of members of the Royal Victorian Order (4th class); (53) wives of officers of the Order of the British Empire; (54) companions of the Imperial Service Order; (55) wives of companions of the Imperial Service Order; (56) wives of the eldest sons of the younger sons of peers; (57) daughters of the younger sons of peers; (58) wives of the eldest sons of baronets; (59) baronets' daughters; (60) wives of the eldest sons of knights; (61) knights' daughters; (62) members of the Order of the British Empire; (63) wives of members of the Royal Victorian Order (5th class); (64) wives of members of the Order of the British Empire; (65) wives of the younger sons of the younger sons of peers; (66) wives of the younger sons of baronets; (67) wives of the younger sons of knights; (68) wives of esquires; (69) wives of gentlemen.

A special table of precedence in Scotland is regulated by a royal warrant dated March 16, 1905, and a special table of precedence in Ireland was set forth by authority of the lord lieutenant (Jan. 2, 1895).

Personal precedence belongs to the royal family, the peerage and certain specified classes of the commonalty. Official precedence belongs to such dignitaries of the church and such ministers of State and the household as have had rank and place accorded to them by parliament or the Crown, to the speaker of the House of Commons and to the privy council and the judicature. Substantive precedence, which may be either personal or official, belongs to all those whose rank and place are independent of their connection with anybody else, as by the archbishop of Canterbury, the lord high chancellor or the lord great chamberlain, peers and peeresses, baronets, knights and some esquires. Derivative precedence, which can only be personal, belongs to all whose rank and place are determined by their consanguinity with or affinity to somebody else, as the lineal and collateral relations of the sovereign, the sons, daughters and daughters-in-law of peers and peeresses in their own right, and the wives, sons, daughters and daughters-in-law of baronets, knights and some esquires. The precedence of the sovereign is at once official and personal, the precedence of peeresses by marriage is at once derivative and substantive. In the case of the sovereign it is his or her actual tenure of the office of king or queen which regulates the rank and place of members of the royal family, and in the case of peeresses by marriage, although their rank and place are derivative in origin.

What are termed "titles of courtesy" are borne by all the sons and daughters of peers and peeresses in their own right. The eldest sons of dukes, marquesses and earls are designated by the names of one or other of the inferior peerages of their fathers, usually a marquessate or an earldom in the first, an earldom or a viscounty in the second and a viscounty or barony in the third case. The rule applicable in former times, still adhered to by the older English dignities, was that a duke's eldest son was styled earl, the son of a marquess, viscount, the son of an earl, baron. No such rule obtained in Scotland. But, whatever it may be, it is without effect on the rank and place of the bearer, which are those belonging to him as the eldest son of his father. The younger sons of dukes and marquesses are styled "lords," followed by both their Christian names and surnames. The younger sons of earls and both the eldest and the younger sons of viscounts and barons are described as "honourable" before both their Christian names and surnames. The daughters of dukes, marquesses and earls are styled "ladies" before both their Christian names and surnames. The daughters of viscounts and barons are described as "honourable" before both their Christian names and surnames. If the eldest son of a marquess or an earl marries a woman of rank equal or inferior to his own, she takes his title and precedence; but if she is of superior rank she retains, with her own precedence, the prefix "lady" before her Christian name followed by the name of her husband's title of courtesy. Again, if the younger son of a duke or a marquess marries a woman of rank equal or inferior to his own, she is called "lady," with his Christian and surname following, and is placed in his precedence, but, if she is of superior rank, she retains, with her own precedence, the prefix "lady" before her Christian name and his surname. If the daughter of a duke, a marquess or an earl marries the younger son of an earl, the eldest or younger son of a viscount or baron, a baronet, a knight or an esquire, etc., she retains, with her own precedence, the prefix "lady" before her Christian name and her husband's surname. If the daughter of a viscount marries the younger son of an earl or anybody of inferior rank to him, or the daughter of a baron marries the younger son of a viscount or anybody of inferior rank to him, she retains her own precedence with the prefix "honourable" before the addition "Mrs." and his surname or Christian name and surname. But, if her husband is a baronet or a knight, she is called the Honourable Lady Smith or the Honourable Lady Jones, as the case may be. The wives of the younger sons of earls and of the eldest and younger sons of viscounts and barons, if they are of inferior rank to their husbands, take their precedence and are described as the Honourable Mrs., with the surnames or Christian names and surnames of their husbands following. The judges were placed by James I. before the younger sons of viscounts and barons and accorded the title of "honourable" (*q.v.*). But this does not apply to their wives.

Some Criticisms.—It is manifest on even a cursory examination of the tables given that they are in many respects very imperfectly fitted to meet the circumstances and requirements of the present day.

In both of them the limits prescribed to the royal family are inconveniently narrow, in contrast to the ample bounds through which the operation of the Royal Marriage act (12 Geo. III, c, 11) extends the disabilities but not the privileges of the sovereign's kindred. Otherwise the scale of general precedence for women compares favourably with the scale of general precedence for men, which is now in nearly the same condition as that in which it has been for between two and three centuries, and the political, to say nothing of the social, arrangements to which it was framed to apply have undergone an almost complete transformation.

It is true that in the professional classes definite systems of subordination are established by either authority or usage, which are carefully observed and enforced in the particular areas and spheres to which they have reference.

As an example of precedence, major generals and rear admirals are of equal rank, and with them are placed commissaries general and inspectors general of hospitals and fleets.

But there is nothing to aid us in determining whether they should be ranked with, before or after deans, king's counsel or doctors in divinity, who likewise are destitute of any recognized general precedence, and, as matters now stand, would certainly have to give place to the younger sons of baronets and knights and the companions of the knightly orders.

No foreigner has any legal precedence in Great Britain, but it is suggested that it being proper courtesy to accord to guests the precedence due to the rank they bear in their own countries, they should rank in society with and immediately before those of the relative rank in England. It should, however, be remembered that the younger sons of counts and other nobles bear the title of count with the addition of the Christian name, and they should be ranked with younger sons of British earls, etc., whatever title they bear.

It has now become usual to recognize ecclesiastical rank derived from the pope, even when held by subjects of the king.

Cardinals, therefore, rank by international usage above archbishops, as princes of the blood royal, and in Ireland, Roman Catholic and Protestant bishops rank as such by warrants there in force.

An order respecting precedence was sent by the secretary of state for the colonies to the governor general of Canada (July 24, 1868).

Precedence in India was formerly regulated by a royal warrant dated May 6, 1871.

See the peerages of Burke, Debrett, etc. (X.)

THE UNITED STATES

Since there is no hereditary ranking in the United States, precedence in official functions and ceremonies is purely according to official position. No statutes determine the order. Custom has set an order as follows: the president; vice president; chief justice; ambassadors of foreign powers in order (*i.e.*, according to date of presentation of credentials); speaker of the house of representatives; ministers of foreign powers in order; associate justices (according to date of commission); retired associate justices; the president's cabinet in order (secretary of state, of the treasury, of defense, attorney general, postmaster general, secretary of the interior, of agriculture, of commerce, of labour, and of health, education and welfare); senators; representatives; chargés d'affaires of foreign powers; under secretaries of cabinet; secretaries of the army, navy and air force; chairman of the joint chiefs of staff; chief of staff of the army; chief of naval operations; chief of staff of the air force, five-star generals and admirals; chairman of the federal reserve board; four-star generals and admirals; lieutenant generals and vice-admirals; counsellors of foreign powers; major generals and rear admirals; brigadier generals and commodores; subordinate government officials.

(J. F. Ss.; X.)

PRECESSION OF THE EQUINOXES, in astronomy, an effect connected mainly with a gradual change of the direction of the earth's axis of rotation. There is a general resemblance between the motion of the earth and that of a spinning top. It is well-known that when a top is slightly disturbed its axis precesses round the vertical so that it traces out a cone; the earth's axis similarly describes a cone at the rate of one revolution in about 26,000 years. In applying this analogy we must take the ecliptic (*i.e.*, the plane of the orbit of the earth round the sun) to correspond to the horizontal; the axis about which the earth spins is inclined at $23\frac{1}{2}°$ to the "vertical," and keeping this inclination it turns slowly round the "vertical." It must be emphasized, however, that this correspondence between the earth and a top is superficial, the cause of the precessional motion being upon different principles.

In this way the north pole of the celestial sphere describes among the constellations a circle of $23\frac{1}{2}°$ radius, making a revolution in 26,000 years. At present it is near the star α Ursae Minoris, which is therefore called the Pole Star; but it has travelled a considerable distance within historic times. About 3000 B.C. the star α Draconis would have served as pole star; in 13000 B.C., also in A.D. 13000 Vega would be near enough to the pole to mark roughly its position. By this displacement the part of the sky visible from a particular terrestrial station gradually changes; certain constellations cease to rise above the horizon and others appear for the first time. In the time of the early Chaldean astronomers it was not necessary to travel so far south to see the Southern Cross as it is now.

Cause of Precession.—This was first explained by Isaac Newton. It is due to the attraction of the sun and moon on the equatorial protuberance of the earth, the moon being responsible for about $\frac{2}{3}$ and the sun for $\frac{1}{3}$ of the motion—the same proportion as the lunar and solar tides. Treating the equatorial bulge as an extra ring of matter surrounding a spherical earth, the attraction of the sun and moon on this ring gives a couple tending to turn the ring into the plane of the ecliptic, since both disturbing agents are in or near the ecliptic. If the earth were not spinning this would turn the earth over until the equator coincided with the ecliptic, but the spinning earth behaves like a gyrostat, so that its axis moves at right angles to the plane of the couple—just as the couple which would upset a top at rest gives the axis of the spinning top a conical motion.

The moon's orbit is inclined at about 5° to the ecliptic, but it does not remain still; its nodes travel round the ecliptic in 18·6 years. Averaged over a long period of time the deviations of the moon from the ecliptic cancel out; but at any moment the precession caused by the moon may be greater or less than the average, according to the position at the time of the lunar orbit. In fact the path of the pole among the stars is a slightly sinuous curve. Astronomers distinguish the average secular motion as *precession* and the periodic fluctuations or sinuosities as *nutation* (*q.v.*).

As the pole (corresponding to the equator) moves round the pole of the ecliptic, so the equinox or intersection of the equator and ecliptic moves round the ecliptic once in 26,000 years. Both right ascensions and longitudes are reckoned from the equinox as zero-point; stellar longitudes on this account increase steadily by nearly a minute of arc every year; the effect on the right ascensions is more complicated, but these also continually increase. The vernal equinox is commonly called the First Point of Aries, but it has already moved away from that constellation and is now in Pisces. It should be understood that the precession of the equinoxes has no effect on the seasons, and, for example, has no connection with the gradual departure of the spring equinox from March 21 which occurred in the old Julian calendar.

Planetary Precession.—Besides the foregoing luni-solar precession, a phenomenon of much smaller magnitude, known as *planetary precession,* is recognized. It is due to perturbations by the planets which cause slow changes in the plane of the earth's orbit. Planetary precession changes the position of the ecliptic, whereas luni-solar precession changes the position of the equator; either change affects the equinox, which is the intersection of the two planes. Corrections for precession and nutation are of great importance in most branches of positional astronomy, and their computation is very burdensome.

For details of the theory of the precessional motions see Newcomb's *Spherical Astronomy,* ch. ix.

PRECIPITATION, in chemistry, is the separation of a solid in a condition to be insoluble in the solution from which it is removed. Precipitation is an important step in many chemical processes. It may be accomplished by the concentration of the solution to the point where it is supersaturated, when, upon cooling, a part of the solid separates out, though this process is usually described as crystallization (*q.v.*). It may also be accomplished by the addition of reagents which may combine with the material to form an insoluble compound, or which may displace the material from the original solution.

The application of heat may cause coagulation, as with certain proteins, and the removal of gas may also alter conditions sufficiently to cause precipitation. A change of temperature is another method.

The salting out process as employed in the soap industry is a familiar example of precipitation. The formation of the fibre from a solution of cellulose by causing it to pass into a setting bath is a case of precipitation used in the artificial silk industry.

PRECISION GAUGES AND COMPARATORS. The vast mechanical facilities which are such an important part of modern civilization could not have been produced without the dimensional control which makes possible the interchangeable manufacture of parts of mechanisms. Precision gauges and comparators form the basis of such control.

Limit Gauges.—The reproduction of dimensions of mechanical parts within specified dimensional limits of variation, or tolerances, is facilitated by checking with gauges, such as a "go" gauge representing the maximum-metal limit and a "not go" gauge representing the minimum-metal limit. Limit gauges used on products are also known as inspection or working gauges. Gauges used as standards of comparison for measuring the dimensions of inspection gauges are known as master or reference gauges.

Gauges are manufactured by highly skilled gaugemakers in a large variety of forms, corresponding to the forms and dimensions of parts to be gauged and to principles of gauge design.

Master Gauges.—Precision gauges and comparators have been extensively developed since about 1850, when Sir Joseph Whitworth produced the original measuring machine and the system of accurate dimensional standards or master gauges (both end gauges and cylindrical gauges) for use with it.

On the market in 1945 were the following forms: (1) Precision gauge blocks or slip gauges, which are end standards of rectangular, square or circular section having accurately flat, parallel ends, available in sets of numerous selected lengths of blocks so that all dimensions, within the range of the set, can be produced in small increments such as 0.00005 in. by combining or wringing the blocks. (*See* METROLOGY.) These were invented in 1896 by C. E. Johansson of Eskilstuna, Sweden, who used a hand-lapping method for their production, and are often called Johansson blocks. In 1918 a machine-lapping method was developed by Maj. Wm. E. Hoke at the national bureau of standards in Washington, D.C. Gauge blocks have since been produced by more than a dozen manufacturers in four standard qualities which are accurate to 0.000002, 0.000004, 0.000008, or 0.000010 in.; (2) end measuring rods in the form of steel bars having flat or spherical ends; (3) master disks which are accurately lapped steel cylinders, frequently preferred to gauge blocks when pieces to be checked by comparators are round; (4) gauges having composite surfaces, such as screw thread, profile or spline gauges; and (5) angle gauge blocks in sets of 13 or 16 selected angles, combinations of which are wrung together to produce any angle to 90°, or with an additional square block to 360°, to the nearest second by addition or subtraction according to the relative directions in which blocks are assembled.

Measuring Machines.—Comparators of the horizontal type are designated measuring machines. These have means provided for measuring the difference between the test object and the

standard, usually a micrometer screw having a divided head. Such comparators also often embody line standards of length, which may be used instead of contact length standards. A massive cast-iron bed is provided with straight ways, on which are mounted the headstock carrying the micrometer screw and one measuring anvil and the tailstock carrying the other anvil. Devices are provided, usually in the tailstock, for ensuring a constant contact pressure, which is necessary to obtain accurate comparisons. However, such devices were absent in the early models, such as the Whitworth and the Rogers-Bond universal comparator patented in 1885. There have been several different measuring machines of the modern type.

A further elaboration of measuring machines is a means for providing high amplification of the displacement of one of the anvils, such as an optical lever in the millionth comparator of J. E. Sears, providing an amplification of 30,000 times, and the Pratt & Whitney electrolimit tailstock, of 5,000 or more.

Vertical Comparators.—In comparators of the vertical type, the master gauge and work are in turn supported on a substantial and level surface plate or anvil. The measuring contact and the amplifying mechanism which it actuates are adjustably mounted on a vertical column. These widely used instruments are available with various amplifications up to 20,000 (sometimes higher), obtained by means of a mechanical amplifying system as in the mikrokator and various dial comparators or by a combination of mechanical and optical levers as in the Zeiss optimeter and the Sheffield visual gauge or by an inductance bridge circuit as in the Pratt & Whitney electrolimit comparator, Sheffield electrichek or DoAll electric comparator.

Related to these in principle is the tilting level comparator, by A. J. C. Brooks, for comparing precision gauge blocks, in which the difference in height of the two blocks is determined by the reading of a highly sensitive spirit level, which rests by point contact upon their upper surfaces through two ball feet.

Interferometers.—Although the lengths of precision gauge blocks may accurately be compared by means of high precision comparators, experience indicates that optical interference methods are generally more reliable. The test block and the master block are both wrung firmly down on a transparent (quartz or glass) optically flat surface, the completeness of the wringing being observed through the optical flat. If another transparent optical flat is placed over the opposite ends of the blocks, the flat being preferably half-silvered and not in contact with the blocks, so that the surface of the flat makes a very small angle with the surfaces of the blocks, interference bands will be seen, whose direction is parallel with the edge of the wedge thus formed. Simultaneously, if the light used is made accurately parallel by a collimating lens system, bands may be seen on the flat to which the blocks are wrung. For length measurements the direction of these bands is set perpendicular to the adjacent edges of the two blocks, the bands being viewed perpendicularly through an ocular. Thus, errors in parallelism of the gauging surfaces do not vitiate the measurements of length at selected reference points on the two gauges. In measuring blocks more than $\frac{1}{2}$ in. to 4 in. in length, krypton radiation is used for the parallelism setting since helium fringes do not persist over such lengths.

If polychromatic light is used, such as the helium radiation in which the yellow is partially suppressed by means of a didymium filter, each band has an individual colour pattern, so that if the blocks are unequal in length and, accordingly, the corresponding bands are displaced from each other, they can readily be identified. Comparison interferometers based on this principle are available, having two adjustable crosslines in the eyepiece, each of which can be positioned to coincide with one of the bands thus identified.

Then by interposing another suitable filter, monochromatic bands are obtained and the difference in length, represented by the spacing of the crosslines, is determined in terms of the wave length.

Gauge blocks used as secondary national length standards are commonly measured by direct comparison with standard wave lengths of monochromatic light by means of the Michelson or Fabry and Perot interferometers and using the method of coincidences of excess fractions. (*See* METROLOGY and LIGHT.)

Internal Comparators.—The precise determination of an internal dimension presents special difficulties, which have been largely overcome by the development of internal comparators of different designs. Prior to the availability of such comparators, or in their absence, the sizes of such objects as ring gauges, either plain or threaded, were usually estimated by the nature of their fit upon corresponding plug gauges.

When a cylindrical plug and ring are perfectly clean and dry, they will assemble if the largest diameter of the plug is the same or smaller than the smallest diameter of the ring. If well finished and liberally covered with a lubricant having high oiliness properties, a cylindrical plug gauge will enter and pass through a ring gauge, which is as much as 0.0002 in. smaller than the plug, without damage to either, provided that distribution of the lubricant is maintained by constant relative motion of the gauges.

The following instruments have become available for the measurement of internal dimensions: the chord contact machine by G. A. Tomlinson, in which the displacement of a ball-ended piece is measured in a direction perpendicular to its length; the displacement type of internal measuring machine, having a micrometer and a double-ended stylus attached to a sensitive indicating mechanism, by J. E. Sears; the Sheffield internal-external measuring machine having gauging fingers which are positioned by means of precision gauge blocks and which move relatively to each other and actuate an amplifying mechanism; the Pratt & Whitney electrolimit universal internal comparator having one fixed and one adjustable gauging finger; and the Swedish internal indicator gauge.

A precision pneumatic micrometer was invented by Marcel Mennesson of France in 1928. This and other types of air gauges are now widely used to compare internal dimensions. A cylindrical spindle, somewhat smaller than the hole to be measured, has diametrically opposed orifices through which regulated compressed air is forced. The spindle is first inserted in a ring gauge of known size and then in the piece to be measured. The difference in pressure or in rate of flow of the air from the spindle in the two cases is indicated in different makes by a manometer, a pressure gauge or a float in a tapered glass tube which are suitably calibrated to yield measurements of differences in size as small as 0.00001 in. or less.

Projection Comparators.—The measurement of the dimensions of profile gauges and the thread angles and profiles of screw thread gauges is facilitated by optical projection methods, developed largely during and after World War I by the national physical laboratory and the national bureau of standards. Further commercial developments of these methods are embodied in projection comparators of the Wilson, Hartness or Jones and Lamson, Bausch and Lomb and other types.

(*See* also DIMENSIONAL ANALYSIS; PHYSICAL UNITS.)

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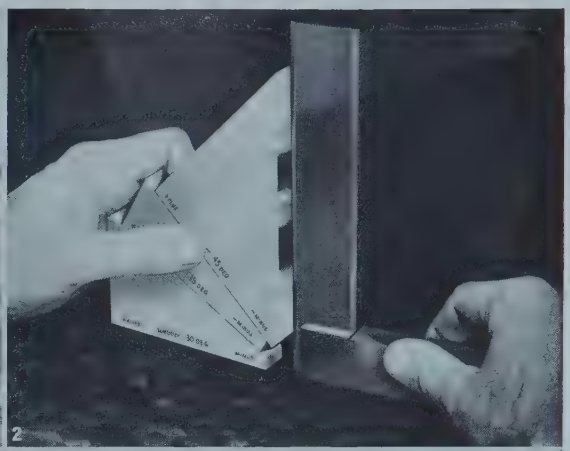
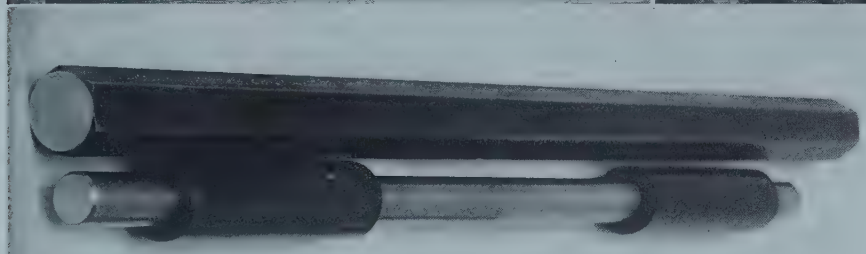
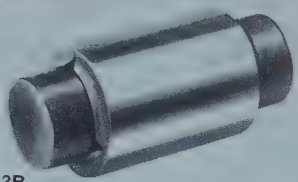
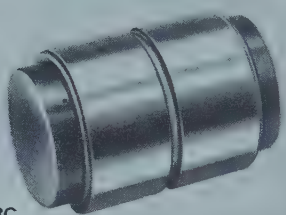
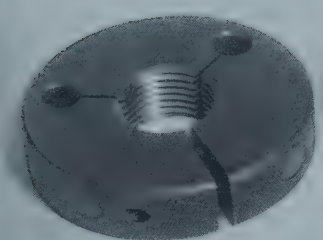
PREDESTINATION, as a theological term is used in three senses: (1) God's unchangeable decision from eternity of all that is to be; (2) God's destination of men to everlasting happiness or misery; (3) God's appointment unto life or "election" (the appointment unto death being called "reprobation," and the term "foreordination" being preferred to "predestination" in regard to it). In the first sense the conception is similar to that of fate; this assumes a moral character as *nemesis*, or the inevitable penalty of transgression. Sophocles represents man's life as woven with a "shuttle of adamant" (*Antigone*, 622–624). Stoicism formulated a doctrine of providence or necessity. Epicurus

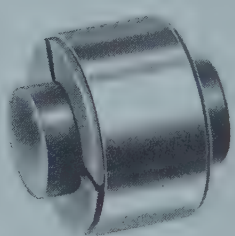












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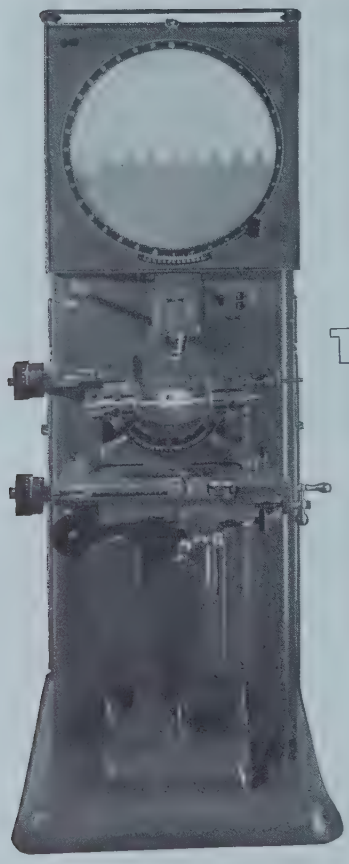
BY COURTESY OF (1, 3A, 4) NATIONAL BUREAU OF STANDARDS, (2) WEBBER GAGE COMPANY, (3B, C, D) PRATT & WHITNEY, DIVISION NILES-BEMENT-POND COMPANY

PRECISION GAUGES AND COMPARATORS

1. Set of precision gauge blocks, applied in inspection of a simple contour gauge
2. Angle gauge blocks applied in testing toolmaker's square
3. (A) End measuring rods; (B, C, D) master disks
4. Screw thread gauges

PRECISION GAUGES AND COMPARATORS



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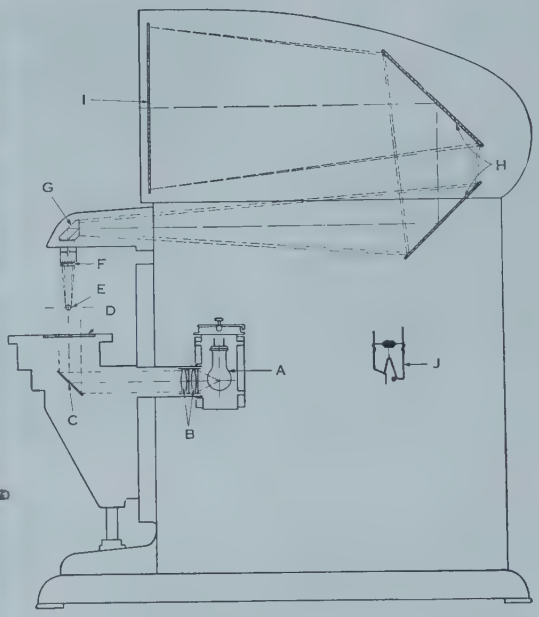

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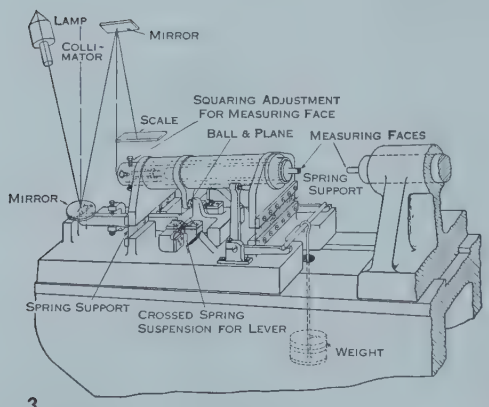

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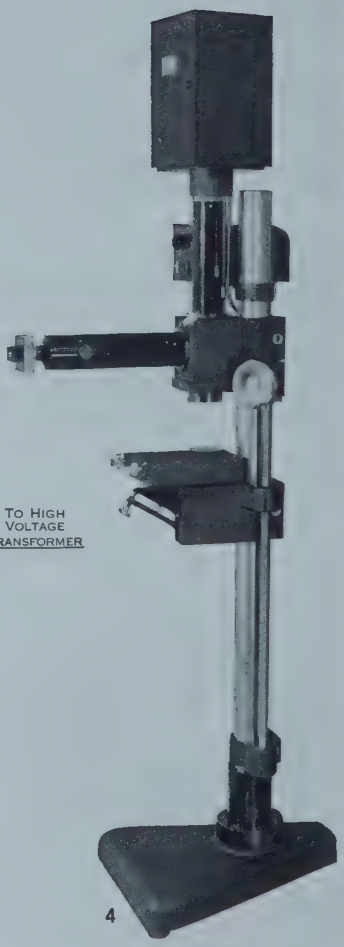

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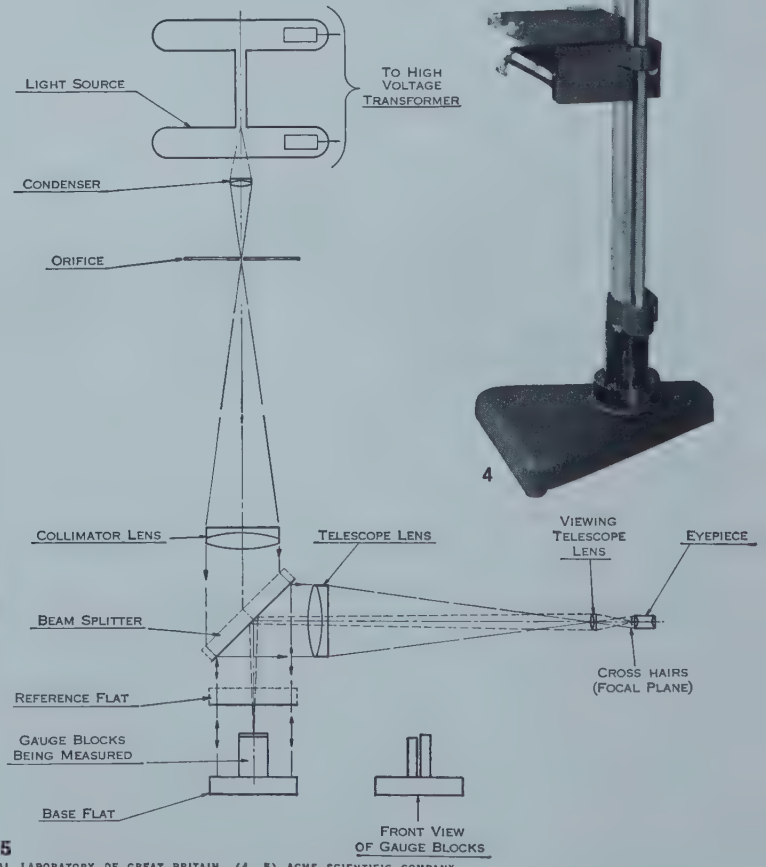

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BY COURTESY OF (1, 2) BAUSCH & LOMB OPTICAL CO., (3) NATIONAL PHYSICAL LABORATORY OF GREAT BRITAIN, (4, 5) ACME SCIENTIFIC COMPANY

PRECISION GAUGES AND COMPARATORS

1. Contour measuring projector—front view showing projection of screw thread gauge
2. Diagram of optical path in contour measuring projector. (A) light source, (B) achromatic condenser, (C) illuminating mirror, (D) glass stage plate, (E) object, (F) projection lens, (G) roof prism, (H) first surface mirrors, (I) translucent screen, and (J) tungsten arc light source
3. Sears' millionth comparator
4. Comparison interferometer
5. Illustration of principle of comparison interferometer shown in Fig. 4

denied a divine superintendence of human affairs. A powerful influence in Scandinavian religion was exercised by the belief in "the *nornir,* or Fates, usually thought of as three sisters." In Brahmanic thought *Karma,* the consequences of action, necessitates rebirth in a lower or higher mode of existence, according to guilt or merit. With some modifications this conception is taken over by Buddhism. The Chinese *tao,* the order of heaven, which should be the order for earth as well, may also be compared. According to Josephus (*Antiq.,* xviii, 1, 3, 4; xiii, 5, 9) the Sadducees denied fate altogether and placed good and evil wholly in man's choice; the Pharisees, while recognizing man's freedom, laid emphasis on fate; the Essenes insisted on an absolute fate. This statement is exposed to the suspicion of attempting to assimilate the Jewish sects to the Greek schools. In Islam the orthodox theology teaches an absolute predestination, and yet some teachers hold men responsible for the moral character of their acts. The freethinking school of the Mo'tazilites insisted that the righteousness of God in rewarding or punishing men for their actions could be vindicated only by the recognition of human freedom.

The question of the relation of divine and human will has been the subject of two controversies in the Christian Church, the Augustinian-Pelagian and the Calvinistic-Arminian. Pelagius maintained the free will of man and regarded grace as only an aid to freedom. Augustine held that God's grace alone is effectual and irresistible; He chooses whom He will have (election) and whom He will leave to perish (reprobation or praeterition).

At the Reformation the Augustinian position was accepted by both Martin Luther and John Calvin. Philipp Melanchthon modified his earlier view in the direction of *synergism,* the theory of a co-operation of divine grace and human freedom. Calvin wavered between the *supralapsarian* view that the fall was decreed in order to give effect to the previous decree of election and reprobation, and the *sublapsarian* of a "permissive decree—a volitive permission." This view repelled Arminius. According to Calvinism God's election unto salvation is absolute, determined by His own inscrutable will; according to Arminianism it is conditional, dependent on man's use of grace. The synod of Dort (1618–19) which affirmed the sublapsarian without excluding the supralapsarian form of Calvinism, condemned the views of Arminius and his followers, who were known as Remonstrants from the remonstrance "which in four articles repudiates supralapsarianism and infralapsarianism (which regarded the Fall as foreseen, but not decreed), and the doctrines of irresistibility of grace, and of the impossibility of the elect finally falling away from it, and boldly asserts the universality of grace."

In the Church of Rome the Dominicans favoured Augustinianism, the Jesuits semi-Pelagianism; the work of Luis Molina on the agreement of free will with the gifts of grace provoked a controversy, which the pope silenced without deciding; but it broke out again a generation later when Jansen tried to revive the decaying Augustinianism. The Church of England has passed through several disputes regarding the question whether the Thirty-Nine Articles are Calvinistic or not; while there is some ambiguity in the language, it seems to favour Calvinism. At the Evangelical revival the old questions came up, as John Wesley favoured Arminianism, and George Whitefield, Calvinism. In Scotland Calvinism was repudiated by James Morison, the founder of the Evangelical Union, who declared the three universalities: God's love for all, Christ's death for all and the Holy Spirit's working for all.

While retained in the creeds of several denominations, in the public teaching of the churches the doctrine of predestination is less emphasized. The problem is the reconciliation of human freedom with divine foreknowledge. It has been argued that, if God allows His activity to be limited by human freedom, He may also so limit His foreknowledge as to know free acts as possible and not as actual.

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PREDICABLES, in logic, are the main types of predicates, or the principal ways in which the predicate of a proposition can be related to its subject. The oldest known doctrine of predicables is that of Aristotle, but the one that had, and still has, the greatest vogue is that of Porphyry, which is not essentially different from that of Aristotle. According to Porphyry there are five predicables; namely, genus, species, differentia, proprium, accident. These five predicables are obtained as follows. When a predicate is affirmed of a subject it must either express something that is essential to the subject (that is, something in the absence of which the subject would not be called by that name) or not. If the predicate is not essential to the subject it is described as an accident. *E.g.,* "many prime ministers of England are Scotsmen" (or "Oxford men," or "wealthy," etc.); but they need not be. If the predicate is essential, then there are four possibilities. The predicate may state the including class in which the subject is included; *e.g.,* "prime ministers are cabinet ministers" (or "rectangles are parallelograms," etc.). In this case the predicate is described as a genus of the subject; and the subject (if a class name) is called a species of the predicate. The predicate is called a species in relation to the subject, if the subject is a singular term and the predicate represents this class (*e.g.,* "Mr. Kellogg is a statesman"), or if the subject is a class name restricted by "some" and the predicate denotes an included class (*e.g.,* "some members of parliament are cabinet ministers," or "some rectangles are squares"). Again the predicate may assert of the subject some character, or group of characteristics, which distinguishes (or differentiates) one species of a genus from the other species (*e.g.,* "squares are equilateral," whereas other rectangles are not). In this case the predicate is called a differentia (or "difference") of the subject term. Lastly, the predicate may assert of the subject something essential, but different from either its genus or differentia, though derivable from these (*e.g.,* "equilateral triangles and equiangular"). In this case it is called a proprium (or "property") of the subject. The predicables are applicable readily enough to ideal objects like those of geometry, but cannot be applied satisfactorily or usefully to empirical objects.

Although they mark distinctions which are important and useful in connection with many ordinary problems, they play no important part in modern science, which needs more precise and more numerous distinctions than they mark. (*See* LOGIC, HISTORY OF.)

See also H. W. B. Joseph, *Introduction to Logic* (1916).

PREECE, SIR WILLIAM HENRY (1834–1913), British electrical engineer, was born in Wales on Feb. 15, 1834, and educated at King's college, London. He became a civil engineer but in 1853 joined the Electric and International Telegraph Co. In 1869 he returned to the civil service and in 1877 was appointed electrician to the post office, in 1899 engineer-in-chief and, after his retirement, consulting engineer. He was a pioneer of wireless telegraphy. He died at Penrhos, Carnarvon, on Nov. 6, 1913.

PRE-ESTABLISHED HARMONY, in philosophy, denotes the relationship between body and mind as conceived by G. W. Leibnitz. According to the interaction theory body and mind act upon each other, so that the body does what the mind wants done, and the mind is affected by the condition of the body. Cartesian dualism excluded the possibility of such interaction, by its conception of an absolute difference and opposition between mental and material substances. To account for the appearance of such interaction some of the Cartesians introduced the theory of "occasionalism"; namely, that the mind does not influence the body nor *vice versa,* but that on every occasion that anything happens to the one, God produces a certain change in the other. This implied God's constant interference with everything. Leibnitz suggested that body and mind have been harmonized by God once for all, so that their changes correspond or synchronize without either influencing the other, and without needing God's incessant intervention. He compares the relation between body and mind to that between two clocks which have been synchronized once for all and so keep step without mutual interaction and without the constant intervention of anybody. This is the theory

of pre-established harmony, which Leibnitz applied to his system of monads. For Leibnitz reality consists of monads or spirits of different degrees of development. Their active side is their spiritual side, and matter is simply the appearance of their passivity or deficiency. As their activity is entirely immanent, the monads do not interact (they "have no windows"), but there is a pre-established harmony between them inasmuch as they all mirror the same universe, though each "from its own point of view." (*See* LEIBNITZ, GOTTFRIED WILHELM.)

PRE-EXISTENCE, DOCTRINE OF, in theology, the doctrine that Jesus Christ had a human soul which existed before the creation of the world—the first and most perfect of created things—and subsisted, prior to His human birth, in union with the Second Person of the Godhead. It was this human soul which suffered the pain and sorrow described in the Gospels. The chief exposition of this doctrine is that of Dr. Watts (*Works,* v, 274, etc.); it has received little support. In a wider form the doctrine has been applied to men in general—namely, that in the beginning of creation God created the souls of all men, which were subsequently as a punishment for ill doing incarnated in physical bodies till discipline should render them fit for spiritual existence. Supporters of this doctrine, the Pre-existants or Pre-existiani, are found as early as the 2nd century, among them being Justin Martyr and Origen (*qq.v.*), and the idea not only belongs to metempsychosis and mysticism generally but is widely prevalent in oriental thought. It was condemned by the council of Constantinople in 540 but has frequently reappeared in modern thought (*cf.* William Wordsworth's *Intimations of Immortality*) being in fact the natural correlative of a belief in immortality.

PREFECT, in France, the title of a high official (*préfet*). The prefects of the department were created by a law of the 28th Pluviose in the year VIII (Feb. 17, 1800). They were intended to be the chief officers of internal administration and have, in fact, discharged this function, especially under the first and second empires, surviving, though with diminished importance, under the other forms of government which modern France has seen.

The prefect has a double character and two series of functions. First, he is the general representative of the government, whose duty it is to ensure execution of the government's decisions, the exercise of the law and the regular working of all branches of the public service in the department. Thus far the role of the prefect is essentially political; he guarantees the direct and legal action of the government in his department. He has the supervision of all the state services in his department, which procures the necessary uniformity in the working of the services, each of which is specialized within a narrow sphere. He serves as a local source of information to the government and transmits to it representations from those under his administration.

In the name of the state he exercises a certain administrative control over the local authorities, such as the *conseil général,* the mayors and the municipal councils. This control, though considerably restricted by the laws of Aug. 10, 1871, and April 5, 1884, still holds good in some important respects. The prefect can still annul certain decisions of the *conseil général.* He can suspend for a month a municipal council, mayor or deputy mayor; certain decisions of the municipal councils require his approval and he may annul such of their regulations as are *extra vires.* He can annul or suspend the *maire's* decrees and he has also considerable control over public institutions, charitable and otherwise. He may make regulations both on special points and for the general administration of the police.

Secondly, the prefect is not only the general representative of the government but the representative of the department in the management of its local interests. But his unfettered powers in this respect were reduced under the third republic, chiefly by the law of Aug. 10, 1871, which led to decentralization, by increasing the powers of the *conseils généraux.*

The *sous-préfets,* having limited powers of deciding questions, serve as intermediaries between the prefect and the persons under his administration. This function was most useful in the year VIII, when communications were difficult even within a department. At the present time their chief service to the administration lies in keeping up good relations with the *maires* of the communes in their *arrondissement* and thus acquiring a certain amount of influence over them.

The national assembly of 1871 proposed to suppress the *sous-préfets,* but the president, L. A. Thiers, persuaded them to reconsider their decision. The question has been raised from time to time, since that date, in the chamber of deputies; and, finally, by the decree of Sept. 6, 1926, the *Conseils de Préfecture* were suppressed and the *Conseils de Préfecture interdépartementaux* created. The suppression of a certain number of the *sous-préfectures* was effected by the decree of Sept. 10, 1926.

See *Journal Officiel* (Sept. 9, 14 and 30, 1926, and June 3, 1927).

PREFERENCE, IMPERIAL: *see* IMPERIAL PREFERENCE.

PREFERENCE SHARES: *see* SHARES.

PREFERRED STOCK: *see* STOCK.

PREGL, FRITZ (1869–1930), Austrian chemist, was born in Laibach on Sept. 3, 1869, and was graduated from the *gymnasium* in that city. In 1887 he matriculated at the University of Graz to study medicine, receiving his M.D. in 1894. His qualifying paper for admission as a lecturer at the Physiological institute at Graz had already been chosen from the field of physiological chemistry, and subsequent work on bile acid led him further into chemistry. After his appointment as assistant professor, he left for Germany in 1904 for an additional year of study. At Leipzig he studied methods of physical chemistry with Wilhelm Ostwald and then went to Berlin where, in association with E. Abderhalden, he worked with the products of egg white when hydrolyzed, and the chemistry of albuminous derivatives in human urine, which are not easily dialyzed.

He returned to Graz in 1904 to become professor in ordinary at the Medico-Chemical institute, teaching physiological chemistry. During the year that followed, he investigated the components of albuminous bodies and the analysis of bile acids. The years between 1910 and 1913, while professor at the University of Innsbruck, were among the most decisive in his career and those in which he completed his pioneer work in the field of microanalysis. He returned to Graz in the fall of 1913 to succeed K. B. Hoffman as director of the Medico-Chemical institute. Lack of material in his work with bile acids had impelled him to look for methods requiring smaller amounts when making quantitative analyses of elements in compounds. By 1912 he was able to make measurements of carbon, hydrogen, nitrogen, sulphur and halogen, using only 5 mg.–13 mg. of starting material with results as accurate as those obtained by existing methods. Later, he perfected his techniques so that as little as 3 mg.–5 mg. were adequate for measurements at least as exact as the results of microanalysis. The development of chemical microanalysis (*see* CHEMISTRY: *Microanalysis*) marked a great advance in organic elementary analysis. In addition to the general factor of economy, it became indispensable in many research problems of pure science, physiology, medicine and industry. Pregl also contributed a number of micromethods for measuring atomic groups and a sensitive microbalance. Two experimental lectures at Berlin and Vienna brought such wide attention and so many visitors to his laboratories that in 1917 he published his monograph *Die quantitative organische Mikroanalyse* (Berlin) which was later translated into English and French. A second edition appeared in 1923 and a third in 1930. Pregl was also interested in many practical problems of medicine. He perfected the Abderhalden dialysis test for the presence of ferment so that less serum was needed for a reaction, invented a simple method for determining the functional capacities of the kidneys and added to medicine an iodine solution, named for him, which is a mild but effective antiseptic. Recognition for his work on microanalysis was accorded with the Lieben prize for chemistry from the Vienna Academy of Science (1914), an honorary doctorate in philosophy from the University of Göttingen (1920) and the Nobel prize for chemistry (1923). He died Dec. 13, 1930.

PREHNITE, a mineral of the composition $H_2Ca_2Al_2Si_3O_{12}$, but containing also small amounts of Fe_2O_3 and traces of Mn, Mg and alkalis; so called after Col. Prehn, who first brought it to Europe from Cradock, in Cape Colony. It crystallizes in the hemimorphic class of the rhombic system, but the hemimorphic char-

acter is often obscured by twinning. Crystals are pyroelectric. The habit is that of flat tables on 001 or elongated along the crystallographic axis *a*. Crystals, however, rarely occur singly, most frequently being aggregated together in divergent groups to form fan-shaped, or globular masses. Prehnite has a dominant 001 cleavage and is usually white or pale green. Though often classed with the zeolites, the contained water is only expelled at a red heat. Optical anomalies are not uncommon, this characteristic being ascribed to twinning on a fine scale. The hardness is 6–6·5 and specific gravity 2·80–2·95. Prehnite occurs in association with zeolites in amygdales of basic igneous rocks such as basalt and dolerite, as well as a purely secondary mineral in veins. In contact-altered limestones the mineral is not uncommon. Here it appears to represent a late hydrothermal stage of alteration, being found in veins and replacing such minerals as labradorite, vesuvianite and scapolite. In the crystalline schists it is sparingly developed in amphibolites, and metamorphosed carbonate sediments. (C. E. T.)

PREJUDICE. In law "without prejudice," means without detriment to a person's rights or claims. When two parties are negotiating for the settlement of an existing dispute, statements or admissions made by or on behalf of either, with a stipulation, expressed or implied, that the statements are made "without prejudice" to the party's claims in the dispute, cannot be put in evidence in litigation to settle the dispute. But a letter which by its nature may prejudice the person to whom it is written may be put in evidence, *e.g.*, if it contain threats. (*See* EVIDENCE.)

PREL, KARL, FREIHERR VON (1839–1899), German philosopher, was born at Landshut on April 3, 1839, and died on Aug. 4, 1899. After studying at the University of Munich he served in the Bavarian army from 1859 to 1872, when he retired with the rank of captain. He then gave himself up to philosophical work, especially in connection with the phenomena of hypnotism and occultism from the modern psychological standpoint. He attempted to deduce the existence of spirit, apart from, and yet entering from time to time into connection with, the phenomena of the senses, by an examination of the relation between the ego of thought and the age of sensible experience as understood by Kant. In *Der Kampf ums Dasein am Himmel* (1874), republished in 1882 under the title *Entwickelungsgeschichte des Weltalls*. Prel endeavoured to apply the Darwinian doctrine of organic evolution not only to the sphere of consciousness but also even more widely as the philosophical principle of the world.

He was one of a large number of German thinkers who during the latter half of the 19th century endeavoured to treat the mind as a mechanism.

PRELATE, ecclesiastical dignitary of high rank. In the early middle ages the title *prelate* was applied to secular persons in high positions and thence it passed to persons having ecclesiastical authority. The *De prelatis* of Valerian is concerned with secular princes, and even as late as the 14th century the title was occasionally applied to secular magistrates. In mediaeval ecclesiastical usage the term might be applied to almost any person having ecclesiastical authority. The term occurs very frequently in the Rule of St. Benedict and other early monastic rules.

In more modern usage in the Roman Catholic Church prelates, properly so-called, are those who have jurisdiction *in foro externo*, but a liberal interpretation has given the title a more general significance. Prelacy is defined by the canonists as "pre-eminence with jurisdiction" and the idea supposes an episcopal or quasi-episcopal jurisdiction. But gradually the title was extended to ecclesiastical persons having a prominent office even without jurisdiction, and later still it has come to be applied to ecclesiastical persons marked by some special honour though without any definite office or jurisdiction.

We may therefore distinguish "true" from "titular" prelates. The true prelacy is composed of the persons who constitute the ecclesiastical hierarchy; jurisdiction is inherent in their office and gives pre-eminence, as with patriarchs, archbishops and bishops. The true, no less than the titular, prelates have their various ranks, differing as regards title, precedence, clothing and other insignia. The distinguishing colour of a prelate's clothing is violet; the form, like the greater or less use of violet, depends on the rank of the prelate. Four classes may be distinguished: (1) Great prelates, *e.g.*, cardinals, archbishops and bishops. (2) Exempt prelates, *i.e.*, abbots and religious superiors, who are withdrawn from the ordinary diocesan jurisdiction and themselves possess episcopal jurisdiction. (3) Roman prelates, (*a*) active and (*b*) honorary. The title is applied to numerous ecclesiastics attached by some dignity, active or honorary, to the Roman court (*see* CURIA ROMANA).

In the Reformed churches the title was retained in England, Sweden, Denmark and Germany. The cathedral chapter of Brandenburg consists of two prelates, the dean and the senior, besides eight other members. The chapter of Merseburg contains five prelates, viz., the dean, senior, provost, custos and scholasticus. In Baden the general synod is presided over by the prelate (*prelat*), *i.e.*, the principal "superintendent." In the Church of England the term prelate has been since the Reformation applied only to archbishops and bishops.

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PRELLER, LUDWIG (1809–1861), German philologist and antiquarian, was born at Hamburg on Sept. 15, 1809. He taught at Dorpat and Jena, and was head librarian at Weimar, where he died on June 21, 1861. His chief works are: *Demeter u. Persephone* (1837); *Griechische Mythologie* (1854–55); and *Römische Mythologie* (1858); with H. Ritter he produced the valuable *Historia philosophiae graecae et romanae ex fontium locis contexta* (1838). He contributed to Ersch and Gruber's *Allgemeine Encyklopädie* and Pauly's *Realencyklopädie der classischen Altertumswissenschaft*. A complete list of his works will be found in *Ausgewählte Aufsätze aus dem Gebiete der klassischen Altertumswissenschaft* (ed. R. Köhler, 1864).

See G. T. Stichling, *Ludwig Preller. Eine Gedächtnissrede* (1863).

PREMONITION, an impression relating to a future event. In modern times the best attested premonitions are those relating to events about to occur in the subject's own organism. The power of prediction possessed by the subject in such cases may be explained in two ways: (1) As due to an abnormal power of perception possessed by certain persons, when in the hypnotic trance, of the working of their own pathological processes; or (2) more probably, as the result of self-suggestion.

Apart from these cases there are two types of alleged premonitions. (1) The future event may be foreshadowed by a symbol. Amongst the best known of these symbolic impressions are banshees, corpse lights, phantom funeral processions, ominous animals or sounds and symbolic dreams (*e.g.*, of teeth falling out). Of all such cases it is enough to say that it is impossible for the serious inquirer to establish any causal connection between the omen and the event which it is presumed to foreshadow. (2) There are many instances, recorded by educated witnesses, of dreams, visions, warning voices, etc., giving precise information as to coming events. In some of these cases, where the dream, etc., has been put on record before its "fulfilment" is known, chance is sufficient to explain the coincidence, as in the recorded cases of dreams foretelling the winner of the Derby or the death of a crowned head. In cases where such an explanation is precluded by the nature of the details foreshadowed, contemporaneous documentary evidence is usually lacking. The persistent belief on the part of the narrators in the genuineness of their previsions indicates that in some cases there may be a hallucination of memory, analogous to the well known feeling of "false recognition."

PREMONSTRATENSIANS, also called Norbertines, and in England White Canons, from the colour of the habit: an order of Augustinian Canons founded in 1120 by St. Norbert, afterwards archbishop of Magdeburg. He had made various efforts to introduce a strict form of canonical life in various communities of canons in Germany; in 1120 he was working in the diocese of Laon, and there in a desert place, called Prémontré, in Aisne, he and thirteen companions established a monastery to be the

cradle of a new order. They were canons regular and followed the so-called Rule of St. Augustine (*see* AUGUSTINIANS), but with supplementary statutes that made the life one of great austerity. St. Norbert was a friend of St. Bernard of Clairvaux—and he was largely influenced by the Cistercian ideals as to both the manner of life and the government of his order. But as the Premonstratensians were not monks but canons regular, their work was preaching and the exercise of the pastoral office, and they served a large number of parishes incorporated in their monasteries. The strength of the order now lies in Belgium, where at Tongerloo is a great Premonstratensian abbey that still maintains a semblance of its mediaeval state.

BIBLIOGRAPHY.—*See* Max Heimbucher, *Orden u. Kongregationen* (1907); ii. § 56; articles in Wetzer u. Welte, *Kirchenlexikon* (2nd ed.); Herzog-Hauck, *Realencyklopädie* (3rd ed.) and *Catholic Encyclopaedia*, art. "Premonstratensians." The best special study is F. Winter, *Die Prämonstratenser des 12. Jahrh. und ihre Bedeutung für das nordöstliche Deutschland* (1865).

PREMYSL, the reputed ancestor of the Premyslide line of dukes and kings which ruled in Bohemia from 873 or earlier until the murder of Wenceslaus III in 1306. According to legend Premysl was a peasant of Stadice who attracted the notice of Libusa, daughter of a certain Krok, who ruled over a large part of Bohemia, and is said to have been descended from the 7th-century hero Samo. Premysl married Libusa, the traditional foundress of Prague, and during the 8th century became prince of the Bohemian Czechs. His family became extinct when Wenceslaus III died, but through females the title to Bohemia passed from the Premyslides to the house of Luxemburg and later to the house of Habsburg.

See F. Palacky, *Geschichte von Böhmen,* Bd. i (Prague, 1844).

PRENATAL CLINICS: *see* ANTENATAL CLINICS.

PRENZLAU or PRENZLOW, a town in Brandenburg, east Germany, on the lower Ücker river, 30 mi. W.S.W. of Stettin. Population (1946) 17,669. Prenzlau is first mentioned at the close of the 12th century and received its municipal charter in 1234. As the capital of the old Ückermark it was a frequent object of dispute between Pomerania and Brandenburg until incorporated with the latter in 1250.

The industries include machine building, iron founding and sugar refining. Tobacco is grown in the neighbourhood, and cigars, margarine and leather are manufactured in the town. Much of the town was destroyed during World War II.

PREPARATORY SCHOOLS in Great Britain form part of the public school system. (In the United States the term is used for those schools which prepare for higher education, and they are discussed in the articles SECONDARY EDUCATION and EDUCATION, HISTORY OF, *United States* sections.)

In Great Britain before Thomas Arnold in the 1830s excluded boys of under 12 years of age from Rugby there were few of these schools, but they are now very numerous. They are privately owned and are free of government control; however, they have usually invited inspection by her majesty's inspectors of schools and indeed are now compelled by law to undergo such inspection periodically. The majority of preparatory schools are linked together by membership in an incorporated association. They cater, for the most part, for boys between the ages of 7 and 14 years, and, outside the large towns and cities, most of the pupils are boarders.

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PREROGATIVE, in English law, means the powers, privileges and immunities peculiar to the King. In the early Middle Ages the word occurs as an adjective meaning "exceptional," as in the sentence "The King *is* prerogative."

A distinction has to be made at the outset between prerogatives peculiar to the King in his "natural" capacity and confined to him, such as the rule that he is personally exempt from all jurisdiction, criminal or civil, and cannot be sued for debt, and prerogatives which belong to his "politic" capacity and as such extend to the whole Government carried on in his name, such as the immunity of "the Crown" from being sued by ordinary civil process. (*See* PETITION OF RIGHT.) English law has, however, never clearly distinguished between the two capacities; indeed Coke declared it "a damned and damnable opinion" to attempt such a distinction. The whole history of "constructive treason" is a witness to this dualism, as when the judge held that "every rebellion intendeth as its natural consequence the death of the King." In other words, a subject indicted for attempting to compel the King to change his counsellors was not allowed to plead that his "overt acts" were not directed against the life of the King but merely against his Government. The result was that the King was completely identified with the State and even to-day our constitutional law knows no such term as "The State." The State *is* the King. All writs run in his name. All indictable offences are offences "against the peace of our Lord the King, his Crown and dignity." All "public" property is legally vested in the King—"his" are the ships of war, the Government buildings; the courts of justice and all other governmental agencies.

All statutory powers conferred upon the Government are declared to be conferred on "His Majesty in Council." All money voted by Parliament is voted to "the King," even though it be appropriated by statute to public services from which the King is powerless to divert it. This identification of the State with the King is nothing but a survival of mediaeval times when the King was, indeed, "every inch a King," when he governed largely by his own will, did justice in person and chose his own servants.

The Crown.—The term "Crown" is occasionally used to mark the distinction between the King's Government and the King's person, but its use is intermittent and, strictly speaking, the Crown is, as has been prettily said, nothing but "a chattel in the Tower which has been entailed upon the Hanoverian dynasty." The common law, apart from statute, makes no distinction, for example, between debts due to the King's household and debts due to the Crown, so that, at common law, debts due to the King personally and taxes due to his Government enjoy, indifferently, the prerogative of priority over all other claims against the estate of a debtor, a bankrupt or a deceased person. In the same way a royal palace and a Post Office are equally exempt from the payment of rates, for it is one of the "prerogatives" that "the King" is not bound, in the absence of express words, by a taxing statute. We see the same identification of the "natural" King and the "politic" King in the rule that the King's Government can never, in any circumstances, be sued for wrongful, *i.e.*, tortious, acts. The immunity of the latter is based, historically, on the rule that the "King can do no wrong" which did not mean originally, *e.g.*, in the time of Bracton, the perfectibility of the King but the simple feudal fact that the King could not be tried or sued in his own courts any more than any other feudal lord in the court of that lord's jurisdiction.

As the King was, and is, the "Government," the rule found a new application in the principle that no governmental acts or defaults could be the subject of legal proceedings. Had this application been carried to its logical conclusion, it would have resulted in the immunity of all the King's officers from being sued for their wrongful acts. But English law was, and is, too practical a science to be logical and a consequence so disastrous to the rights of the subject was avoided by the evolution of the principle, laid down by the judges, that no servant of the Crown could be allowed to plead the command of the King, even where such a command had actually been issued, as a defence for an unlawful act, for to admit such a plea would, they held, be to impute wrong to the King. This theory reaches its triumphant climax in the *dictum* of Blackstone that the King not only can "do" no wrong but cannot even "think a wrong." The failure of the law to make any distinction between the natural and political capacity of the King led to some desperate fictions, of which the supreme example is the legal maxim that "the King never dies." This fiction, in the absence of such a distinction, was necessary because otherwise the death of the King would have dissolved the State in the interregnum between the decease of one King and the coronation of his successor. Indeed, this was actually the situation before the invention of the fiction.

A mediaeval chronicler records that on the death of one of the earlier Kings "every man did what was right in his own eyes." The King was dead, his "peace" died with him and, for the time being, offences ceased to be "crimes" for the legal essence of a crime, as we have seen, is an offence "against the King's peace." Here is the mystical doctrine, so mystically expressed by Allen when he says "When the King dies his politic body escapes from his natural body and by a sort of legal metempsychosis enters into the natural body of his successor; but whilst he is alive the two bodies are indissolubly united and consolidated into one." But the conquest of this fiction was not complete. Right down to 1867 the death of the King operated to dissolve Parliament; the King was, and is, a constitutional element in Parliament and the summons of a Parliament was regarded as an act so personal to him that when he died his Parliament died with him. It was reserved for the Demise of the Crown Act of 1867 to provide that the death of the King should not involve a dissolution. On the other hand the death of the King still operates to dissolve the whole Privy Council from the date of his death until his successor re-appoints the members.

Modern Kingly Prerogative.—The prerogative powers of the King, *i.e.*, powers original and inherent in the Kingship, as distinct from powers conferred on him by statute, have all of them one feature in common which is that they can no longer be exercised by the King in person but only on the advice of Ministers or, what amounts to the same thing, in particular forms and by the use of particular instruments. Long before "responsible government" made its appearance in England and at a time when the Commons even repudiated responsibility for the government of the country, Parliament, guided by a sound instinct, insisted that the royal prerogative in certain matters could only be exercised by the use of certain seals, notably the Great Seal and the Privy Seal, which were in the custody of certain great officers of State. There are innumerable mediaeval statutes to this effect. For the use or misuse of these seals their custodians could be brought to book by *impeachment* (*q.v.*) in Parliament. As early as the 16th century the judges held in *Mildmay's Case* that the King's order to issue "treasure" could only be executed by a warrant under the Great or Privy Seal—a principle now embodied in the Exchequer and Audit Act of 1866 which requires that the sign-manual, *i.e.*, the King's personal signature, must always be countersigned by two Lords of the Treasury before money can issue out of the national exchequer. In the same way the common law courts themselves laid down the rule, at the beginning of the 17th century, that, even in the Court of King's Bench, held *coram rege* and in which mediaeval Kings had presided in person, the King could no longer administer justice in person—"the King cannot speak by word of mouth but only by record." There still remained, it is true, the residuary jurisdiction of the King in Council which could be, and was, exercised by him in person, but with the abolition of the Star Chamber in 1641 this jurisdiction disappeared. By the same statute the King's personal command, *i.e.*, a warrant issued under his hand, was no longer, of itself, to be a decisive answer to an application for a writ of Habeas Corpus by a person arrested under such a warrant. (*See* WARRANT and HABEAS CORPUS.)

So long as it was in the power of the King to remove the judges for decisions adverse to the exercise of his personal will or to dismiss ministers who refused to carry out his wishes, he could, of course, bend them to exercise his prerogatives according to his pleasure, even when their exercise was subject to the formal rules described above. Parliament, however, gradually stopped up every earth in this respect. It refused to accept the King's command as a defence to the impeachment of one of his ministers, as in *Danby's Case* (1679), while by the Act of Settlement (section 3) it enacted that the King's prerogative of pardon under the Great Seal should not be pleadable to an impeachment. So long, however, as the King was not dependent on supplies for the ordinary expenses of the Government he could neglect to summon a Parliament for as many years as he pleased and impeachment was thereby made impossible. What was really decisive in securing the exercise of the King's prerogative by ministers in accordance with popular will was not so much the development of Cabinet Government as the transfer, principally as the result of Burke's reforms, of all governmental expenses from being a charge on the hereditary revenues of the Crown, or the Civil list, to the annual Estimates. In strict law the King can still appoint and dismiss ministers as he pleases, nor is he under any statutory obligation to summon Parliament. But if he did the one and omitted the other, he and his ministers would be without money to carry on the Government. Taxes might still be imposed, for much of our taxation is voted under permanent Acts, but none of the proceeds could be expended. Only the annual Appropriation Act can authorize the expenditure of the public money.

Decreasing Powers.—As with the King's ministers, so with "his" judges. In virtue of the Act of Settlement the King can no longer dismiss judges at his pleasure; they are removable only on an address by both Houses of Parliament. Even their appointment, although technically the act of the King, is the act of a minister, namely the Lord Chancellor who issues, in each case, a "patent" of appointment.

The prerogatives are thus no longer an instrument of arbitrary government. They have, constitutionally speaking, passed into the hands of the Cabinet. Hence Dicey's epigram that "the prerogatives of the Crown have become the principles of the people." Like all epigrams, this statement is, however, more pointed than true. Cabinets may be as arbitrary as Kings, and Prime Ministers as arbitrary as Cabinets. The prerogative of dissolution, for example, now operates, in virtue of the modern convention that the King is constitutionally bound to grant a dissolution to a Prime Minister, even when he has been defeated in the House of Commons, to make the former the master of the latter. So too a Government, faced by a hostile House of Lords, can in certain cases avail itself of the prerogative where it cannot be sure of getting its way by statute. Furthermore the prerogative interposes a shield between a Government department and a subject whose rights it has invaded. (*See* PETITION OF RIGHT.)

Pre-Cabinet Government.—Before the development of Cabinet Government, in other words while the exercise of the prerogative was exclusively in the hands of the King himself, or of ministers subservient to him, the efforts of Parliament were directed to depriving, subjugating or abolishing the prerogative. The chief example is afforded by statutes such as the Petition of Right, the Bill of Rights and the Act for the Abolition of the Star Chamber, statutes abolishing respectively the prerogative of the King in taxation to supply his needs, in raising and keeping a standing army to enforce his will, and in exercising a jurisdiction to punish his opponents. Here Parliament went further than the courts were prepared to go. The courts did, indeed, in the famous "Case of Proclamations" lay down the important principle that "the King hath no prerogative except that which the law allows him." But the law itself, *i.e.*, the common law, was disposed, as in *Bate's Case*, 2 State Trials 371 (1606), and in the *Ship Money Case*, 3 State Trials 1090 (1638), to recognize an arbitrary power in the King by distinguishing an "absolute" prerogative in cases of emergency, of which the King must be the sole judge, and from the exercise of which no King, not even by statute, would contract himself out—at any rate so as to bind his successors. The answer to this doctrine was the pertinent challenge of Mr. Hakewill in the Commons debates, "Who then shall decide what *is* an emergency?". It was the Revolution of 1689 that really decided the issue by settling that the King has no power above and beyond the law and that the real sovereign is not the King but the King in Parliament.

Summary.—The chief prerogative powers may be summarised as follows:

(1) **In foreign relations** the King has the exclusive power of making war and of declaring peace. The power is usually exercised by a Proclamation and an Order in Council and, as such, it is binding on the courts who cannot go behind it but must accord it the same "judicial notice" as an Act of Parliament, *Esposito* v. *Bowden* 7 E. and B. 765. In practice, of course, the power is never exercised except with the approval of Parliament. The treaty-making power may be regarded as an exercise of the

same prerogative. The King can make what treaties he pleases, provided they do not impose a tax on the subject or derogate from common law rights. Whether he can, by the negotiation of such a treaty, cede British territory is more doubtful and has been much disputed; no King, in other words no English ministry, has ventured to exercise such a prerogative since 1894 without seeking the consent of Parliament in the form of a statute and it may be regarded as now settled usage that, as in the case of the Treaty of Versailles, the Crown will always, in the case of a Treaty of Peace involving cession or annexation, seek statutory powers, *ex magna cautela,* to do all such things as may be necessary to carry such a treaty into effect. The Crown has, however, often, as in the case of certain African Protectorates, annexed "foreign" territories by mere prerogative in the form of an Order in Council. Furthermore it rests with the Crown, and the Crown alone, to "recognize" the foreign Governments as *de jure* Governments: a recent case in point is the recognition of the Bolshevik Republic (see *Luther* v. *Sagor* [1921] 3 K.B. 533). Such recognition is binding on the courts and, by a logical sequence, so is a declaration by the Crown that a particular person is entitled to the status of a foreign sovereign and as such is immune from the jurisdiction of the courts—cf. *Mighell* v. *Sultan of Johore* (1880) L.R. 5 P.D. 197. So too with the status of an ambassador and the diplomatic immunity of himself and his "suite"—it has now been held that the courts cannot, in the presence of a Foreign Office certificate, even traverse that certificate in order to decide whether the person, in favour of whom diplomatic immunity from their jurisdiction is claimed, is, as a matter of fact, a member of the embassy or not—*Mussman* v. *Engelke* (1928) A.C.

(2) **Defence.**—The King is head of the naval and military forces of the country and can alone recruit them. It is a statutory offence for any other person to "recruit." The Bill of Rights has limited the exercise of this prerogative by making the raising and maintaining of a standing *army* in *time of peace* illegal. The words italicized are important; they do not prohibit the exercise of the power in time of war and they leave the prerogative unaffected as regards the navy. "The Crown is *not* precluded from raising a standing navy in time of peace nor from imposing a permanent discipline" and in time of war the King can impress sailors and ships by virtue of royal prerogative, *R.* v. *Broadfoot* (Foster, *Crown Cases* p. 154). There is considerable authority for the proposition that in time of war the King can conscript civilians for the defence of the realm although he cannot compel them to serve abroad. So, too, with certain limitations, he can requisition the subject's property and enter on the subject's land in time of war although this prerogative is now entirely regulated by statute (*see* the *De Keyser Case* below). The necessity of an annual statute to put in force the code of discipline known as the Army Act has, as it has been well said, made of the army "a statutory not a prerogative force." The fact also that all Army expenditure is subject to the annual vote of the Army Estimates has the same effect. And it is, in fact, impossible for the King to "make war," as distinct from declaring it, without the consent of Parliament. Not only would a vote of special supplies be necessary but by the Reserve Forces Act of 1882, mobilization itself is subject to Parliamentary consent inasmuch as the Army Reserve cannot be called up for permanent service unless Parliament is summoned within 10 days. The same condition is attached to the embodiment of the Territorial Force. (*See* also MARTIAL LAW and MILITARY LAW.)

(3) **Legislation.**—The requirement of the King's assent to a bill passed by both Houses of Parliament before it can be "enacted" may be regarded as an aspect of the royal prerogative in that the King may, in law, withhold his assent. This prerogative is not dead—"time never runs against the King" so as to make a prerogative wholly obsolete by desuetude—but it has not been exercised since the reign of Queen Anne. But the King may legislate by prerogative, *i.e.,* by Proclamation or by Order in Council, as distinct from statute. But it was long ago laid down by Coke that the King cannot, by his prerogative, alter the common law or create a new offence. In the case of colonies acquired by conquest or cession the prerogative is, however, as absolute as in the time of the earlier statutes. In such cases the King may make what laws he pleases (*Campbell* v. *Hall,* 20 St. Tr. 239). And in the case of all colonies, even the self-governing Dominions, the King can "disallow" an Act to which his local representative, the Governor or Governor-General, has assented. This power is recognized in the constitution of the self-governing Dominions themselves, but it is therein made subject to a period of limitation, usually one or two years.

(4) **Parliament.**—It is the sole prerogative of the King to summon, prorogue and dissolve Parliament. This may properly be regarded as an executive, not a legislative, act and it is, of course, performed on the advice of ministers. As has been said above, it may be regarded as an accepted convention, at any rate since 1924, that the King cannot, under any circumstances, refuse to dissolve Parliament when a request to that effect is preferred by a Prime Minister. But he might still dissolve Parliament *ex proprio motu* and against the wishes of his Prime Minister under certain circumstances, as, for example, when a Prime Minister having been defeated on a direct Vote of Confidence in the Commons refused either to resign or to ask for a dissolution. Such a state of affairs is not likely nor would it, in any case, be durable, but it is not inconceivable.

(5) **Executive.**—The theory of the law is that the Government of the country is still entirely a matter of prerogative, although, of course, many, if not most, of the powers now exercised by the Crown have been conferred upon it by statute—in particular the power of making Statutory Rules and Orders (*q.v.*) to carry a statute into effect. All ministers are appointed by the King—on the nomination of the Prime Minister—and "Kiss hands" or, as in the case of Secretaries of State, receive their seals from the King himself. In law there is no such office as that of "Prime Minister." In the choice of a Prime Minister the King has, both in law and in fact, a discretion and he sends for whom he will, when the outgoing Prime Minister has resigned, but his choice is usually limited to the leader of the Opposition. All military and naval officers are appointed by a "commission" from the King. So too with the Governors of the Colonies. And as he appoints, so he dismisses. Every office under the Crown, except that of the judges and the Comptroller and Auditor General, is held "during pleasure." This doctrine has important legal consequences in that the King's ministers, exercising the prerogative, can terminate any commission or contract of service whenever they please and the servant of the Crown, civil or military, has no remedy. English law "imports into every agreement" for service with the Crown the term "that the Crown has power to dismiss at pleasure" and even that any term of agreement purporting to exclude this power would be void (Lord Watson in *De Dohse* v. *the King* quoted in *Dunn* v. *the Queen* [1896] 1 Q.B. at p. 118). This is a striking example of how the prerogative may operate to invest ministers with arbitrary power. No servant of the Crown has any legally enforceable right to pay, pension or security of tenure.

(6) **General.**—The less important prerogatives of the Crown may be dealt with generally. The King is the supreme landowner, a relic of feudal doctrines, which is only important in the case of a man dying intestate and without heirs in which case his land "escheats" to the Crown. The King also is the depositary of the prerogative of mercy, in other words he can pardon those who offend against his "peace"; the prerogative is now exercised exclusively on the advice of the Home Secretary. He is the "fountain of honour" and as such is the sole grantor of titles such as peerages, baronetcies and knighthoods; his power in this respect is subject to no limitations except those contained in peerage law but "honours" are rarely conferred by him except on the advice of Ministers. He is the "supreme governor" of the Church in virtue of the Acts of Supremacy and Uniformity. The prerogatives of the Crown in the courts are dealt with in the article on PETITION OF RIGHT.

Effect of Statutes on the Prerogative.—As has been seen Parliament has frequently intervened to abolish some particular prerogative, deemed to be oppressive, and since the Revolution of 1689 it has never been doubted that such a statute will bind

not only the King who actually assented to it but all his successors. It has, however, until recently, been a matter of considerable doubt and speculation whether a statute can curtail a prerogative in the absence of express words to that effect. In a book of considerable authority in its day, Chitty (*The Prerogative of the Crown* [1820] p. 383) laid down that "Acts of Parliament which would divest or abridge the King of his prerogative, his interests or his remedies in the slightest degree do not in general extend to bind the King unless there be express words to that effect." This view was expressed more widely by a judge, Hobart, C. J., in 1624 in the quaint words "Everything [in a statute] for the benefit of the King shall be taken largely [*i.e.*, liberally], as everything against the King shall be taken strictly" —*Sir Edward Coke's Case* (1624), Godbee's Reports, p. 289. Thus it has been successfully contended that the Crown is not bound by the Statute of Limitations and it has obtained judgment in proceedings against a subject, by Information of Debt, on a claim thirty years old (*Brummell* v. *M'Pherson* 7 L.J. [O.W. Series] Ch. 1.). But the presumption in favour of the Crown, in the interpretation of a statute, is no longer as strong as it was. In this respect the great case of *Attorney-General* v. *De Keyser's Hotel* [1920] A.C. is decisive to the extent that when Parliament has by statute regulated "the whole field of the prerogative," that particular prerogative can be exercised in no other way than that prescribed by the statute. In that case the Defence Act of 1842 had laid down regulations for the payment of compensation by the Crown for lands taken for the purpose of national defence, and it was held that, though that Act had not expressly abolished the prerogative of taking land or premises in time of war, the prerogative itself could only be exercised in accordance with the terms laid down by the Act, namely the payment of compensation duly assessed by a jury. The Crown's contention that, as there was no direct mention of the prerogative in the Act of 1842, that prerogative was unaffected and unimpaired, was decisively rejected by the courts. The same principle was followed by the courts in the case of *Food Controller* v. *Cork* (1923) A.C. 647. (*See* also ATTORNEY-GENERAL; COMMON LAW; CONSTITUTION AND CONSTITUTIONAL LAW; PETITION OF RIGHT.)

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PREROGATIVE COURTS, the name given to the English provincial courts of Canterbury and York, as far as regarded their jurisdiction over the estates of deceased persons. They had jurisdiction to grant probate or administration where the diocesan courts could not entertain the case owing to the deceased having died possessed of goods above the value of £5 (*bona notabilia*) in each of two or more dioceses. The jurisdiction of the prerogative courts was transferred to the court of probate in 1857 by the Probate Court Act, and is now vested in the probate, divorce and admiralty division of the High Court of Justice by the Judicature Act 1875. In the State of New Jersey, United States, the court having jurisdiction over probate matters is called the prerogative court.

PRESBYTER, the title borne from very early times by certain officers or ministers of the Christian Church intermediate between "bishops" and "deacons." The word is the original form of priest (*q.v.*). The word is not found in pre-Christian writings except in the Septuagint, though as Deissmann has shown it is found on the Papyri as an official title for the village magistrates of Egypt and the members of the γερουσία, or senate, of many towns in Asia Minor. The office is, however, closely analogous to, and perhaps founded on, a similar office in the Jewish synagogue organization among the officials of which were the *zekenim*, or elders, sometimes identified with the archi-synagogues. In the New Testament the Greek word is used both for the ancient Jewish official and for the Christian elder.

The history of presbyteral government as opposed to episcopacy and pure congregationalism is not known in detail. After the Reformation, however, it was adopted by Calvin and his followers, who created that system which has ever since been known as Presbyterianism (*q.v.*). During the last quarter of the 1st century, a threefold organization is found in the Church: (*a*) a spiritual organization composed of "apostles, prophets and teachers who had been awakened by the spirit and by the spirit endowed"; (*b*) an administrative organization, "For the care of the poor, for worship, for correspondence, the congregation needed controlling officials. These were the bishop and the deacons, the former for higher, the latter for inferior services"; (*c*) a patriarchal organization based upon the natural deference of the younger to the older members of the Church. The senior members of the community, by virtue of their age and experience, watched over the conduct and guided the action of the younger and less experienced portion of the Church, though they held no official position and were not appointed for any particular work like the bishops and deacons. In the 2nd century the patriarchal element in the organization was merged in the administrative, and the presbyters became a definite order in the ministry. The time at which the change occurred cannot be definitely fixed. Although presbyters are not mentioned in the genuine Epistles of St. Paul, there are hints that similar officers existed in some of the churches founded by the apostle. There is a reference in 1 Thess. v. 12 to "those who rule over you" (προϊστάμενοι), and the same word occurs in Rom. xii. 8. The term "governments" (κυβερνήσεις) in 1 Cor. xii. 28 obviously refers to men who discharged the same functions as presbyters. If too, as seems most probable, bishops and presbyters were practically identical, there is of course a specific reference to them in Phil. i. 1. The "leaders" who are mentioned three times in Hebrews xiii. were also probably "presbyters" under another name. If the Church at Jerusalem had any officials, it is highly probable that those officials bore the name and took over the functions of the elders of the synagogue. The statement in Acts xiv. 23, that Paul and Barnabas appointed elders in the churches of South Galatia, is more open to objection perhaps, owing to the silence of the Epistle to the Galatians.

The conclusions which we seem to reach are as follows: (1) In the earliest stage (between 30 and 60) there is no uniform organization in the Christian Church. Presbyters are found in Jerusalem from primitive times. In the Pauline churches the name is not found except at Ephesus and possibly in south Galatia, though there are traces of the office, at any rate in germ, under different titles in other churches. (2) In the second stage (between 60 and 100) there is an increasing tendency towards uniformity. The office is found definitely mentioned in connection with the churches of Asia Minor (1 Pet. v. 1), Corinth (Epistle of Clement) and Crete (Titus). The officials were called by two names, "elders" and "bishops," the former denoting the office, the latter the function (exercising the oversight). The substantial identity of the two titles cannot be doubted in the light of such passages as Acts xx. 17, 28; 1 Pet. v. 1, 2; 1 Tim. iii. 1–7, v. 17–19 and Titus i. 5–7.

There is far less controversy with regard to the later history of the presbyters. The third stage of the development of the office is marked by the rise of the single *episcopus* as the head of the individual church (*see* BISHOP; EPISCOPACY). The first trace of this is to be found in the Epistles of Ignatius which prove that by the year 115 "the three orders" as they were afterwards called—bishops, presbyters and deacons—already existed, not indeed universally, but in a large proportion of the churches. The presbyters occupied an intermediate position between the bishop and the deacons. They constituted "the council of the bishop." It was some time before the threefold ministry became universal. The *Didache* knows nothing of the presbyters; bishops and deacons are mentioned, but there is no reference to the second order. The *Shepherd* of Hermas knows nothing of the single bishop; the churches are under the control of a body of presbyter-bishops. Before the close of the 2nd century however the three orders were established almost everywhere. The sources of the Apostolic Canons (which date between 140–180) lay down the

rule that even the smallest community of Christians, though it contain only 12 members, must have its bishop and its presbyters. The original equality of bishops and presbyters was still however theoretically maintained. The presbyters formed the governing body of the church. It was their duty to maintain order, exercise discipline and superintend the affairs of the church. At the beginning of the 3rd century, if Tertullian is to be believed, they had no spiritual authority of their own, at any rate as far as the sacraments are concerned. The right to baptize and celebrate the communion was delegated to them by the bishop.

In the fourth stage we find the presbyters, like the bishops, becoming endowed with special sacerdotal powers and functions. It was not till the middle of the 3rd century that the priesthood was restricted to the clergy. Cyprian is largely responsible for the change, though traces of it are found during the previous half century. Cyprian bestows the highest sacerdotal terms upon the bishops of course, but his references to the priestly character of the office of presbyter are also most definite. Henceforth presbyters are recognized as the *secundum sacerdotium* in the church.

With the rise of the diocesan bishops the position of the presbyters became more important. The charge of the individual church was entrusted to them and gradually they took the place of the local bishops of earlier days, so that in the 5th and 6th centuries an organization was reached which approximated in general outline to the system which prevails in the Anglican Church today.

BIBLIOGRAPHY.—*See* Edwin Hatch, *Organization of the Early Christian Churches* (2nd ed., 1882), and A. von Harnack's *"excursus"* in the German edition of this work (1883); Harnack, *Die Lehre der zwölf Apostel* (1884); Loening, *Die Gemeindeverfassung des Urchristentums* (1889); Sohm, *Kirchenrecht* (1892); an article by Loofs, in *Studien und Kritiken,* for 1890 (pp. 619–658); T. M. Lindsay, *The Church and the Ministry in the Early Centuries* (1902); Schmiedel, article "Ministry," in *Enc. Bib.*

PRESBYTERIAN, the distinguishing name of a group of Christian churches which took form during the British Reformation and subsequently gave rise to other churches bearing the same name in the Americas, Asia and Africa. Also, the specific name of a form of church constitution or polity which claims for itself origin in the Christian church during apostolic times and reformulation during the Swiss Reformation. Subsequently, this system was adopted with variations by many churches in other countries, some using the original name "Reformed Church," others the name "Presbyterian Church," or other names.

THE PRESBYTERIAN CHURCHES

England.—During the Reformation in England several groups arose, each with a different religious and political outlook according to which it sought to shape English life. In time, one of these groups assumed the name Presbyterian. Its name came from its form of church government, but its total program was an all-embracing right-wing Puritan system which took into account theology, ethics, politics and economics. The basis of the whole system was a conception of covenant or contract. William Tyndale had introduced this conception into England in his Bibles and other religious and political writings. The idea had been used in various religious and political systems of the middle ages. Tyndale seems to have gotten it from the reformers of the Rhineland cities, Zürich, Basel and Strasbourg, where it was being made the basis of a Protestant theology and a democratic-republican political theory. Other early English reformers such as John Bale and John Hooper, also used this system in their writings.

Under Edward VI (1547–53) the English Reformation went forward with royal aid. Numerous scholars from the Rhineland, Martin Bucer, Peter Martyr and others, went to England. A strong movement was created based on an Augustinian piety and theology, deeply influenced by humanism, devoted to the Bible, to ethical reform and to democratic political ideas. The covenant-contract notion underlay all of these views, as it did in the Rhineland. Queen Mary (1553–58) restored Roman Catholicism and the leading reformers fled to the continent. During this "Marian exile" the English reforming movement developed three wings. One regarded the moderate reform set up under Edward VI as typically English and final. Another group demanded further reforms, especially doctrinal, along lines laid out by John Calvin in Geneva. A third group, mostly underground in England, was working for reformation by small groups, each free in every way.

Queen Elizabeth (1558–1603) re-established Protestantism, but did so on the basis of a series of compromises framed in the interests of her royal power. After some adjustments most of the Edwardean group of reformers, led by their bishops, accepted Elizabeth's plan. The Genevan group was shunted to one side, since in both theology and politics their ideas were considered too radical. The third group of reformers remained underground and were considered as dangerous and subversive sects.

As the meaning of Elizabeth's policy became clear, open opposition to it arose. Yet, so ably did Elizabeth pursue her course that her opponents were effectively turned against each other. The "vestiarian" controversy of 1567–68 was an attempt to break the Elizabethan compromise settlement by demanding the elimination of all ministerial vestments and church furnishings formerly associated with Catholicism. The name "Puritans" was coined during this struggle. The bishops defeated this attempt by making it to appear as a quarrel over wholly peripheral matters. Then came a frontal attack by a party which came to be known as "Presbyterian."

Thomas Cartwright led a powerful movement, 1570–73, aimed at eliminating the entire episcopal system through which Elizabeth worked. He advocated a presbyterian system, modelled on the system of Calvin, in which the people chose their own pastors and then elected lay elders to share with the pastor in governing the local church. Central authority was vested in representative bodies of ministers and laymen which were chosen by the churches themselves, or by the lower judicatures. Such a system, Cartwright declared, could and would reform the church in England.

This first Presbyterian attempt at reforming the church was defeated. However, it did set in motion endeavours which shortly resulted in the working out by Cartwright and others, of a coherent and comprehensive understanding of Christianity which formed the basis for all subsequent forms of Presbyterianism. Its underlying structure was that of covenant-contract, but now in a much more fully worked out form. The backbone of the system had its nearest likeness in the covenant system of the Rhineland-Netherlands reformers. Its church government theory had its nearest parallel in Calvin's theory. Its austerity, its blue laws and its theocratic outlook have often been traced to Calvin. Yet, mediaeval England and mediaeval Geneva had known blue laws, and Calvin's own attitudes on them had come to him from Zürich via Strasbourg. The Presbyterians were sabbatarian and anti-liturgical, as were the Rhineland-Netherlands reformers. Calvin was the obverse. The Puritan and Presbyterian "prophesyings" were borrowed from Zürich. On decisive doctrines such as faith, repentance, law and gospel, the church, the ministry and the two sacraments the Presbyterians stood nearest to the Rhineland-Netherlands reformers, not to Calvin or Luther. Politically their closest foreign counterparts were the Huguenots.

As early as 1572 (at Wandsworth) Presbyterians began to organize small local bodies in secret. Rather open organization was effected on the Channel Islands by 1576, and among English merchant settlements in Holland by 1585. Secret bodies were in existence in London, Oxford, Cambridge, Warwick, Northamptonshire and elsewhere by 1585. Because of the need for secrecy these bodies came into being as exclusively ministerial, with no lay representation and little or no real participation by the churches. This fact became decisive for the subsequent history of English Presbyterianism. It became a ministerial movement, contending for control of the English Church through the aid of the parliamentary party, with no great popular appeal or support.

As the Civil Wars came on the coalition of parliamentary-presbyterian forces took the lead in the opposition to the royal-episcopal absolutism. In the early phases of the struggle they maintained their leadership through the co-operation of the centre and left-wing Puritans and, particularly, through the aid of the ultra-Presbyterian Scots whom the two Bishops' Wars had brought to their aid. As events moved steadily toward control

of England by the parliamentary-presbyterian party, episcopacy was abolished in the church by act of parliament. Then, an Assembly of Divines was summoned by parliament to act as its advisers on religious affairs. The assembly, later known as the Westminster Assembly of Divines, was chosen to be representative of each of the English counties. It included some mild episcopalians and five Independents. The rest were Presbyterians.

The excesses of the king in 1642–43 drove the Scots once more into an alliance with his enemies. The parliamentary party now signed (1643) the Solemn League and Covenant with the Scots. This agreement pledged the civil and religious unity of England, Scotland and Ireland under a presbyterian-parliamentary system. The parliament now ordered the Assembly of Divines to proceed, with the aid of six Scottish advisers, to the drafting of a complete religious constitution for the three kingdoms. The English Church thus gave up its Thirty-Nine Articles and other constitutional documents, while the Scots gave up their Confession of 1560, and other documents. The assembly then elaborated (1643–49) a *Confession of Faith*, a *Larger* and a *Shorter Catechism*, a *Form of Government* and *Directory for Public Worship*. These documents, the results of years of keen debate by many able scholars, put in classic form a consistent federalism (*i.e.* covenant-contract theory). Since this Assembly of Divines was but an advisory committee of the English parliament its constitutional documents met an odd fate. The Scottish Church and the Scottish parliament accepted them speedily. The English parliament delayed accepting them because of the growing power of the Independents. The English Church never had an opportunity to consider them.

Even with the aid of the Scots the military fortunes of the parliamentary party were unfortunate. It became necessary, at length, to allow Oliver Cromwell to create the New Model army which, although it proved invincible against the king, also proved invincible as the left-wing Puritans' (Independents) force against the right-wing (presbyterian-episcopal) Puritans. The army, not parliament, became supreme in England. Their political-religious program alienated the Scots, and the right-wing Puritan-parliamentary group sought vainly to dissolve the army, without due pay, in order to avoid a military state. The army several times invested London and forced parliament to do its bidding. Some right-wing leaders began to have intelligence with the king, believing that a government of law and order, though despotic, was better than army rule by sectaries. Eventually, in 1648, Col. Thomas Pride's soldiers purged parliament of all Presbyterians (140), leaving about 50 left-wing Puritans in the commons. This Rump parliament tried and executed Charles I, set up a military dictatorship under Cromwell, terminated the Presbyterian establishment and granted freedom to all religious groups while giving special privileges to Congregationalism under a modified form of establishment.

Hopeless chaos reigned after Cromwell's death. Gen. George Monk reassembled the Long parliament, thus putting great powers in the hands of the presbyterian-parliamentary group formerly purged by Colonel Pride. They re-established Presbyterianism, although granting tolerance to other Protestant bodies. Something better than army rule, however, was needed. Hence, all the right-wing groups, parliamentary and Presbyterian, royalist and episcopal, joined in restoring Charles II unconditionally. Charles quibbled briefly with the Presbyterians, who were now in full control of the church with about 8,000 beneficed ministers and professors. These ministers offered to accept a modified form of episcopacy first elaborated by Archbishop James Usher. Charles, realizing that his real supporters were the royalist-episcopal group, rejected this offer and demanded capitulation. About 6,000 ministers accepted reordination, unqualified oaths of obedience to bishops and king, abjuration of the Solemn League and Covenant. Two thousand were ejected, of whom approximately 1,500 were Presbyterian and 500 Independent. Later, many of these (about 500) conformed to the episcopal terms.

The Revolution of 1689 brought to the throne a king genuinely friendly to Presbyterianism. In view of the total situation, however, no more was gained by his accession than a measure of toleration for all Protestants. Under this toleration and its subsequent enlargements, a number (often given as high as 500) of Presbyterian congregations existed. In almost no recorded instances did any of these churches have elders or any lay leadership. Ministerial thought continued to develop along extremely autocratic and high-church lines. Such presbyteries as existed were almost exclusively ministerial. Since many of the stronger churches became endowed, actual control of them passed into the hands of the minister and a few trustees. Laymen lost all part in them. In the early part of the 18th century many of these ministers became Unitarians and numerous others conformed to the Anglican establishment. The greater number of those who cherished the older Puritan ideals became Independent-Congregationalist under the impact of the movement known as the United Brethren, organized under the Heads of Agreement of 1691. By the close of the 18th century English Presbyterianism had become virtually extinct.

The most complete, and even the classic formulation of Presbyterianism had indeed been made by the English Puritan Presbyterians. Lack of popular support, reliance upon parliamentary forces and consequent fear of the Independents, had led to a form of strategy which destroyed English Presbyterianism by making it an exclusively ministerial movement. This unfortunate clericalism had not been the deepest aspect of the movement nor of its ideals. Its basic intent had been to reform the church on genuinely Protestant lines and to give to the people their rightful place. This Presbyterian ideal was first to be achieved in Scotland, whence also Presbyterianism was to be replanted on English soil.

Scots began coming into England in increasing numbers after the union of 1707. Many of these were Seceders, hence rigorous Presbyterians. Soon they had several congregations. In 1847 these, together with certain of the surviving English Presbyterian congregations and other Scottish groups, merged as the United Presbyterian Church. This body joined with the remaining English Presbyterians and most of the other various Scots churches in England to form in 1876 the Presbyterian Church of England. It then had 259 congregations with about 50,000 members. A theological college was founded at London in 1844, which later was moved to Cambridge under the name of Westminster college. By mid-20th century the church had about 71,000 members, 385 ministers, 360 churches; missionary work was being carried on by 30 missionaries at ten stations in China, India, Singapore and Malaya.

Scotland.—Though Presbyterianism as such took form in England, and there received its definitive theoretical delineation by the Westminster Assembly of Divines, it was in Scotland that Presbyterianism was to take its deepest roots. Moreover, although the Scottish Reformation was begun under essentially Genevan Calvinistic patterns, it adopted in time, and became the very incarnation of, the patterns of English Presbyterianism. It was able, however, to give to laymen a real place in the life of the church. Consequently in no country did Presbyterianism so deeply affect the national life. In many ways, therefore, Scottish history provides the best available illustration of Presbyterianism at work.

Scotland's first reforming martyr was Patrick Hamilton (1504–28). He had been influenced by personal contact with Martin Luther, Tyndale and other reformers. George Wishart, burned 1546, had travelled in England and Switzerland. His ideas were essentially Zwinglian. His assistant, John Knox, was to become the real leader of the Reformation in Scotland. Before long Knox had to flee and found refuge in England. During the reign of Edward VI he was an active leader in the English Reformation. When Queen Mary restored Roman Catholicism, Knox fled to the continent with numerous English reformers. Eventually he became pastor of an English refugee church at Geneva. In 1555–56 he visited Scotland and preached vigorously in the interests of the Reformation. The next year, certain nobles, the "Lords of the Congregation," led the Scottish reforming group in signing the first great covenant binding themselves to support the Reformation. Knox returned permanently to Scotland in 1559. A year later the reforming group, through English pressure on the Scottish regent, gained its first great victory. The Scots Confession (of 1560) was drawn up and accepted by parliament. A *Book of*

Common Order (Knox's Liturgy), a *Metrical Psalter* and a *Book of Discipline* (*The First Book of Discipline,* 1561) were also drawn up by the reformers. Parliament did not ratify these, but the church was deeply influenced by a rather general acceptance of them. These documents were all decisively Genevan in character. Knox, who had been deeply influenced by Calvin, was the leader in their framing. The *Book of Discipline* was an advance on Calvin's system in that it applied Genevan ideals on a national scale, following a lead given by the Huguenots. A general assembly was instituted as the national meeting of representatives of the church. Here, in free debate, issues were to be determined by a body of ministers and laymen met under their own chairman and at their own call. This gave the church genuine control of its own affairs. Also a governing body, the church session, was instituted for each local church. This body consisted of elders elected by the people, and had as its chairman the pastor of the church. The people themselves were given the right to elect their pastor and this election, rather than ordination by other ministers, made a man a minister. Episcopacy was abolished, but several superintendents were named to itinerate in areas without ministers and to have some limited administrative duties. The religious prerogatives and authority of bishops were not given to them, however, and they did not preside over the church courts.

The last four decades of the 16th century witnessed the defeat of the reformed, or Presbyterian, Scottish Church in spite of several notable temporary victories. In 1581 the Presbyterians gained parliamentary sanction for their *Second Book of Discipline,* and for the so-called Negative Confession of Faith. Moreover, regional church governing bodies, the presbyteries, began to be set up. Yet, the Black acts of 1584 placed bishops in control of most of the church and the more prominent Presbyterian leaders were forced to flee to England. In 1592 the Presbyterians were able to extort from the king sanction for a parliamentary law which has ever since been regarded as the Magna Carta of Scottish Presbyterianism. Five years later the king, working through bishops forced upon the church, gained almost complete control of the entire church, a control which was to last until the first of the Bishops' Wars in 1639. James became king of England also in 1603 and then set out to make the Scottish Church the principal instrument of his absolutism in Scotland. From 1603 to 1612 he brought the church wholly under the power of his bishops. From 1612 until his death he was occupied in shaping the life and work of the church to serve his general policies. So well did he succeed that at his death Scotland was under an unqualified absolutism.

Charles I continued the Tudor-Stuart policy of using the episcopacy as an instrument in the furtherance of royal absolutism. In Scotland Archbishop John Spottiswoode was his chief agent. When, however, Charles, Archbishop William Laud, and Spottiswoode attempted to force the last degree of submission upon the Scottish Church, namely "Laud's liturgy," popular resentment came to the aid of the church. In a wave of public feeling expressing opposition to the whole of Stuart absolutism, the covenant of 1557 was "renewed" by signatures of all classes all over Scotland. Spottiswoode and all but 4 of his 50 fellow bishops fled to England. In the two Bishops' Wars which followed the Scots demanded, basically, free parliaments and free general assemblies. Charles lost the wars and granted the demands. Parliament and the general assembly abolished the entire episcopal regime in church and state and restored Presbyterianism as of its "Magna Carta" of 1592.

In 1643 the two parliaments signed the Solemn League and Covenant between England and Scotland. Upon this basis of a union of England, Scotland and Ireland in state and church, the two presbyterian-parliamentary groups worked together in opposing the episcopal-royalist absolutism. One aspect of this cooperation was the adoption by the Scottish Church of the religious constitution framed by the Westminster assembly. Scottish Presbyterianism thus passed from a Genevan-Calvinistic pattern to a Puritan-federalist pattern. When the Independents gained control in England, purged the Presbyterians and executed Charles I, many of the Scots objected and proclaimed Charles II. Cromwell defeated the Scots' armies and held the country under military occupation. During this occupation the church was not persecuted. It had, moreover, a great series of religious awakenings under Covenanter leadership.

The English restored Charles II in 1660. He brought back the episcopacy as an instrument of royal absolutism into Scotland as well as into England. Under Archbishop James Sharp a veritable Inquisition reigned in Scotland, "the killing times," as the Covenanter movement was wiped out. When William and Mary came to the throne in 1689 Presbyterianism was restored finally by constitutional act. However, despite some opposition, most of the former episcopal clergy retained their pastorates.

After 1689 Scotland was unquestionably Presbyterian, but new problems arose. Within the established state church were now two parties—one a group of convinced Presbyterians who had only recently been terribly persecuted by king and bishop; and the other, a group who had served the persecutors and now served the current regime with no great concern for it or against it. The next generation saw the rise of a large group of essentially professional clergymen known as the Moderates, whose deepest interests were in social life, in culture and in their prerogatives within a state establishment. An Evangelical group sought to promote the older reformation ideals. In 1707 the Scottish and the English parliaments were united. Five years later the parliament restored patronage in Scotland. This meant that the local landowner, or patron, had the right of nominating the minister for the congregation, and the people lost the right of electing their pastors. This system of patronage quickly brought the Church of Scotland under the control of the Moderate ministers and the wealthy landowners. As many protests were made against patronage, the Moderates claimed supreme powers for the general assembly which they controlled, and did not hesitate to resort to the use of military escorts and to the imprisonment of dissenting ministers to enforce their dictates.

By 1733 resistance to the Moderates and to patronage led to the deposition of four ministers. Led by Ebenezer Erskine they formed a secession church, the Associate Presbytery. This body "renewed" the Solemn League and Covenant in 1742 and 1744. Even so some members desired greater attachment to the old Covenanting ideals and withdrew to form the Reformed Presbytery (1743). In 1811 this group became the Reformed Presbyterian Church. Within the Seceder group also the covenanting principle raised the problem of their relation to the state, which supported the church from which they had seceded. In 1747 they divided into two groups, known after 1788 as the General Associate synod (Antiburgher; *i.e.,* against taking the burgher's oath in various cities); and the Associate synod (Burgher; *i.e.,* willing to take the oaths). By 1799 and 1805, the problem of the civil government's authority in religious matters broke both of these bodies into Auld Licht and New Licht sections.

Meanwhile patronage and the Moderate party caused further discontent. In 1761 Thomas Gillespie (deposed in 1752 for resistance to the general assembly), founded the Presbytery of Relief, a tolerant, evangelical, non-Covenanter body designed to provide relief for ministers and congregations who wished to withdraw peacefully from the establishment. In 1773 it assumed the name the Relief Church of Scotland.

These new groups grew rapidly, and were greatly strengthened by the evangelical revivals, the Sunday-school movement and the new missionary spirit. In 1820 a United Secession Church was formed by certain segments of secession bodies, and in 1827 others formed the Associate Synod of Original Seceders. These unions involved Burghers, Antiburghers, Auld Lichts and New.

From 1833 to 1843 a severe struggle took place within the Church of Scotland between the Moderates and the Evangelical group, now greatly strengthened by the revivals and the Sunday schools. Finally when the government in London supported on legal grounds the entire Moderate structure, the Disruption led by Thomas Chalmers took place. A Free Church of Scotland was formed by 474 ministers and thousands of lay people, free of state control, free of patronage and zealously evangelical. All but one of the Church of Scotland's missionaries, and most of its best

scholars, joined the Free Church. Henceforth the Free Church led all Christian causes in Scotland.

The United Presbyterian Church was founded in 1847 by the union of the Relief Church with the United Secession Church. In 1852 about one-half of the Associate Synod of Original Seceders joined the Free Church of Scotland. The year 1876 witnessed the union of the majority of the Reformed Presbyterians with the Free Church. Union negotiations between the United Presbyterians and the Free Church raised many problems. A small group left the Free Church in protest against the union and formed the Free Presbyterian Church. Eventually, in 1900 the United Free Church was formed by a merger of the Free Church and the United Presbyterians. A small group remained outside as the Free Church of Scotland. In many ways this new United Free Church was the most vigorous and popular religious body in Scotland.

Before long attempts were made to unite the United Free Church and the old Church of Scotland. Patronage had been abolished in 1874, and the old Moderate party had given way to a better leadership in the Church of Scotland. The issue of an established state church proved insoluble, however, until after World War I. Both churches had drawn closer together in the meanwhile. In 1921 the state by law severed its old relation with the Church of Scotland, leaving it "the national church" but not the established state church. This allowed union negotiations to make progress, and in 1929 the two churches united under the original name of the Church of Scotland. A small group remained outside and continued the name United Free Church.

Vast changes, meanwhile, had greatly altered the total religious situation in Scotland. The Lowlands had become industrialized, and had brought in large numbers of Irish workmen, most of whom were Roman Catholics. The Highlands were being depopulated by changing economic conditions. Presbyterianism as a whole enrolled only a fourth of the population of Scotland, and three-fifths of the Scots were nominally in no church. The Church of Scotland had lost heavily among the labouring classes and in the rural areas. Various movements were under way, each seeking in some measure to improve conditions: a high-church liturgical movement; a movement to bring together in the church the labouring classes and student groups (Iona group); and a movement for the recovery of a more adequate theology. The Church of Scotland continued to be active in missionary work, and to take a leading part in the ecumenical movement among the Protestant churches throughout the world.

Six Presbyterian bodies remained in Scotland at mid-20th century. The Church of Scotland had (in 1948) 1,261,646 members, 2,410 congregations, 3,300 ministers, 34,446 elders; 454 missionaries in stations in China, India, Africa, Arabia, New Hebrides, West Indies. The United Free Church (continuing) had 23,863 members, 123 congregations, 81 ministers, 1,154 elders; 8 missionaries in Bechuanaland, Africa. The Free Church of Scotland had 5,500 members, 160 congregations, 111 ministers; with missionaries in South Africa, Peru, India. The Reformed Presbyterian Church had 800 members, 7 congregations, 4 ministers, 30 elders; 6 missionaries at 3 stations in North Syria. The Free Presbyterian Church of Scotland had approximately 800 members. The Original Secession Church had 1,953 members, 18 congregations, 14 ministers, 94 elders; 10 missionaries in India.

Ireland.—Except for scattered Puritan groups, Irish Presbyterianism began with the Irish plantation of 1610. At first these Presbyterians were within the established Church under the tolerant Archbishop Usher. Charles I and Archbishop Laud drove them out. During the Civil Wars they experienced ups and downs almost identical with those of the Scottish Presbyterians. William I was able to gain for them only partial toleration. Until the later Hanoverians their lot was unduly harsh. Hundreds of thousands of them migrated to North America.

Scottish controversies usually had their counterparts in Ulster. Seceders appeared in 1741, and organized in 1750; Reformed Presbyterians came in 1752 and organized in 1792. The Synod of Ulster was the Main Presbyterian body, but did not include the Presbyterians in Dublin, and south and west Ireland. These formed the Synod of Munster.

Severe doctrinal controversies occurred in both the 18th and the 19th centuries. Each time a Unitarian group left the church. Consequently Irish Presbyterianism became very conservative in theology.

In 1840 the Secession Church and the Synod of Ulster merged as the Presbyterian Church in Ireland. The Synod of Munster joined them in 1854. This body in 1948 had 121,989 members, 556 congregations, 75 other preaching points, 546 ministers, 3,644 elders; 39 missionaries at 10 stations in north China and west India. The Reformed Presbyterian Church had about 3,400 members; missionary work was being carried on in North Syria.

Wales.—The Presbyterian Church in Wales, known also as the Calvinistic Methodist Church, grew out of the evangelical revival of the 19th century. Howell Harris and other friends of George Whitefield led the movement and gave to it the general society character of the Wesleyan societies, but the doctrinal convictions of Calvinistic Puritanism. Its earliest organization outside the Church of England in Wales took place in 1811 on a Presbyterian form of polity. Two synods, or associations, were formed, one for South Wales and one for North Wales. Twelve years later a Calvinistic, Presbyterian creed was officially adopted. In 1864 a general assembly was formed to unite, but not to control, the two associations.

The church is distinctly Welsh in all ways. About one-fourth of the congregations use the English language in some measure. The church in 1948 had a membership of 172,754 in 1,467 congregations, with 674 ministers and 7,256 elders; 54 missionaries were at work at 15 stations in India and in Brittany, Fr.

Canada.—Presbyterianism first took real root in Canadian territory after the treaty of Paris in 1763. Settlement of Scots in Nova Scotia brought many Presbyterians there. In 1817 the various elements united as the Synod of Nova Scotia in Connection with the Church of Scotland. Then, 1835, the Synod of New Brunswick in Connection with the Church of Scotland was formed. These bodies were all at work in eastern Canada.

Farther to the west the Church of Scotland was also sending ministers and aid. Secession groups had already organized, in 1826, the United Presbytery of Canada. In 1831 the Synod of the Presbyterian Church of Canada in Connection with the Church of Scotland was organized. These two bodies united in 1840.

The Disruption of 1843 in the Church of Scotland caused parallel ruptures in all the Canadian Presbyterian churches. In 1845 there were seven separate bodies. Thirty years later, in 1875, all had reunited in the Presbyterian Church in Canada, with several colleges and a strong body of congregations and ministers. Their next task was set by Canada's westward expansion.

The 20th century brought new problems to Canada, theological, social and economic. Roman Catholicism was growing. The sparse population of the Canadian prairies put a severe drain on all Protestant home mission efforts. The changing scene in Canada had made Protestantism too greatly urban. As early as 1890 projects for uniting Canadian Protestants had been broached rather widely. The Church of England in Canada quickly dropped out of these negotiations, but the two largest Protestant bodies, the Presbyterians and the Methodists, together with the much smaller Congregational Church, united as the United Church of Canada in 1925. A sizable minority of Presbyterians refused to enter the union and continued as the Presbyterian Church in Canada.

The United Church of Canada continued to maintain official connections with other Presbyterian and Reformed Churches throughout the world. In government the church is essentially Presbyterian, although in doctrine and other matters it allows great latitude to points of view traditionally non-Presbyterian, because of its Methodist and Congregational constituencies. In 1948 it had 791,677 members, 2,710 congregations, 6,784 additional preaching points, 3,256 ministers, 28,057 elders; missionaries were at work in stations in Trinidad, Africa and Asia.

The Presbyterian Church in Canada in 1948 had 173,152 members, 1,044 congregations, 1,193 additional preaching points, 732 ministers, 6,510 elders; 38 missionaries at 7 stations in Asia,

Trinidad, British Guiana and Poland.

Australia.—Australian Presbyterianism was essentially Scottish in origin and character. The first organized body was founded in 1826 by Church of Scotland ministers. During the stormy years following, the divisions of the homeland had their counterparts in the South Pacific. Reunions of fragments formed the Presbyterian Church of New South Wales in 1865; the Presbyterian Church of Victoria in 1870; and smaller bodies in Queensland, West Australia, South Australia and Tasmania. A federal union of most of these bodies was formed in 1886, and in 1901 all united in the Presbyterian Church of Australia. Considerable local autonomy was granted each of the regional bodies. From 1918 to 1923 strenuous efforts were made to achieve a union among Presbyterians, Methodists and Congregationalists similar to that achieved in Canada, but without success.

This church in 1948 had 104,944 members, 584 congregations, 174 additional preaching points, 704 ministers, 5,018 elders; plus missionary work in Asia and the New Hebrides.

New Zealand.—Presbyterianism in New Zealand arose in two distinct migrations. To the northern regions came Church of Scotland ministers as early as 1840. The first presbytery was founded at Auckland in 1856. Later it grew into the Presbyterian Church of New Zealand. In the southern area Scottish Free Churchmen founded a model religious colony at Dunedin in 1848. Their church grew first into the Presbytery of Otago (1854), then into the Presbyterian Church of Otago and Southland. In 1901 these bodies united as the Presbyterian Church of New Zealand.

The church in 1948 had 61,799 members, 354 congregations, 1,027 additional preaching points, 364 ministers, 2,877 elders; missionary work was being conducted in Asia and the New Hebrides.

Africa.—Scottish Presbyterians first organized in South Africa in 1892. The Presbyterian Church of South Africa was formed in 1897. This body did not include the native congregations, and the problem continued to agitate the church. Eventually, in 1923, it was solved by creating a Bantu Presbyterian Church wholly separate from the white church but with fraternal relations. This arrangement, however, resulted in little more than qualified segregation. As race tensions mounted after World War II the Presbyterians made great efforts to frustrate the all-out movement for total segregation known as *apartheid*. The entire status of missionary educational and medical work was also challenged, and the Presbyterians made strenuous efforts to improve native-white relations.

The Presbyterian Church of South Africa in 1948 had 20,996 members, 83 congregations, 53 additional preaching points, 95 ministers, 621 elders; also missionary work in South Africa. The Bantu Presbyterian Church of South Africa had 30,308 members, 61 congregations, 750 additional preaching points, 49 ministers, 1,061 elders.

Other African Presbyterian bodies, with 1948 statistics, are: the Presbyterian Church in Basutoland, about 25,000 members; the Presbyterian Church of Central Africa, 105,558 members, 116 congregations, 57 ministers, 2,192 elders; the Presbyterian Church of Gold Coast, 30,132 members, 51 congregations, 70 ministers, 895 elders; the Ewe Presbyterian Church, 15,742 members, 210 congregations, 23 ministers, 235 elders; the Synod of the Nile, 24,200 members, 168 congregations, 162 ministers and 235 elders.

United States.—The 11 Presbyterian bodies in the U.S. at mid-20th century made up the largest group in the Presbyterian family. Two of these bodies accounted for nearly 3,200,000 members, and more than 98% of all U.S. Presbyterians were in the four largest bodies. Repeated attempts at union had failed, largely because of nonreligious; *i.e.*, political, social and regional causes.

The Presbyterian Church in the U.S.A.—The earliest Presbyterian churches in the American colonies were planted on Long Island by New England Puritans who preferred the Presbyterian way to the Congregationalist. Very soon after Scotch-Irish, English and other settlers formed Presbyterian churches in Maryland, Delaware and Pennsylvania. In 1706, some of these joined in a loosely organized presbytery which in 1716 was expanded to a synod of three presbyteries. The church continued to be a blend of New England Puritan Presbyterians and Ulster Presbyterians, plus Welsh and other elements.

Shortly, repercussions of British struggles against Arianism brought trouble to the new colonial church. A Scotch-Irish group, led by John Thomson, asked for unqualified subscription by all to the Westminster Confession and a powerful centralized church government as bulwarks against heresy. The New England group, led by Jonathan Dickinson, resisted, asserting that no human creed could be absolutized, that ecclesiastical authority could not prevent heresy and that only a deeper piety would suffice. In 1729 the synod compromised by adopting the confession, but allowing men to distinguish between its essential and its nonessential points. The church government issue was avoided. The compromise did not satisfy all.

In 1733, a new group, led by William Tennent and his son Gilbert, began in Presbyterianism the revival later termed the Great Awakening. The Thomson group fought the revival bitterly, and would have driven it out of the church but for the chance appearance of George Whitefield, whom the Tennents persuaded to aid them. Whitefield won mass popular support for the Tennents, and drew the New England group closer to them. In a typical frontier controversy both the Thomson and the Tennent groups went to extremes. Serious moral failures weakened the hold of the Thomson group on the people. The climax came in 1741 when the Thomson group gained momentary control of the synod and illegally expelled the Tennents.

The Dickinson group, the more stable and best-based section of the church, sought first to mediate. Rebuffed by the Thomson group, they joined the Tennents in forming a new church, the Synod of New York, popularly called the New Side. They stood for an American, democratic, evangelistic church of all nationalities, with a deep concern for ethics, led by a ministry trained in the colonies. In 17 years they trebled their membership, established the College of New Jersey (later Princeton university) and expanded as far as western Pennsylvania and the Carolinas. The Thomson group took the name the Synod of Philadelphia, (popularly the Old Side). They stood for an autocratic ministry, a church committed to being Scottish-Scotch-Irish in all things and opposed to revivals. From 1741 to 1758 this group lost ground steadily.

The schism was at length healed in 1758, by mutual concessions, and the name of the Synod of New York and Philadelphia was adopted. In the synod there was now a preponderance of directly or indirectly New England-trained ministers, and the strongest presbyteries were those composed of churches with New England backgrounds. Beginning in 1760, however, several hundred thousand Scotch-Irish immigrants arrived in the colonies. Many of these joined the Presbyterian Church, and the character of the church gradually changed to a Scotch-Irish pattern.

In the struggles leading up to the Revolutionary War the Presbyterians took a vigorous part. They formed an alliance with the Congregationalists of New England in order to prevent the settling of Anglican bishops on the colonies, because they feared an intolerant establishment was contemplated. The struggle for colonial independence was, in time, called a Christian cause. In personnel and property the church suffered heavily in the war. The near triumph of deism among Americans after the war came as a staggering blow to the church. During the years 1785–88 a general assembly was founded with an explicit constitution. Some resistance was offered by those who feared extreme centralization. In the constitution all reserve powers were, therefore, left with the presbyteries, and the higher, central, courts were given limited and fixed powers only. Doctrinal subscriptions continued to be flexible.

The church took up frontier missions, benevolent work, the founding of schools, etc. with vigour. A series of revivals greatly increased the church's strength, despite some concurrent problems. Charles G. Finney and Lyman Beecher were active evangelistic leaders of the second quarter of the 19th century.

In 1801 the church entered into a Plan of Union with the New

England Congregationalists. These churches themselves did not merge, but they federated their home missionary work on the frontier. This did, however, draw the two denominations closer together everywhere, and reraised the old Scotch-Irish *v.* New England antipathies of 1741–58. Moreover, New England theology was restless and inquiring. The Scotch-Irish considered theology a finished structure which must now be protected against innovation. In the south the church was almost wholly Scotch-Irish, and proslavery sentiment there kept most northern Scotch-Irish Presbyterians either proslavery or neutral. The New England background Presbyterians were generally antislavery.

After years of turmoil a majority in the asembly of 1837 abrogated the Plan of Union, expelled illegally all the federated churches and demanded total subjection by all to the assembly. During the ensuing year about four-ninths of the church refused to recognize these acts and joined the expelled group in declaring themselves to be the genuine Presbyterian Church and the group who had ousted them to be a schism. The civil lower courts declared them to be the continuing church, but the appellate court reversed the decision. They continued the name the Presbyterian Church, U.S.A., and added "New School." The other group took the same name but added "Old School."

The New School denomination continued, as before 1837, to work in close co-operation with the Congregationalists in home and foreign missions, in antislavery, temperance and other work. They had a few congregations in the south (these withdrew in 1856–57), but were largely a northern church. The Congregationalists abrogated the Plan of Union in 1852, though the two churches continued some joint work. Even so, the abrogation was a setback for the Presbyterians. In frontier missions, education and benevolent work they made great contributions. Union Theological seminary, New York City, became their great centre. During the Civil War the church was active on the northern side.

The Old School Presbyterians built a well-organized church on the basis of their doctrinal, racial and social homogeneity. Though spread over all the nation, their great strength was among the Scotch-Irish and the Scottish groups. Princeton seminary became their focal point. A solid denominational structure enabled them to make great strides in missions, colleges and Sunday-school work. The Civil War brought new issues. The O.S. assembly of 1861 passed the Gardiner Spring resolutions which so wholly committed the church to the northern view that the entire southern section of the church seceded to form the Presbyterian Church in the Confederate States of America.

After the war the north-south groups of the two churches could not agree to reunite. Unions took place instead of New School and Old School in the south to form the Presbyterian Church, U.S. (*see* below), and in the north, the Presbyterian Church, U.S.A.

The northern reunited church took up frontier mission work anew, built new colleges and institutions, expanded Sunday-school, youth and benevolent work, as the nation moved westward. A quarter of a century of achievement was interrupted by a major controversy which arose as a result of the influence of the new scientific views upon Christian thought. There came first (about 1892) a long struggle over biblical criticism, followed (about 1910) by the organization, on an international scale, of an interdenominational group, strongly Presbyterian, to defend the "fundamentals" of the faith. By World War I the Fundamentalist-Modernist controversy was intense. Moderate groups pleaded for comprehension within the church of all essentially Christian views, but without success. The struggle now assumed a new form. The Fundamentalist group attacked various boards and institutions of the church as unorthodox and founded within the church rival institutions of their own to compete with the church's institutions. This brought judicial process in the church courts against J. Gresham Machen and other Fundamentalist leaders. Most Fundamentalists then drew back from the controversy. A few, however, joined with Machen in founding the Presbyterian Church in America.

Between World Wars I and II the Presbyterian Church, U.S.A., came to have one of the largest foreign missionary enterprises in the world. In the U.S. the church had more than 50 colleges and 9 theological schools. As national and international co-operative ventures among churches were launched the Presbyterians took an active part. Negotiations for union were had also with other Reformed and Presbyterian bodies and with the Methodists and the Episcopalians. In only two instances did success come. The Cumberland Presbyterian Church (*see* below) reunited with the U.S.A. Presbyterians in 1906. The Welsh Calvinistic Methodists merged with the Presbyterians in 1920. On the foreign field Presbyterians moved to turn their missionary work over to independent native churches. In China and India Presbyterians united with other denominations to form new "younger churches." A Presbyterian Church of Brazil and a Presbyterian Church of Mexico, each self-controlled, were founded. In other countries local leaders took charge instead of the missionaries.

World War II brought havoc to many regions. As peace came the Presbyterians raised nearly $27,000,000 to aid in reconstruction, principally in Europe and on mission fields in former war areas. Wholly new approaches also were worked out by the church to Sunday-school studies, to youth work, etc.

The Church in 1950 had 2,401,849 members, 8,538 congregations, 9,392 ministers. In 1948 it had 56,260 elders, 1,368 missionaries at 151 stations in Africa, India, China, Japan, Korea, Mexico, Iran, the Philippines, Thailand, South America, Central America, Syria and Mesopotamia.

The Presbyterian Church in the United States.—This body, commonly called the Southern Presbyterian Church, came into being during the Civil War. Prior to the war furious controversy had split the Presbyterian Church, U.S.A., in two bodies—New School and Old School. These divisions were not geographical; N.S. and O.S. congregations existed in both north and south. The south was predominantly O.S. The N.S. was unofficially the antislavery force in the central states, while the O.S. was officially neutral on the issue and actually proslavery in most regions. The coming of the war brought a wave of nationalism over the north, one aspect of which was the adoption in 1861 by the O.S. general assembly of the so-called Gardiner Spring resolutions which put the church so unequivocally behind the federal government that the O.S. churches in the Confederate states seceded to form the Presbyterian Church in the Confederate States of America.

The war cut off other southern Presbyterian bodies also from their northern brethren. Older lines of cleavage lost their meaning. In 1864 the United Synod of the South (largely N.S.) merged with the Confederate Presbyterians, so also did certain small units of Seceders and Covenanters. Border state Presbyterian bodies, at first neutral, joined also: Synod of Kentucky, 1869; Synod of Missouri, 1874. After the war, the name Presbyterian Church in the United States was adopted.

The church continued to devote its energies to the so-called southern states, Texas, Arkansas and Missouri marking in general its western boundaries. The church is essentially Scottish, Scotch-Irish in membership and traditions. Its homogeneity racially, geographically and socially make it a very close-knit body. Traditionally the church divides between a spiritual and a political approach to problems. The latter approach has always been rejected. As a result the church has been very conservative on all religious, political and social issues. Yet in educational and benevolent enterprises the church has long been a leader in the south. Its educational and missionary ventures have been especially significant. In its polity great care has been taken to promote local initiative and to restrict the powers of all central agencies.

The church in 1949 had 653,594 members, 3,542 congregations, 2,621 ministers, 19,270 elders; 346 missionaries in Africa, Brazil, Mexico and Asia.

Southern Presbyterians and northern Presbyterians continued to talk of reunion from the 1870s. The two churches adhered to almost identical constitutions, but continued to be separated by essentially nonreligious differences; *i.e.*, the continuing problem of the Civil War Reconstruction. While the northern church is less conservative all ways than is the southern, north-south rela-

tions remain the serious obstacle to reunion. Fraternal relations between the two bodies have long been excellent, and ministers, members and students freely transfer from one church and its institutions to the other. There is little overlapping of territory, less of competition and a growing area of co-operative endeavour (*i.e.*, joint schools, common missionary projects, etc.).

The United Presbyterian Church of North America.—Covenanter, or Reformed Presbyterian, people began coming to North America, principally from Ireland, before 1750. In 1774 their first presbytery was founded. Seceder Presbyterians organized a presbytery in 1758. Both groups were located principally in Pennsylvania. In 1782 the Reformed Presbyterians and some of the Associate (Seceder) Presbyterians united, and these together with other Secession groups merged to form in 1858 the United Presbyterian Church of North America. Covenanter and Secession backgrounds made this church very conservative in doctrine and worship. At first the church practised closed communion, sang only psalms in public worship and adhered to the Solemn League and Covenant. Gradually, however, changes came as the memory of Scottish issues faded away. The church was early engaged in the antislavery cause and other significant reform movements. Because of its solid Scottish, Scotch-Irish background its main strength lies in the regions of Pennsylvania, Ohio, New York, Illinois and Iowa. The church in 1949 had 213,810 members, 841 congregations, 908 ministers, 5,684 elders; 117 missionaries were at work in Egypt, India, the Sudan and Abyssinia.

The Cumberland Presbyterian Church.—The Cumberland Church grew out of a purely American situation; *i.e.*, frontier conditions. Differences of opinion regarding the great Kentucky revival of 1799–1802, impatience with high educational requirements for a frontier ministry, excessive use of ecclesiastical authority and differences on the subject of predestination brought about a separation in 1810 from the Presbyterian Church, U.S.A., of a group on the Kentucky-Tennessee frontier. They founded the Cumberland Presbyterian Church, stressed evangelism, repudiated predestination and avoided highly centralized church authority. Their membership was almost wholly second and third generation Scotch-Irish from the southern Atlantic states. During the 19th century the church spread through Ohio, Pennsylvania, Missouri and Texas. Until the Civil War Negroes, lay and ministerial, had a significant place in the church. In 1869, however, they formed a church of their own.

Early in the 20th century negotiations for reunion with the Presbyterian Church, U.S.A., began. A majority of the Cumberland Presbyterians rejoined the older church in 1906. Others, however, continued as a distinct group under the Cumberland name. The church in 1949 had 80,236 members, approximately 1,033 congregations and more than 750 ministers. Missionary work was being done in China and South America.

The Cumberland Presbyterian Church, Coloured, set off from the above in 1869, reported in 1944 approximately 30,000 members in 121 churches.

Churches Continuing the Covenanter-Secession tradition.—These include: (1) The Associate Reformed Presbyterian Church (General Synod), which in 1948 had 24,957 members in 142 congregations; (2) the Associate Reformed Presbyterian Church of North America, which in 1947 had 300 members in 8 congregations; (3) the Reformed Presbyterian Church (Old School), with 6,617 members in 74 congregations (1948); and (4) the Reformed Presbyterian Church (General Synod), with 1,559 members in 11 congregations in 1948.

Later Bodies.—The Fundamentalist-Modernist controversy of the 20th century was particularly severe within the Presbyterian Church, U.S.A. From that church a Fundamentalist group led by J. Gresham Machen formed in 1936 the Presbyterian Church in America. Further doctrinal controversy broke this group into two distinct bodies in 1938: (1) the Orthodox Presbyterian Church, a body stressing classical Presbyterian orthodoxy and very conservative in worship, organization and practice, with 5,543 members, 71 congregations, 98 ministers in 1949; and (2) the Bible Presbyterian Church, a body stressing revival evangelism, Bible institute work and much more loosely organized than the above.

THE PRESBYTERIAN SYSTEM

The Presbyterian way of ordering the life of the church intends to be no more than a systematic and consistent attempt to follow the general principles laid out in the New Testament. It is confessed that the New Testament presents no single, definite, complete pattern. However, the very nature of what is there said of the Gospel, the church, the ministry, etc., is taken by those who hold this system as an adequate indication of the basic elements essential to the ordering of the church's life.

The name "Presbyterian" when used of this system is one of late origin. John Calvin and his associates, who rediscovered and reformulated the system during the 16th century, did not name their system as such. The name came into general use only during the controversies of the following century. The name is derived from a Greek word meaning "elder," and therefore the name designates specifically that aspect of the system which has to do with the ministry of the church. As Calvin and his colleagues elaborated the system, however, its distinctive and basic feature was the doctrine of the church, which in turn was based on their understanding of the Gospel.

Calvin learned much from the earlier reformers, and his work was not wholly original. His greatest contribution lay in his bringing into one clear, systematic statement the general Reformed view. Not all who have called themselves Reformed have ever followed him in all things, but the system is best described by reference to his presentation of it.

The Church.—Calvin's view of the church was shaped by his understanding of the Gospel. The Gospel was the "good news" of God's forgiveness of man, and the call to man to return and be reconciled to God; *i.e.*, to repent. Forgiveness and reconciliation were inseparably bound together, as Calvin saw it. This he took to mean that men were to be reconciled to God by receiving His forgiveness, and to be reconciled to their fellow men by their mutual forgivenesses. To be reconciled to God was to come into His fellowship, and to be reconciled to one's fellows was to come once again into their fellowship. On that basis, Calvin believed, there could be no private, or individualistic salvation. He declared that salvation was intensely personal, because the Christian became a responsible actor, but never a matter involving only the individual soul and God. He was, therefore, much opposed to mysticism and its view that each individual sought God alone and directly. In this connection he quoted the old saying, "Outside the Church there is no salvation." No one could invent his own way to heaven. This view became of great importance in Calvin's doctrine of the sacraments also.

This sense of community, or fellowship, in Calvin's opinion, was to be seen also in God's method of redeeming men. It was God who sought men, rather than men who sought God. Yet, God did not work directly, but through agents, through means. This idea was basic to all of Calvin's thinking about the church. God redeemed men through the agency of their fellow men. Consequently God's love which brought men to Himself was given to men through other men, thereby forming a bond of unity among them greater than any other conceivable bond. Calvin applied this same idea also to all aspects of life. God, he declared, was the source of all good, spiritual and temporal. But because He dispensed this good to men by the labours of others, each owed to the other that which he had received. Therefore, mutual sharing was necessary. This was part of reconciliation and love.

The church, then, according to Calvin, had as its sole function the task of telling men of God's forgiveness and of leading them to reconciliation with God and their fellows. This involved several other things. Men could not accept forgiveness and agree to be reconciled to God and man without confessing that they were in need of so doing. Moreover, to be reconciled, Calvin interpreted as meaning to be reconciled to the service of God among one's fellow men. This meant that the Christian life was to be lived among God's people for their good and God's glory, not for any selfish desire for temporal or eternal gains. Ethics,

therefore, were always part of theology in Calvin's thinking. Political and moral problems dominated his activities. Though the economic application was stated in principle, it was never as fully worked out.

Following St. Paul, Calvin made great use of the idea of the church as the Body of Christ. Here again the community, or corporate, aspect of the church was to the foreground. The members, he pointed out, are held together, directed and governed by the Head in one common life which fulfils the will and purpose of the Head. It is the Head, not the members, to whom all things about the church are to be referred.

Since there is only one Christ, or Head, Calvin declared, there can be only one church or Body. Wherever Christ is present redeeming men in a manner essentially agreeable to the pattern He Himself laid down, there men are to know is the church. Wherever a religion contrary to Christ's own pattern was being offered to men, there, Calvin believed, men were to know that there was no church of Christ. This, he said, was the one basic difference between the papacy and the reformers. The unity, continuity and universality of the church were all to be found in the redeeming presence of Christ, not in any particular form of government, doctrine, leadership or lineal descent of ministers.

The church was the Body of Christ on earth among men, and therefore plainly visible to all, Calvin said. Yet, he continued, because it is all too human there are senses in which it is impossible for men to mark out its exact boundaries. In that sense the church is invisible, and we are "to believe the Church," he said; *i.e.*, we are to believe that this very imperfect community is truly the Body of Christ.

The Ministry.—Two aspects of the nature of the Church, Calvin said, provide the occasion or reason for the ministry, namely that the church is a community and that its own life and felicity are not the reasons for its existence. It exists for the service of God. Consequently direction and leadership are needed, and this the government or ministry of the church is instituted to provide.

The one Head of the church is Christ, Calvin declared, and no one is ever His substitute or vicar. However, Christ moves His people to elect from their membership various persons to discharge the various aspects of the church's function. Some are to preach, some to teach, some to care for the poor and sick, some to exercise discipline. As Calvin believed, God Himself called His ministers, but He did it through the church. The ministry does not exist parallel to, or prior to the church. God, working through the people's election, calls the ministry. The ministry is not a sacred or spiritual order of men. It is a group of officeholders within the Body of Christ.

The church ordered its life in the service of God, then, in Calvin's thinking, by means of a ministry exercised by a variety of officeholders: pastors, teachers, elders and two types of deacons. The pastors were to preach the Gospel, to administer the sacraments and to serve as president of the other officers. Because they had the most responsible office within the total ministry, they might be called "the ministers." The teachers were to devote their whole time to teaching. Elders were to share with the pastors the spiritual oversight of the church. Deacons, men and women, were to care for the poor and the sick. No one was to exercise any function to which he had not been elected, and election to an office by the people was the sole necessary qualification. No matter to what office a man had been elected he remained merely one of the brethren. Calvin rejected the distinction between clergy and laity. All were priests on behalf of all.

God's call, made known through election by the people, was for Calvin all that was needed to make anyone the holder of any office in the ministry. Ordination by other ministers, he asserted, could not make anyone eligible to serve any office. When the ceremony of ordination was used, it meant, he declared, no more than that the ministers led the people in a solemn prayer that God would recognize as His act that which they had done in electing the man in accord with what they believed was His will.

Those who hold offices in the ministry do so only within the church. They have no personal authority or virtue, Calvin said. Consequently, they may act only on the authority and prerogatives given them. (This view determined certain aspects of Calvin's doctrine of the sacraments.)

The Sacraments.—Because, Calvin asserted, it is God who seeks His prodigal children rather than they who seek Him, and because it is God who directs His church in the life which it lives in His service, public worship is primarily the assembling of the people of God to hear what He has to say to them. They do not assemble to seek Him, but to meet Him and to hear His word. When this takes place, they respond by receiving His love, His grace, His fellowship; and then they present their prayers and petitions.

The action of public worship was for Calvin the hearing of the Gospel, and the joyful communion with God to which that Gospel summoned men. By preaching and teaching the Gospel was to be made known and understood in the church. In the sacraments there were provided ways whereby men could actually appropriate and receive the grace offered in the Gospel.

The sacraments in themselves possessed no particular powers. Whatever man received he received by faith. The sacraments, therefore, Calvin said, are not independent of faith. They are rather a "lively preaching" intended to call forth faith. By this very fact they could not be considered necessary to salvation. Yet, since Christ commanded the church to carry out its mission in this manner, and since He did by means of the sacraments truly call forth faith, it was the duty of the church faithfully to use these "means of grace." Preaching and the sacraments could never be separated.

Baptism.—The promise of God in the Gospel, Calvin said, is that God will forgive and receive into His fellowship those who have forsaken Him. That promise was fulfilled, or sealed, when Jesus Christ came, and was crucified and raised from the dead for man's redemption. What remains to be done, Calvin believed, is that man must actually return to the fellowship of God and become a member of the community of believers who make up the church, the Body of Christ. This must be done as an act of faith, and under normal circumstances; it is to be done through receiving baptism.

Baptism symbolizes the death, burial and resurrection of Christ, according to Calvin. By accepting baptism, in an act of faith, men confess that they hope for salvation only in Christ, and that they do in fact return to God. This is their part in the sacrament. God, then and there, "incorporates" the believer into the Body of His Son, the church. This is the all-important aspect, for Calvin.

Calvin elaborated, not a doctrine of "infant baptism," but a doctrine of "Christian baptism," and then urged that children as well as adults might receive it. Children were to be given the promise held out in baptism and then brought up to exercise such faith as their growing years and perception might enable them to do. Until they exercised faith their baptism would be incomplete. Yet, Calvin thought, since their salvation depended upon God's love, and not upon baptism itself, they were safe in God's care while unable to exercise faith. Baptism was intended by God as an aid to faith, not as an indispensable rite necessary for salvation. God could, therefore, dispense with it if He chose. Men, however, were never to omit it, unless unable to use it.

Baptism could be administered by any method, Calvin believed (immersion, sprinkling, etc.), provided only that the method used clearly symbolized and proclaimed the death and resurrection of Christ. Baptism ought to take place only in the midst of the public worship of the church because it symbolized entrance into the Christian communion. Also, only those who led in public worship should baptize. There could be no private baptism because there was no private salvation. There could be no "emergency baptism" because baptism had no such character about it as to create any emergency.

The Lord's Supper.—The Lord's Supper, Calvin believed, was instituted by God to support, nourish and increase the faith of the Christian church. It was rooted in the event of Christ's death on the cross and symbolized that death. It proclaimed, therefore, the fact that God had fulfilled His promise, and that men had

been forgiven. Moreover, it invited men to "take," to receive, the offered mercy of God. Receiving the sacrament in an act of faith meant, Calvin said, that one believed that God truly held out something to man in it, and that man truly received in it just what God offered, namely forgiveness, reconciliation, continued fellowship and communion with God.

The elements (bread and wine) themselves, Calvin thought, had no particular merit or significance beyond their historical connection with Christ's last supper with the disciples. Nothing in the ritual changed the elements in any way. Christ was indeed present during the sacrament as He was present in preaching or in baptism. But His presence was not associated with the bread and wine. He was present to meet with, and commune with His followers.

The sacrament should follow each occasion on which the Gospel was preached, Calvin urged. In the sermon the Gospel was proclaimed; in the sacrament it was set before men symbolically. In faith they were to receive it.

The setting for the sacrament demanded a table, Calvin said. Thus Christ instituted the sacrament, and thus it should be continued. The table symbolized the fact that God is offering to man, and that man is to come, to receive. The altar, Calvin declared, symbolized that man is offering something to God. Also, the sacrament belongs to the whole church, not to the ministers. It is to be administered only in the public worship of the congregation. All were to be invited to come. Any who feared they were "unworthy" were to know that only the confession of need could constitute worthiness. Those who came inwardly ungodly and unrepentant rejected God's mercy in the sacrament just as they rejected it when they heard it preached. Calvin believed that private communion, even for the sick, obscured the true nature of the church as a community and fostered superstitious ideas about the sacrament.

Church Government.—Though Calvin believed that the system of church government which was used by himself and his associates in Strasbourg and Zürich was based upon the Bible and the experience of the church, he did not claim for it exclusive divine right. He acknowledged the English Church under Archbishop Thomas Cranmer, and the Lutheran Churches of Germany under their consistorial system as true and complete churches. Cranmer and the Lutherans also acknowledged the Reformed Churches.

The primary elements of Calvin's theory of church government may be summed up as three. The church is a community, or body in which Christ only is Head, and all other members are equal under Him. The ministry is given to the whole church, and is there distributed among many officers according as God has gifted and called them. All who hold office do so by election of the people whose representatives they are. The church is to be governed and directed by assemblies of officeholders, pastors and elders, so chosen as to provide just representation for the church as a whole.

Since the Reformation the various Reformed Churches, Presbyterian Churches and others, have made many adaptations of this basic structure, generally without departing from it in essentials.

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PRESBYTERY, in architecture, that portion of the choir of a church in which the high altar is placed, and which is generally raised a few steps above the rest of the church. It is reserved for the priests and differs from the choir, the stalls in which are occasionally occupied by the laity. In Westminster abbey the space east of the transept is the presbytery, and the same arrangement is found in Canterbury cathedral. In S. Clemente at Rome the presbytery is enclosed with a marble balustrade or screen. For the use of the word in church government *see* PRESBYTER and PRESBYTERIAN.

PRESCOT, urban district, Lancashire, Eng., 8 mi. E. of Liverpool by the London Midland Region railway route. Pop. (1951) 12,474. Area 1.4 sq.mi. It is of considerable antiquity and received a grant for a market and fair by Edward III. A church existed in the 13th century. The present church of St. Mary is in various styles, with a lofty tower and spire and carved timber roof. Since John Miller brought the industry from Yorkshire (1730) the town has been famed for watches, watch movements and tools. Electric cables are also manufactured. To the north is Knowsley Park, seat of the earls of Derby.

PRESCOTT (SPOFFORD), HARRIET ELIZABETH (1835–1921), U.S. author, was born on April 3, 1835, at Calais, Me. Her family later moved to Newburyport, Mass., where she attended the Putnam free school. For a short time, she was also a student at the Pinkerton academy at Derry, N.H.

Her father, Joseph Newmarch Prescott, a merchant, was stricken with a chronic illness about 1850, and she turned to writing in an attempt to help support the large family. Encouraged earlier by Thomas W. Higginson (*q.v.*), Harriet Prescott first gained recognition in 1859 when the *Atlantic Monthly* published "In a Cellar," an adventure story distinguished by rich description. Her reputation grew rapidly and she became a popular contributor to leading periodicals.

She published *Sir Rohan's Ghost* (1860), a novel dealing with the plight of a man who falls in love with the daughter of a mistress he tried to kill; *The Amber Gods, and Other Stories* (1863), a collection of stories in the romantic tradition; and *Azarian: An Episode* (1864), the story of egocentric, artistic Azarian who could not understand another's idealism.

Her magazine contributions of romantic tales, poems and articles were later collected in a number of books, which include *New-England Legends* (1871); *A Scarlet Poppy and Other Stories* (1894); *In Titian's Garden and Other Poems* (1897); *Hester Stanley's Friends* (1898); *Old Madame and Other Tragedies* (1900); and *The Elder's People* (1920).

After her marriage in 1865 to Richard Smith Spofford, Jr., a lawyer, she spent a great deal of time in Washington, D.C. Interested in the local colour of Washington, she later wrote *Old Washington* (1906), a novel.

She died on Aug. 14, 1921, at her home on Deer Island, in the Merrimack river, near Newburyport, Mass.

PRESCOTT, WILLIAM (1726–1795), U.S. soldier, was born in Groton, Mass., on Feb. 20, 1726. A descendant of John Prescott, one of the early settlers of Lancaster, Mass., Prescott lived as a farmer on his estate at Pepperell, Mass. He returned there after having served as an officer with the provincial army during King George's War and the French and Indian War. He had refused the offer of Gen. John Winslow, his commanding officer during the Nova Scotia expedition, to become an officer in the regular army.

Prescott helped supply food to Boston in 1774, when it was closed by the British parliament, and in the same year he was appointed a colonel in command of a regiment of minutemen. Prescott and his troops attempted to intercept the detachment of British regulars which had been sent by Gen. Thomas Gage, royal governor of Massachusetts, to Concord, where colonists had begun to store military supplies. Prescott and his force did not arrive in time to join the engagement at Lexington April 19, 1775, and he continued to Cambridge, where he joined the council of war. The majority of his troops volunteered to continue serving with him.

With about 1,000 men, he left Cambridge on June 16, 1775, to defend Charlestown, Mass. While historians have disagreed whether Prescott or Israel Putnam (*q.v.*) was in general command of the American forces at the battle on June 17, 1775, at Bunker hill, Charlestown, Prescott played a vital part in that action. (*See* BUNKER HILL.)

The alleged famous order which tradition gives as "Don't fire till you see the white of their eyes" may have been given at

Bunker hill by Prescott. Israel Putnam, it is said, relayed it as "Men, you are all marksmen—don't one of you fire until you see the white of their eyes."

Although Prescott participated in military actions in 1776 and 1777, he had sustained an injury in farm work and had to retire from military life. Returning to his estate at Pepperell, he served for a number of years as a representative in the Massachusetts legislature. He died at Pepperell on Oct. 13, 1795. In 1881 a statue of Prescott by William Wetmore Story was erected on Bunker hill.

PRESCOTT, WILLIAM HICKLING (1796–1859), U.S. historian, was born in Salem, Mass., on May 4, 1796, his grandfather being Col. William Prescott (1726–95), a commander at the battle of Bunker hill, and his father, a well-known lawyer. Although he was blinded in one eye by a crust of bread flung in the Harvard Commons, he graduated with honour in 1814 and entered his father's office as a student of the law.

The verdict of physicians abroad was that the injured eye was hopelessly paralyzed and that the preservation of the sight of the other depended upon the maintenance of his general health. His further pursuit of the legal profession seemed to be out of the question, and on his return to Boston he remained quietly at home. On May 4, 1820, he was married to Susan Amory.

Prior to his marriage he had made a few experiments in composition, but he now finally decided to devote his life to literature. A review of Lord Byron's *Letters on Pope* in 1821 constituted his first contribution to the *North American Review*, to which he continued for many years to send the results of his slighter researches. He next turned to French literature and to the early English drama and ballad literature. Of the direction and quality of his thought at this time he left indications in his papers on *Essay-Writing* (1822) and on *French and English Tragedy* (1823). In pursuance of his method of successive studies he began in 1823 the study of Italian literature, passing over German as demanding more labour than he could afford. In the following year he made his first acquaintance with the literature of Spain under the influence of his friend and biographer, George Ticknor; and, while its attractiveness proved greater than he had at the outset anticipated, the comparative novelty of the subject as a field for research served as an additional stimulus.

In the meantime his aims had been gradually concentrating. History had always been a favourite study, and G. Bonnot de Mably's *Observations sur l'histoire de France* appears to have influenced him. After prolonged hesitation he recorded in Jan. 1826 his decision "to embrace the gift of the Spanish subject." The choice was certainly a bold one. He could only use the eye which remained to him for brief and intermittent periods, and as travelling affected his sight prejudicially he could not anticipate any personal research among unpublished records and historic scenes. He was happy, however, in the possession of ample means and admirable friends. His method of work is an excellent illustration of his resourcefulness and perseverance. Seated in a darkened study, he kept his writing apparatus (a noctograph) before him, and his ivory stylus in his hand to jot down notes as his assistant read aloud. These notes were in turn read over to him until he had completely mastered them, when they were worked up in his memory to their final shape. So proficient did he become that he was able to retain the equivalent of 60 pages of printed matter in his memory, turning and returning them as he walked or drove. The rate of progress was necessarily slow, apart from any liability to interruption by other undertakings and illness. He still continued his yearly experimental contributions to the *North American Review*, elaborating them with a view as much to ultimate historical proficiency as to immediate literary effect, the essays on *Scottish Song* (1826), *Novel-Writing* (1827), *Molière* (1828) and Washington Irving's *Granada* (1829) belonging to this preparatory period. On Oct. 6, 1829, he began the actual work of composition of his *History of the Reign of Ferdinand and Isabella*, the concluding note being written June 25, 1836. Another year, during which his essay on *Cervantes* appeared, was spent in the final revision of the *History* for the press. Its success was immediate. From the position of an obscure reviewer Prescott suddenly found himself elevated to the first rank of contemporary historians.

After considering for a short time the project of a life of Molière, he decided to follow in the track of his first work with a history of the conquest of Mexico. Irving, who had already made preparations to occupy the same field, generously withdrew in his favour. Prescott's five years of labour on this second book were broken by the composition of various reviews and by the preparation of an abridgment of his *Ferdinand and Isabella*. In Dec. 1843 the *Conquest of Mexico* was published with a success proportionate to the wide reputation he had won. The careful methods of work which he had adopted from the outset had borne admirable fruit. While the consultation of authorities had been no less thorough, his style had become more free and less self-conscious; and the epic qualities of the theme were such as to call forth in the highest degree his powers of picturesque narration. It was only a step from his great work on Mexico to that on Peru, and scarcely three months elapsed before he began to break ground on the latter subject. In Feb. 1845 he received the announcement of his election as corresponding member of the French Institute in place of the Spanish historian M. Fernández Navarrete, and also of the Royal Society of Berlin. The winter found him arranging for the publication in England of his *Critical and Historical Essays* (New York ed., *Biographical and Critical Miscellanies*). The *Conquest of Peru* was completed in Nov. 1846 and published in the following March.

Prescott was now over 50 and his sight showed serious symptoms of enfeeblement. Although during the composition of the *Ferdinand and Isabella* it had been of very intermittent service to him, it had so far improved that he could read with a certain amount of regularity during the writing of the *Conquest of Mexico*, and also, though in a less degree, during the years devoted to the *Conquest of Peru*. Now, however, the use of his remaining eye had been reduced to an hour a day, divided into portions at wide intervals, and he was driven to the conclusion that whatever plans he made must be formed on the same calculations as those of a blind man. He had been for many years collecting materials for a history of Philip II, but he hesitated to attempt a work of such magnitude, occupying himself in the meantime with the slighter labours of a memoir of John Pickering for the Massachusetts Historical society and the revision of George Ticknor's *History of Spanish Literature*. But in March 1848 he set himself with characteristic courage to the accomplishment of the large project. Through the aid of Don Pascual de Gayangos, then professor of Arabic literature at Madrid, he was enabled to obtain material not only from the public archives of Spain but from the muniment rooms of the great Spanish families. With an exceptional range of information thus afforded him, he wrote the opening of his history in July 1849; but, finding himself still unsettled in his work, he decided in the spring of the following year to carry out a long projected visit to England, where he was received with great honour. In Nov. 1855 the first two volumes of his uncompleted *History of Philip II*, were issued from the press, their sale eclipsing that of any of his earlier books. This was his last great undertaking; but a year later he published in revised form William Robertson's *Charles V*. A slight attack of apoplexy on Feb. 4, 1858, foretold the end, though he persevered with the preparation of the third volume of *Philip II* for the press, and with the emendation and annotation of his *Conquest of Mexico*. On the morning of Jan. 28, 1859, a second attack occurred, and he died in the afternoon of the same day.

Prescott's power lies chiefly in the clear grasp of fact, in selection and synthesis, in the vivid narration of incident. For extended analysis he had small liking and faculty; his critical insight was limited in range and he confined himself almost wholly to the concrete elements of history. When he does venture upon more abstract criticism, his standards are often commonplace and superficial, and the world scheme to which he relates events is less profound than the thought of his time altogether warranted. Moreover, the authorities on whom he relied had to be corrected later in many points of detail in the light of later archaeological research. Few historians have had in higher degree that artistic

feeling in the broad arrangement of materials which ensures popular interest.

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PRESCOTT, a city of central Arizona, U.S., on federal highway 89 and the Santa Fe railway at an altitude of 5,389 ft.; the county seat of Yavapai county. Pop. (1950) 6,764; (1940) 6,018 by the federal census. It lies in the middle of the Prescott National forest in a region rich in mineral resources, flocks and herds, picturesque life (of Indians and ranchers) and natural beauty. The mines of the county produce copper, gold, silver, lead and zinc. Manufactures include plastics, sportswear, furniture and castings. Grand Canyon college, coeducational, is located there.

It has held a Frontier Days' celebration and rodeo annually since 1888, and the Smoki people of Prescott have since 1921 presented some of their ceremonial dances in an annual pageant of primitive Indian life. The reservation of the Yavapai Indian tribe is there. Prescott was founded in 1864, to be the capital (1864–67) of the newly organized Territory of Arizona.

PRESCRIPTION, in the broadest sense, the acquisition or extinction of rights by lapse of time. The term is derived from the *praescriptio* of Roman law, originally a matter of procedure. It seems to have been introduced by the praetor to meet cases affecting aliens or lands out of Italy where the *usucapio* of the civil law (the original means of curing a defect of title by lapse of time) could not apply. The prescription of Roman law (and of modern systems based upon it) is both acquisitive and extinctive. It looks either to the length of time during which the defendant has been in possession, or to the length of time during which the plaintiff has been out of possession.

In English law prescription is used in a comparatively narrow sense. It is acquisitive only, and is very limited in its application. A title by prescription can be made only to incorporeal hereditaments—*i.e.*, in legal language, hereditaments that are or have been appendant or appurtenant to corporeal hereditaments—and to certain exemptions and privileges. The rights claimable by prescription for the most part consist of rights *in alieno solo*. The most important are advowsons, tithes, commons, ways, watercourses, lights, offices, dignities, franchises, pensions, annuities and rents. Land or movables cannot be claimed by prescription. The foundation of prescription is the presumption of law that a person found in undisturbed enjoyment of a right did not come into possession by an unlawful act. In the English courts this presumption was, perhaps still is, based upon the fiction of a lost grant. The enjoyment of the right must have been from a time whereof the memory of man runneth not to the contrary. After one or two previous enactments the date was finally fixed by the Statute of Westminster the First (3 Edw. I. c. 39) at the reign of Richard I., which was interpreted to mean the first year of the reign of Richard I. (1189). This is still the law with respect to claims not falling within the Prescription Act, 1832. By that act (extended to Ireland in 1858, but not to Scotland) claims to rights of common and other profits *à prendre* are not to be defeated after 30 years' enjoyment by any person claiming right thereto without interruption for 30 years by showing only the commencement of the right, and after 60 years' enjoyment the right is absolute and indefeasible unless had by consent or agreement by deed or writing (s. 1). In claims of rights of way or other easements the periods are 20 years and 40 years respectively (s. 2). The beforementioned periods are to be deemed those next before suits, and nothing is to be deemed to be an interruption unless acquiesced in for one year (s. 4). The time during which a person otherwise capable of resisting a claim is an infant, idiot, *non compos mentis*, *feme covert* or tenant for life, or during which an action or suit has been pending until abated by the death of a party, is to be excluded in the computation of the periods unless where the right or claim is declared to be absolute and indefeasible (s. 7). An act to define the period of prescription for a *modus decimandi*, or an exemption from tithes by composition, was passed the same year. The claim under the statute must be one which may be lawfully made at common law. The principal rules upon the subject are these: (1) The title is founded upon actual usage. The amount of actual usage and the evidence necessary to prove it vary according to the kind of claim. (2) The enjoyment must (except in the case of light) be as of right—that is to say, peaceable, openly used, and not by licence. (3) The prescription must be certain and reasonable. Inhabitants cannot, however, claim by prescription, as they are an uncertain and fluctuating body, unless under a grant from the Crown, which constitutes them a corporation for the purposes of the grant. (4) The prescription must be alleged in a *que estate* or in a man and his ancestors. Prescription in a *que estate* lies at common law by reason of continuous and immemorial enjoyment by the claimant, a person seised in fee, and all those whose estate he had. Prescription in a man and his ancestors is not of ordinary occurrence in practice. Corporations, however, occasionally claim by a prescription analogous to this, viz. in the corporation and its predecessors. Such claims by either a person or a corporation are not within the Prescription Act, which applies only where there are dominant and servient tenements. By 32 Hen. VIII. *c.* 2 (1540) no person can make any prescription by the seisin or possession of his ancestor unless such seisin or possession had been within three score years next before such prescription made. (5) A prescription cannot lie for a thing which cannot be granted, as it rests upon the presumption of a lost grant.

Prescription must be carefully distinguished from custom. Some rights may be claimed by custom which cannot be claimed by prescription, *e.g.*, a right of inhabitants to dance on a village green, for such a right is not connected with the enjoyment of land.

International Law uses the term "prescription" in its wider or Roman sense. "The general consent of mankind has established the principle that long and uninterrupted possession by one nation excludes the claim of every other" (Wheaton, *Int. Law*, s. 165). Historic instances of rights which were at one time claimed and exercised by prescription as against other nations are the sovereignty of Venice over the Adriatic and of Great Britain over the Narrow seas, and the right to the Sound dues long exacted by Denmark. But such claims were rejected by the highest authorities on international law (*e.g.*, Grotius), on the ground that they were defective both in *justus titulus* and in *de facto* possession. In private international law prescription is treated as part of the *lex fori* or law of procedure. (J. WIL.; X.)

Scotland.—In the law of Scotland "prescription" is a term of wider meaning than in England, being used as including both *prescription* and *limitation* of English law. In its most general sense it may be described as the effect which the law attaches to the lapse of time, and it involves the idea of possession held by one person adverse to the rights of another. Though having its basis in the common law, its operation was early defined by statute, and it is now in all respects statutory. Prescription in Scots law may be regarded (1) as a mode of acquiring rights—the positive prescription; (2) as a mode of extinguishing rights—the negative prescription; (3) as a mode of limiting rights of action—the shorter prescriptions. It must, however, be observed with reference to this division that the distinction between (1) and (2) is rather an accidental (due to a loose interpretation of the language of the act of 1617, *c.* 12) than a logically accurate one. It is, moreover, strictly confined to heritable rights, having no application in the case of movable property.

Positive Prescription.—The positive prescription was introduced by the Act of 1617, *c.* 12, which regulated the prescription of land rights till 1874. The provisions of the Act of 1874 are repealed as from Jan. 1, 1930, by the Conveyancing Act, 1924 (s. 16). As from that date the prescription will be 20 years without allowance for legal disability. The Acts of 1874 and 1924 provide that possession for 20 years upon "an *ex facie* valid irredeemable title recorded in the appropriate register of sasines" should in future give the same right as 40 years' possession upon charter and sasine under the earlier laws. These Acts also provide that the 20 years' prescription is not to apply to servitudes, rights

of way and public rights generally.

Negative Prescription.—This prescription was introduced by the Act of 1469, *c.* 28, and was substantially re-enacted by the Act of 1474, *c.* 55. The negative prescription accordingly extinguishes *in toto* the right to demand performance of an obligation after 40 years, the years being reckoned from the day on which fulfilment of the obligation can be first demanded. Such a lapse of this period of time creates a conclusive presumption—one incapable of being reargued—that the debt or obligation has been paid or fulfilled. But it must be kept in view that the negative prescription does not *per se*—without the operation of the positive—establish a right to heritable property (Erskine, *Inst.* bk. iii. tit. 7. s. 8). The negative prescription of heritable debts (Act of 1617) is reduced to 20 years without allowance for legal disability as from Jan. 1, 1930, by the Conveyancing Act 1924 (s. 17). This reduction of period does not apply to the prescription of servitudes and public rights.

United States.—Prescription in the United States though often used synonymously with adverse possession is technically confined as at common law to the acquisition of rights to incorporeal hereditaments, chiefly easements. The common law doctrine of presuming a lost grant after a certain period of undisturbed enjoyment of the right prevailed in the States. Upon an analogy to the period of limitations prescribed by the Statute of James I., undisturbed enjoyment of the right for 20 years was deemed to raise the presumption of a lost grant. Some differences of opinion have prevailed as to whether the presumption is a matter only of fact and hence rebuttable or is conclusive as a matter of law, the latter view being the majority rule. Thus prescription has in many States been assimilated to the acquisition of title to land by adverse possession. Statutes have commonly dealt with prescription, abolishing the lost grant presumption and substituting the doctrine of acquisition of title through adverse possession. As at English common law the adverse use must be open and notorious and not under licence of the owner; it must be uninterrupted for the statutory period, and the right acquired is limited to the extent of the use and the enjoyment of it during the period of prescription. No easement can be acquired save as appendant to an absolute estate in land. No right to maintain a nuisance can be acquired by prescription nor can a right of user be acquired by prescription against the State.

PRESERVING AND BOTTLING, terms used for methods of saving perishable foods from moulds, yeasts and bacteria. (*See* Food Preservation.) In the United States the term "canning," instead of "bottling," is used for the preservation of food in containers, whether of glass or tin, and the word "preserves" implies that sugar is added to the food material.

The application of heat in some form is one of the commonest means of destroying bacteria, yeasts and moulds, and is utilized in jam-making (*see* Jams and Jellies), bottling, canning, pickle-making, drying and crystallizing. Pickle-making is a method of preserving in which heat, vinegar, sugar or salt, or both, are used to destroy the micro-organisms contained in fruit and vegetables. The acetic acid in the vinegar acts as an antiseptic and prevents further growth of bacteria, moulds or yeasts. Chutneys, pickles, catchups and sauces are examples of foods preserved with vinegar.

BOTTLING FRUIT

The aim when bottling is to sterilize the contents of the bottle, and having done so to prevent any germs from entering by sealing it. Bottling is one of the simplest, but most useful methods of preserving fruit and vegetables, for their character and flavour is unaltered, whereas in jam and pickle-making both taste and appearance are changed. Provided attention be paid to a few important points success is assured, and a lavish supply of peas, beans, cherries, currants, etc., is available for winter use at little cost beyond the initial expense of buying a supply of vacuum jars. These are not essential, however, for ordinary jam jars can be used, although special care and precautions must be taken to obtain an airtight seal. When bottling is done regularly it is advisable to purchase a supply of vacuum jars and a sterilizer.

Vacuum jars or bottles consist of (a) a glass container with wide neck. It should be without flaws and it is important that the rim should not be chipped; (b) a metal or glass lid; (c) a rubber band, which acts as a washer between the bottle and lid; (d) a metal screw band or clip. When bottling is carried out on a large scale special sterilizers are employed, but in the home a large zinc bath, fish kettle, bath or even a large clothes boiler or copper, can be used. As bottles are liable to crack if they are placed in immediate contact with the heated bottom of the pan some good non-conductor of heat must come between them. A simple slatted wood board to fit the copper, bath or fish kettle makes an excellent false bottom.

Selecting and Preparing the Fruit.—(1) Select sound fruit which is very slightly under-ripe, with the exception of pears, which are better bottled when fully ripe. (2) Wash to remove dust, grade according to degree of ripeness and pack neatly and firmly, using a smooth piece of wood or bone spatula. The bottle should be shaken from time to time to ensure a tight pack. Loose packing is responsible for the fruit rising when sterilized, leaving a space of one to two inches at the bottom of the jar. (3) Fill each jar with cold water and pour away. This is to rinse the fruit as it is handled during the packing process. (4) Fill the jars with syrup or water, taking care that the fruit is completely covered. The flavour is improved when syrup is used, but if sugar is scarce or unavailable water can be used. (5) Put the rubber rings, lids and screw bands or clips in position. When screw bands are used, they should be screwed down tightly and then unscrewed for rather less than a half turn to allow the steam and air to escape. (6) Stand the bottles in the sterilizer or bath, which should contain sufficient cold water to cover the bottles completely, and apply gentle heat until the correct temperature is reached. This varies according to the variety of fruit from 125° F for small soft fruit, such as raspberries and blackberries, to 185° F for fruit salad, plums, cherries and pears. The process must not be hurried and approximately 1½ hours should be taken in bringing the water to the correct temperature. (7) Allow the bottles to remain at this temperature for from 10 to 30 minutes. Most soft fruit requires about 15 minutes and pears and apples about 30 minutes. (8) When sterilizing is completed remove the bottles from the boiler, stand on a wooden table or some other good non-conductor, tighten the screw bands and leave until cold. (9) Next day examine the bottles to see if they are airtight. To do this, remove the screw bands and clips, hold the bottles by the lid and raise them. If the lid is firm and secure the seal is perfect. Should the lid show the slightest signs of movement or come off the seal is imperfect, and the bottle should be re-sterilized.

To Make the Syrup.—Dissolve four to six pounds of sugar in a gallon of water—according to the sweetness of the fruit being bottled—bring to the boil and when cool fill the bottles.

BOTTLING VEGETABLES

Vegetables require rather more severe treatment than fruit, particularly peas and beans, as they contain nitrogen, which renders them favourable to the growth of certain micro-organisms Prepare brine of a suitable strength by dissolving 2½ oz. salt in one gallon of water and adding 5 fluid oz. or ¼ pint lemon juice, when preserving peas and beans. Boil the water, add the salt and the exact quantity of lemon juice. When cold it is ready for use.

Peas must be cleaned thoroughly by washing, and as a precaution it is advisable to soak them for 15 minutes in a weak solution of permanganate of potash. Sufficient crystals should be added to the water to produce a deep magenta colour. Remove the pods and shell the peas. Put them loosely in muslin and dip in a saucepan of boiling water for 1–1½ minutes Then place in cold running water for about 10 minutes. Pack into the bottles and fill with acidified brine.

French and Runner Beans.—Wash the beans thoroughly, using a nail brush if necessary to remove soil from the pods; string (the runner beans will also require slicing); pack lengthways in the jars. After packing, rinse out the jars with water, cover with acidified brine and place the rubber ring, glass lid and screw band in position. (*See* detailed instructions for fruit bottling.) Put in the sterilizer or boiler, bring very slowly to the boil

and boil for 1½ hours. If, after the bottles have been boiling the brine has boiled away, remove the jars and fill up with boiling brine. Replace the rings and complete the cooking. Next day examine and test the seal as when fruit bottling.

CANNING

The same principles and methods are used in canning as bottling, the chief difference being that metal, and not glass, containers are used, and the method of sealing is therefore different.

Canning has the advantage that it occupies less time than bottling and less care is necessary as there is no risk of breakage. It has not been widely practised by housewives, chiefly owing to the fact that until recently soldering was necessary, a process which the majority of women found difficult. This drawback no longer exists, for a small hand sealing machine is now available which eliminates soldering. Numerous tests with the machine have been carried out and the results are invariably extremely satisfactory and reliable. In conjunction with the hand sealer, special straight sided sanitary cans with open ends must be used. The cans may be either plain or lacquered. The latter are preferable, as they prevent the acid fruit coming in contact with the tin. The outer rim of the lid has a groove which is treated with rubber solution and which acts in the same way as the flat rubber band used when fruit bottling.

Method of Canning.—(1) Wash the cans thoroughly in hot water before use. Pack with prepared fruit or vegetables, and cover entirely with boiling syrup or brine. (2) Put the lids in position and with the aid of the sealing machine close the can. As the escape of steam exhausts the air it is important to seal the can whilst very hot; therefore only two or three should be filled with boiling syrup at one time, otherwise they cool down before there is time to seal them. (3) When all the cans have been sealed, place them in any large container, such as a clothes boiler, large pan or zinc bath containing sufficient boiling water to cover them completely. (4) Bring to the boil and boil gently for 15–40 minutes, according to the fruit. Small soft fruit requires 15 minutes only, and pears from 35 to 40 minutes. The time must be calculated from the moment the water boils again after all the cans have been put in. Small bubbles rising from the can whilst it is in the water indicates that it is not airtight, and has been sealed imperfectly. The contents must be removed, put into a new can and resealed. (5) When sterilizing is complete, cool the cans quickly by placing them in a bath or sink of cold water. When cold, dry and label. (*See* also Food Preservation.)

(D. D. C.-T.)

In the United States processing is the term applied to the heating of the material to a temperature and for a length of time that will kill bacteria producing spoilage, and the following methods are used: (A) Water-bath canner, in which the containers are set far enough apart to allow free circulation of the water. This must be boiling when the sealed containers are set in (glass jars being preheated to avoid breakage) and must come over the top of the containers. (B) Steam-pressure canner, in which only enough water is put to come almost to the rack on which the containers are set.

The hot-pack method of canning is recommended by the United States Department of Agriculture. The food material is first heated to boiling point in a minimum of water, is packed while boiling hot into the containers, then processed. In the cold-pack method the material is packed cold into the container (often after first being blanched), then processed. (I. E. L.)

PRESIDENCY, an administrative unit of the Indian empire. The word is derived from the title of president or chief of the council of a principal factory under the East India Company—a title which lasted until governors were appointed under act of parliament in 1784. It thence came to be applied to the three original provinces of Bengal, Madras and Bombay. It is now restricted to Madras and Bombay, in distinction to the lieutenant-governorships. In Anglo-Indian usage, "presidency" was also applied to the capital city as opposed to the country beyond, termed the "mofussil"; and this usage lingers in such phrases as "presidency town," and "presidency magistrate."

PRESIDENT, a style of title of one who presides. In classical Latin the title *praeses,* or president, was given to all governors of provinces, but was confined in the time of Diocletian to the procurators who, as lieutenants of the emperor, governed the smaller provinces. In this sense it survived in the middle ages. Du Cange gives instances from the capitularies of Charlemagne of the style *praeses provinciae* as applied to the count; and later examples of *praeses,* or *praesidens,* as used of royal seneschals and other officials having jurisdiction under the Crown.

In England the word survived late in this sense of royal lieutenant. Thus, John Cowell, in his *Interpreter of Words* (1607) defines "president" as "used in common law for the king's lieutenant in any province or function; as president of Wales, of York, of Berwick, president of the king's council." In some of the British North American colonies (New Hampshire, Pennsylvania, South Carolina) there was a president of the council, usually elected by the council; and when Pennsylvania and New Hampshire became States, one member of the executive council was called president. The chief (and single) executive head in Delaware, South Carolina and New Hampshire (1784–92) was called president.

During the revolutionary struggle in America from 1774 onwards, the presiding officer of the continental congress was styled "president" and when the present constitution of the United States was framed in 1787 (in effect 1789) the title of president was transferred to the head of the Federal Government. "President" thus became the accepted style for the elected chief of a modern republic.

In the simple sense of "one who presides" the word "president" preserved its meaning alongside the technical use implying royal delegation. In ecclesiastical terminology *praesidens* was sometimes used for the head of cathedral chapters, instead of dean or provost; and it was sometimes the title given to the principal visitor of monasteries. In Great Britain the heads of many colleges are styled "president," the title being of considerable antiquity in the case of one college at Cambridge (Queens', founded in 1448) and four at Oxford (St. John's, Magdalen, Corpus Christi, Trinity). At five Cambridge colleges (Pembroke, Gonville and Caius, St. Catherine's, St. John's, Magdalene) the title "president" is borne by the *second* in authority, being the equivalent of "vice-master." In the United States "president" is the usual style of the head of a college and also of a university wherever this has developed out of a single college. "President" is also the style of persons elected to preside over the meetings of learned, scientific, literary and artistic academies and societies, *e.g.,* the president of the Royal Academy (P.R.A.) in London; the title of the president of the Royal Society (P.R.S.) dates from its foundation in 1660. In the United States the style "president" is also given to the person who presides over the proceedings of financial, commercial and industrial corporations (banks, railways, etc.), in Great Britain usually styled "chairman," but in the Bank of England and certain other banks "governor."

In France, besides the president of the republic, there are presidents of the senate and of the chamber of deputies. In Germany the word *Präsident* is used in most of the English senses of "president," *e.g.,* of a corporation, assembly or political body.

PRESLAV, a village of Bulgaria, situated on the north edge of the Balkans, south of Shumen (*q.v.*). Preslav was the second capital of the mediaeval Bulgarian tsars, and was raised to great splendour by Tsar Symeon (893–927). It was then compared to Constantinople, and described as "full of high palaces and churches, with countless stones, woods and paintings, so adorned with marble and copper, silver and gold, that the visitor knows not wherewith he shall compare it." It fell into decay on the fall of the first Bulgarian Empire, and was later plundered to adorn the new capital of Trnovo (*q.v.*). It is now a heap of ruins.

PREŠOV, a town in eastern Slovakia, 25 m. north of Košice. Situated on the left bank of the river Tarcza, a tributary of the Theiss, it is a very old town but has been almost entirely rebuilt since a great fire in 1887. Following the foundation of the town by German colonists in the 12th century its history has been much affected by the nodal character of its site; today it is the

seat of the District authorities, the centre of a Greek Catholic diocese and an important railway junction for the Carpathians and Poland. In the neighbourhood of the town is an opal mine and mineral springs, but importance rests on its administrative functions supplemented by small manufactures. Pop. (1930) 21,870.

PRESS. For the history of the liberty or freedom of the press *see* PRESS LAWS; also NEWSPAPERS and PERIODICALS. For the punishment of "pressing" *see* PEINE FORTE ET DURE. For the "press gang" *see* IMPRESSMENT.

PRESS ASSOCIATION, THE, the oldest and largest news agency operating exclusively in Britain, was founded by provincial newspapers on a co-operative basis in 1868, and began active work on February 5, 1870, when the post office took over the private telegraph companies which had previously supplied the provincial papers with news. For 50 years the P.A. transmitted news by press telegrams, but in 1920 it leased private telegraph wires from the post office. Its private wire system embraces over 3,000 miles of telegraph circuits radiating from London and serving either direct or through centres at Birmingham, Bristol, Manchester, Leeds, and Glasgow, about 120 provincial morning and evening newspapers. It also operates a direct printer system to offices in London. The P.A. has always had the exclusive right to supply in the provinces Reuters' (*q.v.*) imperial and foreign news services. The two agencies are closely associated. With the Exchange Telegraph Company, the P.A. operates in the provinces a joint telephonic service for the rapid collection and distribution of racing results, etc., and cricket and football scores.

The P.A. is governed by a board of seven directors. One new director is elected annually by the shareholders (the provincial newspapers). The Association's new headquarters' building, which it occupied in July, 1939, is at 85, Fleet Street, London. From this building it supplies news to all the London daily and Sunday newspapers, provincial newspapers, and trade journals and other periodicals. (H. C. RO., X.)

PRESSBURG: *see* BRATISLAVA.

PRESSED METAL, a broad term which includes that class of merchandise made by the process of bending, shaping and forming sheets, strips, plates or bars of metal in either hydraulic or mechanically-driven presses. Steel so treated is referred to as "pressed steel" or "stampings." While brass, aluminium, zinc and various alloys are all formed in substantially the same manner as steel and with similar equipment, this article will be largely confined to pressed steel.

The greater portion of the work is done cold and pressed steel is generally assumed to mean the cold forming of sheet steel in power-driven presses. Castings and forgings constitute the classes of material that are most generally replaced by pressed steel. Pressed steel is different from both castings and forgings in that, while either a casting or a forging may have a solid section of varying degrees of thicknesses, except in rare cases, pressed steel is a flat or hollow form, such as a shell, the walls of which are of equal thickness throughout. While by special processes and by specially constructed tools it is possible to make a wall of varying thickness, it generally follows that if the sheet of steel which is used as raw material is $\frac{1}{8}$ in. thick, the walls of the finished pressed steel form will also be substantially $\frac{1}{8}$ in. thick. Cold forming of steel first became industrially important through its adoption by bicycle manufacturers. When bicycles became popular, pressed steel replaced forgings and castings because of the need of producing a lighter vehicle at a lower cost.

The next great advance in the use of pressed steel was by the automobile manufacturer. By the 1930s, apart from units such as the engine, front axle and a few minor parts, most automobiles were being made almost entirely of pressed steel. (*See* MOTOR CAR: *Motor Car Body Design.*) Other manufacturers, perceiving the advantages of pressed metal over castings and forgings, changed their methods so that pressed steel went into many other manufactured products. It is impossible here to give a complete list but a few of the better known products are beds, alarm clocks, cooking utensils, gas and electric ranges, lighting fixtures, electrical conduits, switch boxes, push button plates, office furniture, filing cabinets, concrete forms, car wheels, hot water heaters, gasolene pumps, washing machines and typewriters. Wherever a large number of individual units are demanded for mass production, pressed metal has, in the majority of cases, been utilized.

The equipment used for the manufacture of pressed steel carries the general term of *presses.* There are two general classes known as hydraulic and mechanically-driven. The majority, however, are belt-driven power presses of varying size. The press furnishes the power and the means of holding the "tools" or punches and dies that do the actual forming of the metal. These "tools" consist of an upper or male section, which is known as a punch, and the lower or female section, which is known as a die. A piece of steel is held over the lower section (the die) and the upper section (the punch) is brought down on this by the power press, thus cold forming the steel into the desired shape. The majority of pressed steel parts are made by several successive operations. A certain shape of flat blank receives the first operation in one set of tools, it is then passed along to a second press carrying a second set of tools and is further formed or drawn, and so on through various stages.

It is usually necessary to heat-treat the steel between these various operations as cold pressing makes steel harder and tougher and without heat-treating the steel would not withstand the strain to which it is subjected. Soft, well-annealed steel is ductile, while steel that has been worked in the tools is tough and hard. The tensile strength of a piece of steel can be increased as much as 30% by a single drawing operation. Holes are punched and edges trimmed smooth and round by specially designed tools. While forgings are heavy and castings are both brittle and heavy, a pressed steel part, when properly manufactured, is both lighter and stronger, has a smoother surface and requires less finishing or machining. It replaced wood in many cases.

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PRESSENSÉ, FRANCIS DE (1853–1914), French politician and man of letters, was born in Paris on Sept. 30, 1853, being the son of Edmond de Pressensé, and was educated at the Lycée Bonaparte. He served on General Chanzy's staff in the war of 1870, and was taken prisoner at Le Mans, but after the war entered the public service. After a short period at the ministry of public instruction he entered the diplomatic service, and was appointed first secretary at Washington. In 1882 he returned to France and took up journalism, becoming in 1888, foreign editor of the *Temps.* At the time of the Dreyfus case (1895) de Pressensé identified himself with the cause of the prisoner. He wrote in support of General Picquart, and in consequence of his advocacy of Émile Zola's cause was struck off the roll of the Legion of Honour. This led to his resignation from the *Temps,* and he came forward as a socialist politician, being in 1902 elected socialist deputy for the Rhône. He took part in the debates on the question of the separation of church and state, and a bill brought in by him formed the basis of the one finally carried by Briand. He died in Paris on Jan. 19, 1914.

His works include *Le Cardinal Manning* (1896), and *L'Irlande et l'Angleterre depuis l'acte d'union jusqu'à nos jours, 1800–1888* (1889), besides many articles in the *Temps,* the *Revue des Deux Mondes, Aurore* and *Humanité.*

PRESSES AND PRESSWORK. The method of converting ingots of steel into forgings depends upon the size of the completed pieces and the number of these required. Hammer heads are formed in dies under a drop hammer. (*See* DROP FORGING.) Locomotive connecting rods would probably be forged under a steam hammer (*q.v.*). Ingots larger than 3 ft. in diameter, however, would usually be forged under a hydraulic press. The present article will confine itself to the latter type, although many hydraulic presses are used for the manufacture of seamless tubes, shells or flasks, and adapted to many forming operations in trades other than metal working. Machines for forming cold sheet metal and thin plate (*see* PRESSED METAL) are also called presses, although the dies are opened and closed by cam or eccentric-driven

levers.

In a forging press the hot metal rests on a stationary anvil and is squeezed by a pallet forced downward by a hydraulic ram. Four heavy round columns act as tension members with both ends fixed into massive rectangular slabs called entablatures; the lower entablature rests directly on the foundation and supports the anvil; the upper entablature or cap carries the hydraulic cylinder. Fluid pressure in this cylinder forces a closely fitting ram downward; to the bottom of the ram is attached a cross head guided by four bushings sliding over the columns, and to this cross head is secured the upper working tool or pallet. Auxiliary cylinders are provided for lifting the cross head after the force has been exerted, and to move the ram up to its work. High pressure in the ram cylinder may be built up directly from a pump, from an accumulator (*see* STEAM ACCUMULATORS) or by a steam intensifier. Frequently more than one pressure is available so that work of various sizes can be handled. Reliable valves and packing at all sliding joints are essential. The capacity of a press is rated by the total squeeze it can exert. The smaller sizes, which compete with steam hammers, are designed for rapid operation and economy of power and water; in the bigger ones these considerations are subordinated to the necessity for complete reliability.

So much improvement has been made in the art of casting and heat treating alloy steels that the large expense of forging is now justified only when the utmost of uniformity, soundness and toughness is essential. Castings and ingots are made up of interlocked fern-like crystals of metal, whose size depends upon the slowness of solidification. Long continued heat treatment may be able to refine this structure into an aggregate of microscopic crystals, but it is much more amenable to heat treatment if the hot ingot has been squeezed and the coarse crystals more or less broken up mechanically. Accidental internal cavities may also be closed up and welded shut. This kneading of metal, to be effective, should obviously extend to the very centre of the section. Hence large ingots need the slow, deliberate, irresistible squeeze of a hydraulic press. The sharp blow of the biggest hammer is cushioned by the outer layers of metal and fails to reach the centre of the slab. American railroad practice in 1929 calls for a 5 to 1 reduction from the ingot and a 4 to 1 from rolled billets. Recent investigations have shown, however, that fine grain can be obtained with even less than 3 to 1 reduction if proper precautions are taken. The irregularities caused by segregation (*see* IRON AND STEEL) can more than counteract the advantages of large reduction under the press. The carbon is lower in the bottom and sides of the ingot and higher in the centre and top; to counteract this in big ingots requiring the full capacity of several furnaces, metal containing less and less carbon is poured in the successive heats.

It is impossible to make absolutely clean steel. Tiny non-metallic inclusions will be caught between the crystals throughout the ingot; soluble impurities like phosphorus will concentrate in the metal locked within the crystal branches. Forging tends to arrange these impurities into planes parallel to the pallet faces; the more the reduction the more pronounced would these "flow lines" become. Thus if tensile test pieces are cut from a thick forged slab in three directions (*a*) parallel to the main extension, (*b*) crosswise and (*c*) from front to back, the ultimate strength of all might be fairly close. However, the first or longitudinal piece would have satisfactory contraction of area and impact toughness; the second or tangential test piece would have markedly less toughness; the third, or transverse test piece would be the most brittle. Such "transverse weakness," as it is called, is a great danger to cylindrical objects which must withstand bursting pressure, because the greatest stress is in a tangential direction. Transverse weakness may be minimized by making ingots of cleanest steel, and also doing no more work in forging than is necessary. Hence the modern method of minimizing the size of ingots and degree of forging avoids undue trouble from segregation and transverse weakness. Tensile properties taken from representative large forgings are as follows:

Article	Steel	Size	Ultimate strength	Yield point	Elongation in 2 in.	Reduction in area
Hydraulic press column	Nickel-chromium	24 in. dia. by 36 ft.	115,000	85,000	21	55
40,000 lb. Intensifier	Nickel-chromium	18 in. dia.	148,500	110,000	15 (tangential)	50
47,000 lb. Extrusion press	Chromium-vanadium	32 in. dia.	..	110,000	..	..
Boiler drum	0·26% Carbon	63 in. dia.	64,000	29,000 min.	25 in 3 in.	45

(*See* IRON AND STEEL.) (E.E.T.)

PRESS GANG. The Press Gang was the name given to the naval parties who, until the beginning of the 19th century, were used forcibly to take or "impress" men for service in the British fleet. From mediaeval times the Crown claimed the power to impress able-bodied subjects for the defence of the realm, and as early as the time of Edward III. complaints are recorded in Parliament of the excessive use of this power. From the earliest time, England depended upon her professional seamen, the merchantmen, to man her fighting ships: but it was not until the end of the 16th century that fishermen, watermen and mariners were exempted by law from being "pressed" as soldiers: they remained liable to impressment for service in the Navy. The needs of Elizabeth's fighting fleet became so large that the Vagrancy Act was passed, rendering all "disreputable persons" liable for impressment for service in the fleet: the sheriffs and mayors being bound, upon the production of the warrant of the "takers" or "press gang," to produce the number of men required. This naturally led to jail clearance; the law remaining unaltered, throughout the 17th and 18th centuries there were constant complaints from naval officers of the quality of men supplied. In the 18th century certain exemptions were made, in the case of apprentices, a proportion of fishermen, seamen employed in the coastwise coal trade, but even at the height of Britain's maritime power, from 1780 to 1815, the press gang was the chief means of recruiting the fleet.

The action of English cruisers in pressing men from the merchant ships of the American colonies was one of the causes that led to the War of Independence. A favourite means of completing the complement of warships was by stopping homeward bound merchantmen and removing some of their seamen. Service became so unpopular that in 1795 the press gangs and the jails failed to provide sufficient men. An Act was passed directing each county to provide a "quota" of men, with the result that the authorities of each district handed all malcontents and agitators over to the press gangs, by whom they were taken to the guard ships stationed round the coast for drafting into the fleet. The introduction of this bad element into the Navy was one of the causes of the mutiny of 1797 which nearly brought disaster to the country. The insistence of the right to press British subjects in America was one of the chief causes of the war between Great Britain and the United States in 1812.

The press gangs were not used after the close of the Napoleonic Wars in 1815, although it is lawful to this day to impress men for service in the navy, though not in the army. By an Act of 1835 a "pressed" man is exempt after five years' service and seamen in the Merchant Service, fishermen and certain other persons are exempted from impressment. With the introduction of the long service system in 1853 all need for impressment disappeared and since that date there have always been more volunteers than could be accepted for service in the Royal Navy. (S. T. H. W.)

PRESSING: *see* PEINE FORTE ET DURE.

PRESS LAWS, the laws affecting the products of the printing-press and newspapers in particular. (*See* NEWSPAPERS.) In English-speaking countries the liberty of the press is nowadays taken for granted. It was not always so, but in 1784 Lord

Mansfield made the following pronouncement in *R.* v. *Dean of St. Asaph* (3 T.R. 431 n): "The liberty of the press consists in printing without any previous licence, subject to the consequences of the law." This liberty was a plant of slow growth in England, and in some Continental countries the State still exercises an authority over the newspaper press which in Anglo-American spheres would be considered intolerable in time of peace. (*See* also CENSORSHIP.)

In the middle ages the church kept a firm hand on the free expression of opinion, spoken or written, and when printing was discovered co-operated with the secular authority in keeping an even tighter hand on the printed word. The principle of the censorship over the products of the press, which is still maintained by the Roman Catholic Church (*see* INDEX LIBRORUM PROHIBITORUM), was initiated by a bull issued by Pope Alexander VI. in 1501 against unlicensed printing. In 1535 Francis I. issued an edict prescribing the death penalty for the unauthorized printing of books, and soon afterwards the Sorbonne became the licensing authority and remained so until the French Revolution.

England.—In England after the Reformation in Henry VIII.'s reign most of the rights of censorship passed from the ecclesiastical authorities to the Crown, which began to grant by letters patent the privilege of printing or selling books as a monopoly. Under Queen Mary the right of printing was limited to 97 members of the Stationers' company, founded by royal charter in 1556, and their successors by apprenticeship. Under Queen Elizabeth the Star Chamber limited the number of printers and presses, and ordained that printing should be carried on only in London, Oxford and Cambridge. In view of the increase in unlicensed printing-presses, the Star Chamber in 1637 decreed that all printed books must be submitted for licence and registered by the Stationers' company before publication, with the penalty of forfeiture of all presses belonging to disobedient printers, who were disabled thereafter from carrying on their trade. The old formula *imprimatur* (let it be printed) thenceforward denoted the authority to print the book. Law books had to be licensed by one of the chief justices or the chief baron of the Exchequer, certain other classes of books by special dignitaries, but most of the licensing devolved on the archbishop of Canterbury and his coadjutors and the chancellors or vice-chancellors of the universities. It was a similar ordinance made by the Long Parliament, after the Star Chamber had been abolished, that called forth John Milton's unlicensed essay, *Areopagitica, a Speech for the Liberty of Unlicensed Printing*. Under the Licensing Act of 1662 (in effect reproducing the Star Chamber order of 1637), practically the newspaper press was reduced to the *London Gazette*. In 1695 the Licensing Act lapsed and, to quote Macaulay, "English literature was emancipated for ever from the control of the Government." Lord Chief Justice Russell (of Killowen) said in *R.* v. *Gray* 1900, 2 Q.B. at p. 40: "The liberty of the press is no greater and no less than the liberty of every subject of the queen." (*See* CONTEMPT OF COURT.)

One effect of unlicensed printing was to lay authors open to the attacks of literary piracy, and in 1709 the first Copyright Act (8 Anne c. 19) was enacted for their protection. The old power of a secretary of State to issue a warrant, general or special, for the purpose of searching for and seizing the author of a libel, or seizing the libellous papers themselves, was not finally declared illegal until the case of *Entick* v. *Carrington* in 1765 (*St.Tr.* xix. 1030). In 1776 the House of Commons passed a resolution in accordance with this decision. The compulsory stamp duty on newspapers was abandoned in 1855 (18 Vict. c. 27), the duty on paper in 1861 (24 Vict. c. 20), the optional duty on newspapers in 1870 (33 and 34 Vict. c. 38).

A declaration in favour of the liberty of the press is usually a prominent feature in the written constitutions of foreign States, but in England it rests upon a constitutional rather than a legal foundation. (Dicey's *Introduction to the Law of the Constitution*, 7th edition, chap. 6.)

The last relic of the censorship before publication is to be found in the licensing of stage plays. (*See* THEATRES, LAW RELATING TO.) The last relic of the monopoly of printing formerly granted to licensees of the Crown is found in the exclusive right of the king's printer and the universities of Oxford and Cambridge to print the Bible and the Book of Common Prayer, and of the king's printer to print Acts of parliament, statutory rules, and other State documents. This monopoly, so far as the Bible is concerned, extends only to the Authorized Version, and not to any accompanied by annotations or new marginal readings. In the case of *re Red Letter New Testament* (Authorized Version) in 1900, on the application of the queen's printers an order was made by a chancery judge expunging from the register of copyrights of the Stationers' company an entry whereby an American was registered as the owner of the copyright in that book (17 T. L.R. 1). The rights of the king's printers are protected by 8 and 9 Vict. c. 113 and 45 Vict. c. 9; the rights of the printers of the journals of either house of parliament are protected by 8 and 9 Vict. c. 113.

By 32 and 33 Vict. c. 24 the printer of any paper or book for profit is required under penalties to print thereon his name and address or the name of a university press, and is to keep a copy of everything printed, with a few exceptions. Penalties must be sued for within three months, and no proceeding for penalties can be begun unless in the name of the attorney-general or solicitor-general of England or the lord advocate of Scotland.

Under the Copyright Acts a newspaper is a book, and the obligation imposed by the 1842 Act still remains of delivering (without request) to the British Museum a copy of any work published within the United Kingdom, and of delivering (on request) copies for the use of the university libraries at Oxford and Cambridge, the library of the faculty of advocates at Edinburgh, the library of Trinity college, Dublin, and the national library of Wales (1 and 2 Geo. V. c. 46, s. 15; *see* COPYRIGHT).

In the High Court a request by a judge that certain details be not published is equivalent to a command. By the Judicial Proceedings (Regulations of Reports) Act 1926 there is a declaration of the common law as to the offence of publishing indecent matter in reports of judicial proceedings and a special proviso limiting the reports of matrimonial causes. (*See* DIVORCE.) By the Children Act 1906 (8 Edw. VII. c. 67) reporters cannot be excluded from children's courts, subject to any powers that a police magistrate has of hearing proceedings *in camera*, but the normal practice is not to report the names and addresses of child offenders. By the Criminal Justice Act 1925 no photographs or sketches may be taken in court, or, if they are taken contrary to the law, published. Seditions, blasphemous, or obscene words in a newspaper may be punished as treason, treason felony, seditious libel, or misdemeanor. (W. LA.)

United States.—There is no body of law in America which with strict accuracy may be called "the law of the press." Except for a few statutes and peculiar rules of common law, journalists are not singled out for special legal favours or restrictions. Naturally, however, the press comes into more direct and frequent contact with certain branches of law than with others. These branches, touching content and distribution of newspapers, may, for convenience, be grouped under the above title.

The sources of press law are found in the Federal and State Constitutions, statutes and in decisions of Federal and State courts interpreting constitutional and statutory provisions and declaring the common law. Some branches are restrictive, others protective. Nearly all are relatively modern and all are in process of development, chiefly toward enlarged freedom for ethical journalism.

The restrictive laws are those thought necessary by legislatures or courts to serve three purposes: protection of Government and its processes, including judicial action, from violent disruption and unlawfully created disrespect; protection of individuals in good name, business reputation and right of privacy; and protection of the morals of the public and of its right not to be defrauded or deceived.

The chief instances of restriction for governmental protection are the statutes condemning publications constituting contempt of court, sedition (*e.g.*, the war-time Espionage Acts of Congress), criminal anarchy and syndicalism. Acts of Congress and State

statutes generally deal with contempt of court and courts have repeatedly held certain publications to be contemptuous. Federal statutes prohibiting various forms of seditious publications have been common in war time, but ordinarily have been repealed on restoration of peace. Their constitutionality has been upheld with great uniformity. Many State statutes condemn criminal anarchy and syndicalism. The New York Criminal Anarchy statute (Penal Law, Sect. 160–161) is typical. These statutes are directed against advocacy of overthrow of Government and of destruction of property (sabotage) by violence or other unlawful means.

The chief instances of restriction for protection of individuals are the libel law and the prohibition of unauthorized publication of photographs and names of individuals for purposes of advertising or trade. This prohibition is statutory in two States (New York and California) and exists by judicial decision in others. It is destined to become general, if not universal.

Every State has libel law, usually expressed partly in statutes and partly in court decisions declaring common law rules. This is by far the most important phase of press law. It has its origin in the common law and many of its fundamental rules were laid down when the art and practice of printing were in their infancy. Even now the law for the most part is found, not in statutes or codes, but in court decisions. In general, the judicial tendency has been to abandon or relax common law rules thought too harsh for conditions of modern journalism. In the main, at least from the standpoint of importance, the statutes are relaxations of former harsh common law rules; in some instances the legislatures have codified liberal court decisions and in others they have advanced beyond the courts in enlarging the freedom of decent journalism.

Fundamentally, the libel law in the various States is substantially the same, though naturally there are variations in details, some of which are important, and in the application of underlying rules. Published matter is libellous if its natural tendency, in the opinion of a substantial number of right-thinking persons, is to induce an ill opinion of an individual or is to affect injuriously a person's standing in his business, profession or office or is to impugn the management or credit of a corporation in such manner as to be calculated to cause pecuniary loss. Libellous publications may be the subject of civil suits and criminal prosecutions but may not be restrained by injunction.

The generally recognized complete defences are that the published matter was true, that it was a fair and true report of legislative, judicial or other public and official proceedings published without malice, that it was fair comment or criticism concerning a matter of public interest, that it was published in good faith in defence of some attack upon the publisher or that it was published with the consent of the person named. Partial defences—those which mitigate or reduce damages—are also allowed. They consist generally of proof concerning the publisher's good faith and the reasons why he believed his publication to be true or otherwise justifiable.

The chief instances of restriction for the protection of public welfare are the statutes prohibiting publication of obscene matter; advertisements of such matter as lotteries, betting odds and other data useful in gambling; intoxicating liquor, abortifacient drugs and instruments, cures for venereal disease, procuration of divorce; false statements of circulation and false and misleading merchandise advertisements. Federal and some State statutes require that reading matter which is in fact paid advertising shall be plainly marked as advertising. A few States, in varying forms of phraseology, prohibit the publication and sale of newspapers "devoted to" or "principally made up" of stories of bloodshed, lust or crime.

The protective branches of newspaper law consist mainly of constitutional guaranties of freedom of the press, the copyright law and trade-mark law. Comment upon the latter two branches, each of which is a special body of law not peculiar to newspapers, is beyond the scope of this discussion, except to say that newspapers enjoy the same rights and privileges thereunder as do citizens generally.

The U.S. Constitution (1st amendment) provides that Congress shall pass no law abridging the freedom of the press and the State Constitutions, in varying phraseology, declare that citizens may freely speak, write and publish their sentiments on all subjects, being responsible for the abuse of that right, and that no law shall be passed to restrain or abridge the liberty of the press. Controversy concerning the proper interpretation of these guaranties rages endlessly and even now the subject is in doubt. Those favouring a narrow interpretation contend that the guaranties mean merely that there shall be no restraint in advance of publication or prevention of future publication, that Congress and the State legislatures are free to provide for punishment after the event for the publication of any sort of matter that they think objectionable and that the legislative conclusion of objectionableness is not subject to judicial scrutiny. Those favouring a broad construction contend—and sometimes with more emotion than logic—that the guaranties, properly interpreted, prevent any form of legal responsibility for any publications except those which are seditious, obscene or libellous. That contention has been rejected in a number of decisions of appellate courts. The truth lies, it is believed, between the two extremes. These guarantees do not protect a publisher from the consequences of a crime committed by the act of publication. They mean, however, more than that there shall be no restraint of future publications. They imply not only liberty to publish but complete immunity from legal punishment for the publication so long as it is not harmful in its character when tested by such standards as the law affords.

(H. L. Cr.)

The British Empire.—In the British dominions and possessions overseas the press is, generally speaking, as free as in England. In India the press laws are contained in a series of Acts of which the last and most important is No. XIV. of 1922, known as the Press Law Repeal and Amendment Act. The governor-general is given wide powers with regard to preventing a seditious use of newspapers, whether printed in English or in the vernacular, and there are elaborate provisions for the registration of printers and publishers, for the seizure and confiscation of seditious matter and for preventing its importation or circulation, and for the punishment of those responsible for its publication or distribution. Every copy of a newspaper must bear the name of the responsible editor.

Other Countries.—The press law in Austria is contained in the federal law of April 1922, which guarantees the freedom of the press subject to limitations set out in 51 articles. In Hungary the press law of 1914 (Act XIV.) is an elaborate set of regulations containing 64 articles, the first of which says: "It is open to every one to communicate and propagate his ideas by means of the press." Art. 14 of the Argentine Constitution provides that any inhabitant may publish his ideas in the press without any previous censorship. The only restrictions of the liberty of the press are contained in the penal code and social defence law dealing with defamation and other offences. By the Belgian Constitution of 1831 the liberty of the press is declared. In Bulgaria the press law of 1921 deals mainly with questions of responsibility and procedure, press offences being set out in the penal code. By the Constitution of Chile the liberty of the press is guaranteed, subject to ordinary restrictions. In China newspapers are governed by the press law of 1914, which follows the model of most European countries in its general outline, except for the important difference that in theory all leading articles have to be passed before publication by the police. The Czechoslovakian press law of May 1924 consists of 42 articles which amplify previous laws relating to the press passed when this country was part of the Austro-Hungarian empire. In the main the 1924 law deals with questions of procedure and responsibility and does not enact new offences. In Denmark press laws date from 1851, subject to amendments in the general civil penal law of 1866. As one of the new independent post-War States, Finland's press law dates from Jan. 1919.

In France the press is controlled by the law of July 1881, which declares the liberty of the press, subject to the prohibition of abuses. In Germany, by the Constitution of Aug. 1919, Art.

118, "every German has the right, within the limits of the common law, to express his opinion by word of mouth, in writing, in print, or in any other way. A censorship will not be established, but certain regulations will be laid down dealing with cinematograph exhibitions. Legal measures are permissible for the prevention of immoral literature." For the rest the press is subject to the press law of May 1874.

Liberty of the press is provided in the Constitutions of Greece and Holland. In Holland it actually exists as in England, but the troublous political developments in Greece during and since the World War have resulted in a considerable limitation.

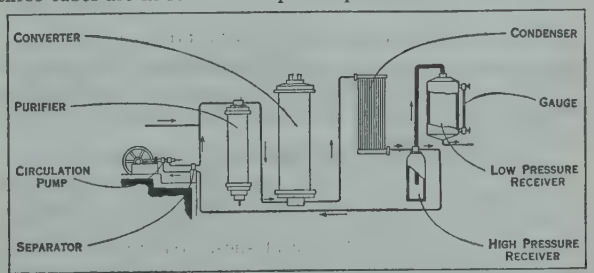
In Italy the press has become under Signor Mussolini's régime almost entirely, on its political side, an exponent of the Fascist idea. Nearly all professional journalists perforce belong to an organization under Government control, and by a decree of July 1924 the responsible editor of a newspaper must be approved by the prefect of the province. A prefect may warn the newspaper editor or manager who publishes false or tendencious news calculated to embarrass the country with foreign Governments, or to damage the national credit, or in any way to disturb public order, and may revoke his recognition of the editor who has been so warned twice in a year. An appeal lies, not to a judicial tribunal, but to the minister of the interior. For breaches of these rules newspapers may be confiscated. In practice the Fascist press laws have, at any rate for the present, done away with the nominal liberty of the press expressed in the royal edict of 1848.

The press law of May 1901 in the main governs the activities of newspapers in Japan, other forms of print being dealt with in an earlier law of 1893. The various press laws under which partitioned Poland lived are being replaced by a uniform law based on the principle of freedom of opinion. In Portugal, Yugoslavia and Rumania there is a theoretical liberty for the press, liable to be waived during not infrequent periods of unrest. In other respects the press is subject to the usual restrictions against abuse of the printed word. In Russia by a decree of 1921 the Government of the Republic of Soviets has practically brought the newspaper press and all printed publications under State control, and there is no independent press. Unauthorized printing results in confiscation and the trial of those responsible. In Spain, since the abolition of parliamentary government, which was superseded by the régime of the Marques de Estella, the press has been in a political sense subject to Government control, but in other respects it is governed by laws passed since 1883 which are more or less in common with the press laws of other Roman Catholic countries. In Norway and Sweden there are voluminous press laws in operation, but they follow the usual order of things, freedom of opinion being allowed. The same applies to Switzerland. (W. La.)

PRESSURE CHEMISTRY. The influence of pressure on chemical transformations has long been recognized, but it is only within the 20th century that high pressures have been applied to industrial chemical processes. Haber's process for the direct synthesis of ammonia from its elements, which has been developed in Germany by the Badische Anilin und Soda Fabrik, has not only solved the problem of the world's supply of fixed nitrogen but has produced a technique in dealing with gases under conditions of high pressure and temperature, which is now being applied in the field of organic chemistry. Bergius's process for the production of oil from coal involves treatment of the latter with hydrogen at high temperatures and pressures. This process, after over 20 years' sustained research, has been placed on a manufacturing basis, and affords a solution of one of the greatest European problems, namely, the creation of an adequate oil supply.

Pressure and Chemical Action.—Le Chatelier's principle states, in effect, that if a system in equilibrium be subjected to a constraint, a change will take place in the system which is in opposition to the constraint. An increase of pressure favours the system formed with a decrease in volume, while a reduction of pressures favours the system formed with an increase in volume. Pressure may consequently be employed in gaseous reactions, which proceed with diminution in volume, to change the equilibrium in favour of the product desired. The attainment of this equilibrium or a close approach to it is brought about by the use of a catalyst, which may be defined as a substance which can accelerate a chemical change without itself undergoing permanent alteration. The development of ammonia synthesis has shown that a catalyst may be specially sensitive to the presence of certain substances which may either inhibit or enhance its activity. For example, the activity of iron as an ammonia catalyst is partially or totally destroyed by the presence of traces of sulphur, selenium, tellurium and other elements which act as poisons. Catalyst masses must consequently be prepared with great care, and the reacting gases need special purification. In contrast to the poisoning action of the elements mentioned above, the presence of a small proportion of certain substances called promoters, as for example the oxides of the alkalis and alkaline earths, greatly enhances the activity of the iron catalyst. Lowering the temperatures of reaction has the same effect on the ammonia equilibrium as raising the pressure. Haber has calculated that if the temperature of reaction could be reduced to 300° C, satisfactory yields of ammonia would result at ordinary pressures. No catalyst is known which will bring about reaction at so low a temperature, therefore the industrial procedure is to obtain a catalyst highly reactive at as low a temperature as possible, and to raise the pressure till adequate yields of ammonia result.

Synthetic Ammonia Processes.—Nitrogen and hydrogen subjected to high temperatures and pressures in the presence of a suitable catalyst unite to form ammonia, in accordance with the equation $N_2+3H_2 \rightleftharpoons 2NH_3$. Variations in the different industrial processes lie principally in the pressures employed, the special form of catalyst, and in the method of preparing the nitrogen hydrogen mixture. The Haber-Bosch, Casale, and Claude processes operate at pressures of about 200, 800 and 900 atmospheres respectively. The first two processes employ circulatory forms of plant (figs. 1 and 2), where the nitrogen-hydrogen mixture is passed over the catalyst at a temperature of 500°–600° C. The partial pressure of ammonia in the gases leaving the converter amounts to about 12 atmospheres in the Haber-Bosch, and 160 atmospheres in the Casale process. Ammonia is removed in the former process by solution in water, and in the latter by condensation at ordinary temperatures. Unchanged gas is circulated by a pump over the catalyst together with fresh gas mixture added to maintain the pressure. A flow-through form of plant is employed in the Claude process. The catalyst is held in a battery of six converter tubes, one of which is shown in fig. 3. In the first of these, which contains the old catalyst, any carbon monoxide in the gas is converted to methane. The next two tubes are arranged in parallel to prevent overheating due to excessive reaction, while the last three tubes are in series. The partial pressure of ammonia in the



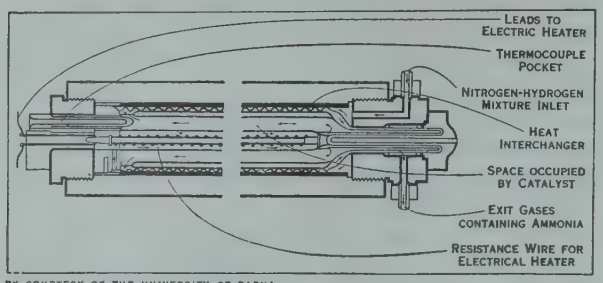
BY COURTESY OF THE UNIVERSITY OF PADUA

FIG. 1.—DIAGRAMMATIC PLAN OF CASALE SYNTHETIC AMMONIA PLANT

gases leaving each converter tube is about 250 atmospheres. Ammonia is removed by simple condensation after each contact with the catalyst. In all, 85% of gas is converted to ammonia. The residual gas after reduction to atmospheric pressure is used for other purposes.

In the three processes provision is made for heat interchange between gas entering and leaving the converter, either inside the converter itself or in a separate heat interchanger, so that the heat of reaction maintains the temperature of the catalyst. Nitrogen and hydrogen are prepared as a mixture in the Haber-

Bosch process from producer gas (a mixture of nitrogen and carbon monoxide) and water gas (a mixture of hydrogen and carbon monoxide). Water gas and producer gas in suitable proportions are passed with steam over an iron oxide catalyst kept at a correct temperature, when nearly all the carbon monoxide reacts with steam to give a mixture of hydrogen and carbon dioxide; the latter gas is removed by solution in water under



BY COURTESY OF THE UNIVERSITY OF PADUA

FIG. 2.—SECTION OF CASALE CONVERTER

high pressure, while any unchanged carbon monoxide is absorbed by a solution of a cuprous salt (*e.g.*, ammoniacal cuprous formate). In the Casale process hydrogen is produced electrolytically, and in the Claude process the gas is obtained from coke-oven gas by a process in which other constituents are removed by liquefaction. In both processes the nitrogen-hydrogen mixture is produced by burning a calculated amount of air in the hydrogen.

Alcohol Synthesis.—G. Patart has shown that methyl alcohol (methanol) is produced by the interaction of carbon monoxide and hydrogen, under conditions of high temperature and pressure, in the presence of zinc oxide. The activity of zinc oxide as a methanol catalyst is increased by the addition of certain acidic oxides (*e.g.*, oxides of chromium, manganese and uranium). A most efficient catalyst is produced by the reduction of a basic zinc chromate ($3ZnO{\cdot}CrO_3$). Two litres of methyl alcohol per hour can be produced for each litre of space occupied by catalyst when a mixture of hydrogen (two parts by volume) and carbon monoxide (one part) is passed under a pressure of 200 atmospheres over the catalyst kept at 400° C, at a rate corresponding to 20,000 litres per hour (measured at N.T.P.) of gas mixture.

Audibert has found that copper prepared by regulated reduction of cuprous or cupric oxide acts as a methanol-forming catalyst; both the activity and stability of this catalyst may be increased by the addition of small amounts of oxides of various metals (zinc, manganese, beryllium or cerium) which act as promoters. A catalyst containing 0·01 atoms of cerium for each atom of copper is stated to be highly reactive at so low a temperature as 300° C.

Experience in high-pressure practice gained through the development of ammonia syntheses enabled the Badische Anilin und Soda Fabrik to place the methanol synthesis on a manufacturing basis, and in 1925 to export 500,000 gallons of synthetic methanol to the United States.

The possible number of reactions that can be effected between a mixture of carbon monoxide and hydrogen is theoretically almost unlimited, and the course of reaction is largely dependent on the nature of catalyst employed. A catalyst made from zinc chromate leads to the production of substantially pure methanol from a mixture of carbon monoxide and hydrogen under conditions detailed above, but if the catalyst is made alkaline by the addition of, *e.g.*, potassium carbonate or chromate, the product contains beside methanol, *n*-propyl, *iso*butyl and higher alcohols, together with acids, free or combined as esters. The proportion of the various constituents depends on the rate of passage of the carbon monoxide-hydrogen mixture over the catalyst.

Addition of metallic cobalt to zinc chromate produces a catalyst which brings about the formation of methyl, ethyl, *n*-propyl, *iso*butyl, *n*-butyl and higher primary alcohols; small amounts of aldehydes can also be isolated, but the product contains no acids free or combined.

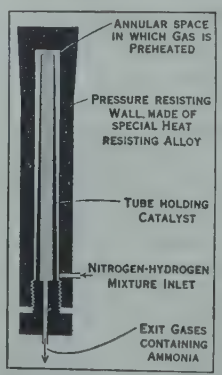
Production of Oil from Coal.—Bergius's process for conversion of coal into oil consists in heating powdered coal, preferably in a liquid medium, to a temperature of 450°–470° C, in the presence of hydrogen under a pressure of about 250 atmospheres. The introduction of 5% of hydrated ferric oxide (bog-iron ore) assists the process by combining with sulphur contained in the coal; the oxide possibly functions also as a catalyst. A large amount of heat is produced by the hydrogenation which may result in rise of temperature and the consequent formation of coke.

The oil-coal mixture has a much better thermal conductivity than powdered coal alone, and it is possible with the assistance of a stirrer to keep the reacting mass within the necessary limits of temperature.

The liquefaction of coal is regarded by Bergius as proceeding in two stages: (1) hydrogen addition, and (2) a splitting up of large molecules into smaller ones, with subsequent further addition of hydrogen. Bergius's liquefaction process is applicable to all types of coal, including lignites, except the anthracites and coals which consist chiefly of fusain. A continuously acting plant is usually employed on the works scale. The coal-oil mixture is forced in at one end of a long, cylindrical iron converter down which it is propelled by a mechanically driven stirrer. Hydrogen is circulated through the converter which is partially immersed in a gas-heated lead bath. The products from 100 parts of bituminous coal are as follows: gas (methane and ethane), 20 parts; oil boiling up to 230° C, 20 parts; oil boiling at 230°–330° C, 10 parts; and oil boiling above 330° C, including pitch, 20 parts. The remaining products are ammonia, 0·5 parts; water, 8 parts; and ash, 10 parts. The oily products consist of members of the aliphatic, aromatic and hydroaromatic series. Compounds of a phenolic character, chiefly cresols, are also included. Motor spirit obtained from the products (about 15%) is very rich in aromatic and hydroaromatic hydrocarbons, and may be blended with petrol to give a mixture with good anti-knocking qualities.

The process of heating materials with hydrogen under pressure is termed berginisation and has been applied to asphalts, coke-oven tars, and heavy distillate oils for the production of light-boiling oil suitable for use as motor spirit.

High-pressure Plant.—Gases used in high-pressure processes are usually stored at atmospheric pressure in ordinary inverted bell-type, water-sealed gas holders. Gas from the holders is then compressed and passed into the high-pressure system as required. Multiple-stage compressors should be specially designed for the particular gas mixture, since gases vary in their deviation from Boyle's law. The design of the compressor should also guard against leakage of gas to atmosphere and the possibility of air being drawn into the plant.


ANNULAR SPACE IN WHICH GAS IS PREHEATED
PRESSURE RESISTING WALL MADE OF SPECIAL HEAT RESISTING ALLOY
TUBE HOLDING CATALYST
NITROGEN-HYDROGEN MIXTURE INLET
EXIT GASES CONTAINING AMMONIA

BY COURTESY OF THE SOCIÉTÉ DE CHIMIE INDUSTRIELLE

FIG. 3.—CLAUDE BOMB TUBE

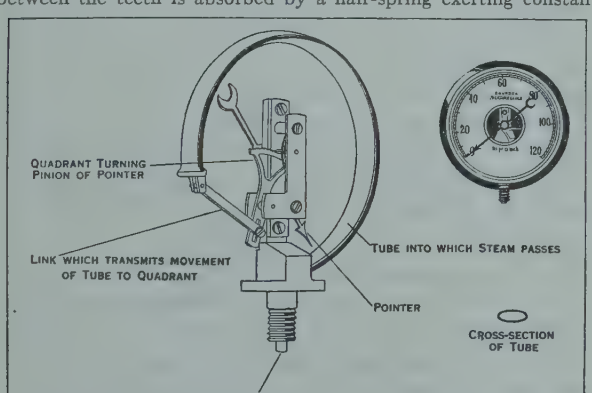
A large factor of safety must be employed in the construction of high-pressure vessels, owing to the possibility of blow holes and other structural faults. Vessels for use at ordinary temperatures are usually constructed of mild steel. When the vessel is to be subjected to both high pressure and high temperature, mild steel can no longer be used since its tensile strength begins to decrease very appreciably at about 300° C. If the reacting gases contain hydrogen, the metal may also suffer serious deterioration in strength owing to the removal of carbon by the action of hydrogen at the elevated temperature. In practice, a complex form of vessel is constructed in which the outer pressure-resisting shell, made of mild steel, is kept cool and away from the action of the hot gases (compare fig. 2); or else some special steel or alloy is used which retains a high tensile strength at the temperature to which it is subjected, and which suffers little deterioration through contact with gases employed in the process. (*See* fig. 3.) Steels containing chromium and nickel have been found to be best suited to this purpose.

The construction of plant for chemical processes, involving the use of gases at high pressures and temperatures, has presented many difficulties, for example the making of pressure-tight enclosures, glands and valves, but the advantages which arise from the reduction in gas volumes and possible efficient heat recovery make such processes in many ways preferable to normal pressure systems.

BIBLIOGRAPHY.—F. Fischer, *Conversion of Coal into Oil* (trans. by R. Lessing) [1925] (includes chapters on hydrogenation of coal and synthetic processes under pressure); R. Taylor, *High Pressure Chemistry* [in the press]; B. Waeser, *Atmospheric Nitrogen Industry* [1926] (includes chapters on Haber-Bosch Synthesis of Ammonia, Production of Nitrogen and Hydrogen, also Bibliography); H. Wölbling, *Die Hydriesung* [Halle, 1926] (Technical Application of Catalytic Hydrogenation, including Fischer's Synthol and Bergius's Processes); Proceedings of the International Conference of Bituminous Coal, Nov. 1926, Carnegie Institute of Technology (includes papers by F. Bergius, F. Fischer and G. Patart). (R. TA.)

PRESSURE GAUGE, a term commonly applied to an instrument for measuring pressure, as distinct from a barometer, a manometer (*qq.v.*), or a gauge employed in vacuum practice. The following article deals with the type of gauge which registers pressure by the distortion of a metal tube or diaphragm, and which may be used to indicate the pressure of steam, gas, ammonia, water, brine, petrol, or oil. The lowest pressure requirements are those for blast pressures, or gas or air, working up to about 2 lb. per sq.in., and the highest the hydraulic gauges up to 12 tons per square inch. For very low pressures a diaphragm arrangement is employed. In the Schaffer gauges a corrugated diaphragm is acted upon by the pressure and its deflection communicates the movement through a link and toothed quadrant to the pinion, which turns the pointer around the gauge dial. Such gauges will withstand rough usage, as on road vehicles and portable engines.

The Bourdon type has a bronze tube of elliptical cross-section bent into circular form. One end is soldered to a central block through which the fluid enters (*see* fig.) and the other end is sealed, and coupled by a link to a pivoted quadrant with teeth meshing with those of a pinion on the pointer spindle. Backlash between the teeth is absorbed by a hair-spring exerting constant


QUADRANT TURNING PINION OF POINTER
LINK WHICH TRANSMITS MOVEMENT OF TUBE TO QUADRANT
TUBE INTO WHICH STEAM PASSES
POINTER
CROSS-SECTION OF TUBE
STEAM INLET

BY COURTESY OF THE BUDENBERG GAUGE CO.

THE BOURDON GAUGE, SHOWING FLATTENED TUBE, WHICH UNCOILS WHEN PRESSURE IS ADMITTED AND AFFECTS THE POSITION OF THE POINTER AROUND THE DIAL

pressure on the pinion. Pressure within the tube tends to change its cross-section from elliptical to circular, and the tube consequently uncoils to a slight degree, so turning the pointer.

In a vacuum gauge the reduction of pressure has an opposite effect, and the mechanism must be arranged in reverse fashion to cause the pointer to move clockwise. In a *compound* gauge, reading for both pressure and vacuum, the latter figures are placed to the left of the pressure figures. For high pressures a steel tube is fitted instead of bronze, being more elastic and less affected by high temperatures. Special construction or some suitable safeguard is necessary in dealing with some gases, such as oxygen, or where corrosive action is set up.

Special types include the *differential* pressure gauge for registering the difference only in pressure at any two points. There are two inlet tubes and two hands, and if the pressures are equal there is no reading on the dial. The *electric alarm* gauge possesses electric contact devices to ring a bell at a definite minimum or maximum pressure. The *electric control* gauge closes a circuit at a definite pressure, and operates a relay in the circuit of an electric motor; *e.g.*, an electrically-driven air-compressor may be started and stopped automatically in accordance with the demands for air. The *self-recording* pressure-gauge traces a permanent record of varying pressures upon a chart. *See* also VACUUM and VACUUM-PUMP.

PRESTEIGN, urban district, Radnorshire, Wales, on the Lugg, which here forms the boundary between Wales and England. Pop. (1938) 1,102. Area, 4.2 sq.mi. It has a G.W.R. station. The village was in the lordship of Moelynaidd until the 14th century, when Bishop David Martin of St. David's (1296–1328) conferred valuable market privileges upon his native place. In 1542 Presteign was named as the meeting-place of the county sessions for Radnorshire in conjunction with New Radnor. It has the fine parish church of St. Andrew, dating chiefly from the 15th century but with traces of Norman work. Presteign is the most easterly spot on the Welsh border; hence the expression "from St. David's to Presteign" to mark the breadth of Wales.

PRESTER JOHN, a fabulous mediaeval Christian monarch of Asia. The history of Prester John no doubt originally gathered round some nucleus of fact, though what that was is extremely difficult to determine. Before Prester John appears upon the scene we find the way prepared for his appearance by a kindred fable, which entwined itself with the legends about him. This is the story of the appearance at Rome (1122), in the pontificate of Calixtus II., of a certain Oriental ecclesiastic, whom one account styles "John, the patriarch of the Indians," and another "an archbishop of India." This ecclesiastic related wonderful stories of the shrine of St. Thomas in India, and of the miracles wrought there by the body of the apostle, including the distribution of the sacramental wafer by his hand.

Nearly a quarter of a century later Prester John appears upon the scene, in the character of a Christian conqueror and potentate who combined the characters of priest and king, and ruled over vast dominions in the Far East. This idea was universal in Europe from about the middle of the 12th century to the end of the 13th or beginning of the 14th. The Asiatic story then died away, but the name remained, and the royal presbyter was now assigned a locus in Ethiopia. Indeed, it is not improbable that from a very early date the title was assigned to the Abyssinian king, though for a time this identification was overshadowed by the prevalence of the Asiatic legend. At the bottom of the double allocation there was, no doubt, that confusion of Ethiopia with India which is as old as Virgil and perhaps older.

The first mention of Prester John occurs in the chronicle of Otto, bishop of Freisingen. This writer states that when at the papal court in 1145 he met with the bishop of Gabala (Jibal in Syria), who related how "not many years before one John, king and priest (*rex et sacerdos*), who dwelt in the extreme Orient beyond Persia and Armenia, and was, with his people, a Christian but a Nestorian, had made war against the brother kings of the Persians and Medes, who were called Samiards (or Sanjards), and captured Ecbatana their capital. After this victory *Presbyter John* —for so he was wont to be styled—advanced to fight for the Church at Jerusalem; but when he arrived at the Tigris and found no means of transport for his army, he turned northward, as he had heard that the river in that quarter was frozen over in wintertime. After halting on its banks for some years in expectation of a frost he was obliged to return home." About 1165, a letter was circulated purporting to be addressed by Prester John to the emperor Manuel. This letter, professing to come from "Presbyter Joannes, by the power and virtue of God and of the Lord Jesus Christ, Lord of Lords," claimed that he was the greatest monarch under heaven, as well as a devout Christian. The letter dealt at length with the wonders of his empire. It was his desire to visit the Holy Sepulchre with a great host, and to subdue the

enemies of the Cross. Seventy-two kings, reigning over as many kingdoms, were his tributaries. His empire extended over the three Indies, including that Farther India, where lay the body of St. Thomas, to the sun-rising, and back again down the slope to the ruins of Babylon and the tower of Babel. In war thirteen great crosses made of gold and jewels were carried in wagons before him as his standards, and each was followed by 10,000 knights and 100,000 footmen. There were no poor in his dominions, no thief or robber, no flatterer or miser, no dissensions, no lies, and no vices. His palace was built after the plan of that which St. Thomas erected for the Indian king Gondopharus. Before it was a marvellous mirror erected on a many-storeyed pedestal; in this speculum he could discern everything that went on throughout his dominions, and detect conspiracies. He was waited on by 7 kings at a time, by 60 dukes and 365 counts; 12 archbishops sat on his right hand, and 20 bishops on his left, besides the patriarch of St. Thomas's the protopope of the Sarmagantians (Samarcand?), and the archprotopope of Susa, where the royal residence was. Should it be asked why, with all this power and splendour, he calls himself merely "presbyter," this is because of his humility, and because it was not fitting for one whose chamberlain was a bishop and king, and whose chief cook was an abbot and king, to be called by such titles as these.

How great was the popularity and diffusion of this letter may be judged in some degree from the fact that Zarncke in his treatise on Prester John gives a list of close on 100 mss. of it. Of these there are 8 in the British Museum, 10 at Vienna, 13 in the great Paris library, 15 at Munich. There are also several renderings in old German verse.

The only other surviving document of the 12th century bearing on this subject is a letter of which ms. copies are preserved in the Cambridge and Paris libraries, and which is also included in mediaeval chronicles. It is a letter purporting to be written by Pope Alexander III. on Sept. 22, 1177, to *carissimo in Christo filio Johanni, illustro et magnifico indorum regi,* of whom he had heard from his physician Philip.

There is no express mention of the title "Prester John" in what seem the more genuine copies of this letter. But the address and a warning against a boastful spirit appear to indicate that the pope supposed himself to be addressing the author of the letter of 1165. In 1221 a rumour came out of the East that a great Christian conqueror was taking the hated Muslims in reverse and sweeping away their power. The name ascribed to the conqueror was David, and some called him the son or the grandson of Prester John of India. The conqueror was in fact the famous Jenghiz Khan: but the delusion was dissipated slowly.

European travellers in Asia looked for a prince to whom the legend of Prester John could be attached. Carpini (1248) makes him the king of the Christians of India the Greater; Rubruquis (1253) gives the title of "King John" to Kushluk, king of the Naimans, and makes him a brother of Ung Khan (d. 1203), the ally of Jenghiz. In Marco Polo's narrative "Unc Khan," alias Prester John, is the lord of the Tatars up to the advent of Jenghiz Khan. This story is repeated by other writers. Both Marco Polo and Friar John of Montecorvino speak of the descendants of Prester John as holding territory in the plain of Kuku-Khotan (about 300 miles north-west of Peking). Friar Odoric gives a circumstantial account of this kingdom, and with this Prester John disappears from Asia to figure in African legend.

It is indeed probable that, however vague may have been the ideas of Pope Alexander III. respecting the geographical position of the potentate whom he addressed from Venice in 1177, the only real person to whom the letter can have been sent was the king of Abyssinia. The "honourable persons of the monarch's kingdom" whom the leech Philip had met with in the East must have been the representatives of some real power, and not of a phantom. It must have been a real king who professed to desire reconciliation with the Catholic Church and the assignation of a church at Rome and of an altar at Jerusalem. Moreover, we know that the Ethiopic Church did long possess a chapel and altar in the Church of the Holy Sepulchre, and, though we have been unable to find travellers' testimony to this older than about 1497, it is quite possible that the appropriation may have originated much earlier. We know from Marco Polo that about a century after the date of Pope Alexander's epistle a mission was sent by the king of Abyssinia to Jerusalem to make offerings on his part at the Church of the Sepulchre; and it is extremely likely that the princes of the "Christian families" who had got possession of the throne of northern Abyssinia should have wished to strengthen themselves by a connection with European Christendom, and to establish relations with Jerusalem, then in Christian hands.

From the 14th century onwards Prester John had found his seat in Abyssinia. It is there that Fra Mauro's great map (1459) presents a fine city with the rubric, "Qui il Preste Janni fa residentia principal." When, nearer the end of the century (1481–1495), King John II. of Portugal was prosecuting inquiries regarding access to India his first object was to open communication with "Prester John of the Indies," who was understood to be a Christian potentate in Africa. And when Vasco da Gama went on his voyage from Mozambique northwards he began to hear of "Preste Joham" as reigning in the interior—or rather, probably, by the light of his preconceptions of the existence of that personage in East Africa he thus interpreted what was told him. More than twenty years later, when the first book on Abyssinia was composed—that of Alvarez—the title designating the king of Abyssinia is "Prester John," or simply "the Preste."

BIBLIOGRAPHY.—For the older aspects of the subject, *see* Ludolf's *Historia Aethiopica* and its *Commentary,* passim. The excellent remarks of M. d'Avezac, comprising a conspectus of almost the whole essence of the subject, are in the *Recueil de voyages et de mémoires* published by the Société de Géographie, iv. 547–564 (Paris, 1839). Two German works of importance which have been used in this article are the interesting and suggestive *Der Presbyter Johannes in Sage und Geschichte,* by Dr. Gustav Oppert (2nd ed., Berlin, 1870), and, most important of all in its learned, careful and critical collection and discussion of all the passages bearing on the subject, *Der Priester Johannes,* by Friedrich Zarncke of Leipzig (1876–79). *See* also Sir H. Yule's *Cathay and the Way Thither,* p. 173 *seq.,* and in *Marco Polo* (2nd ed.), i. 229–233, ii. 539–543.

PRESTIDIGITATION: *see* CONJURING.

PRESTON, municipal, county, and parliamentary borough and port, Lancashire, England, on the river Ribble, 209 mi. N.W. from London by the L.M.S.R. Pop. (1938) 113,200; area 9 sq.mi. The site consists of a ridge rising from the north bank of the river, while the surrounding country, especially to the west about the estuary, is flat. Among the numerous parish churches that of St. John, built in Decorated style in 1855, occupies a site which has carried a church from early times. Among several Roman Catholic churches, that of St. Walpurgis (1854) is a handsome building of Early Decorated character. Of public buildings the most noteworthy is the large town hall, with lofty tower and spire, in Early English style, built in 1867 from designs by Sir Gilbert Scott. The free public library and museum were established by the trustees of E. R. Harris in 1879, and a new building opened in 1893. This contains Dr. Shepherd's library and the Newsham collection of pictures. In addition, the same trustees endowed the Harris institute, a science and art school, in 1849, with £40,000. The grammar school, founded in 1550, was housed in a building of Tudor style in 1841, but was purchased by the corporation in 1860. A blue-coat school was founded in 1701. The Victoria Jubilee technical school was established in 1897 by the Harris trustees. There is also a deaf and dumb school. Preston is well supplied with public parks, there being Avenham park, Miller park, Moor park, the Marsh and the Deepdale grounds with an observatory. In early days Preston, owing to its geographical position, became an important trade centre with an agricultural market. Its importance progressively increased after the advent of the cotton industry, and in addition there are iron and brass foundries, engineering, cotton machinery, chemical and soap works, boiler works and shipbuilding and ship repairing works. Preston became an independent port in 1843, and after that time was progressive in increasing the depth of the seaward channel and building and improving the docks and quays. The main wet dock is 3,240 ft. long and 600 ft. wide. There is a total quayage of 8,500 ft. and the depth of the channel is 19 ft. at ordinary spring tide. A chamber of commerce was formed in 1916. A canal connects Preston with

Lancaster and Kendal. The parliamentary borough returns two members. The county borough was created in 1889.

History.—Preston, otherwise Prestune, was near the Roman station at Walton-le-Dale, and the great Roman road running from Warrington passed through it. It is mentioned in Domesday Book as one of Earl Tostig's possessions which had fallen to Roger of Poictou, and on his defection it was forfeited to the Crown. Henry II. (about 1179) granted the burgesses a charter—the first of 14 royal charters which have been granted to Preston. Elizabeth (1566) granted the town its great charter which ratified and extended all previous grants. Charles II. (1662 and 1685) granted charters, by which an additional weekly market on Wednesday was conceded and a three days' fair, beginning on March 16. The most important industry used to be woollen weaving. Other early industries were glove-making and linen weaving. The first cotton-spinning mill was built in 1777 in Moor Lane, and in 1791 John Horrocks built the Yellow factory. In 1835 there were 40 factories, chiefly spinning, yielding 70,000 lb. of cotton yarn weekly.

A gild existed perhaps in Saxon times, but the grant of a gild merchant dates from Henry II.'s charter, about 1179. The first gild of which there was any record was celebrated in 1328, at which it was decided to hold a gild every 20 years. Up to 1542, however, they do not appear to have been regularly celebrated, but since that year they have been and still are held at intervals of 20 years. A special gild mayor is appointed on each occasion. The first mention of a procession at the gild is in 1500. One of the most important items of business was the enrolling of freemen, and the gild rolls are records of the population. The statement that Preston was burnt in 1322 by the Scots is probably false. The town suffered severely from the Black Death (1349–50), and again from pestilence in the year Nov. 1630 to Nov. 1631. During the Civil War Preston became the Lancashire Royalist headquarters. In February 1643 a Parliamentary force marched from Manchester and successfully assaulted it, but in March the earl of Derby recaptured the town. The Royalists did not garrison it, but after demolishing the greater part of the works left it unfortified. After the battle of Marston Moor Prince Rupert marched through Preston in September 1644 and carried the mayor and bailiffs prisoners to Skipton castle. On Aug. 17, 1648 the Royalist forces under the duke of Hamilton and Gen. Langdale were defeated at Preston by Cromwell. During the Rebellion of 1715 the rebel forces entered Preston Nov. 9, and after proclaiming the chevalier de St. George king, remained here for some days, during which the government forces advanced. The town was assaulted, and on Nov. 14, Gen. Forster surrendered his army to the king's forces. In 1745 Prince Charles Edward marched through on the way south and north. The borough returned two members from 1295 to 1331, then ceased to exercise the privilege till 1529, but since that date (except in 1653) it has always sent two representatives to parliament. In the 18th century Preston had a high reputation as a centre of fashionable society, and earned the epithet still familiarly associated with it, "proud."

See H. Fishwick, *History of the Parish of Preston* (1900); W. F. Fitzgerald, "The Ribble Basin," *Journ., Manchester Geog. Soc.* (1927).

PRESTONPANS, a small burgh and watering place of East Lothian, Scotland, on the Firth of Forth, 9½ mi. E. of Edinburgh by the L.N.E.R. Pop. (est. 1938) 2,669. A mile to the east of the village is the site of the battle of 1745, in which Prince Charles Edward and his highlanders gained a complete victory over the royal forces under Sir John Cope. The salt trade, formerly flourishing, has declined. There are manufactures of firebricks, tiles and pottery, besides brewing and soapmaking, and rich collieries at Tranent, 1 mi. S.E., and elsewhere in the neighbourhood. Contiguous to Prestonpans is a model mining village. Fisheries are less important than formerly. There are harbours at Morrison's haven to the west and at Cockenzie and Port Seton to the northeast, which form one small burgh with a population (est. 1938) of 2,690.

PRESTWICH, SIR JOSEPH (1812–1896), English geologist, was born at Clapham, Surrey, on March 12, 1812. He was educated in Paris, Reading and at University College, London. He was a wine merchant in London, and devoted his leisure more especially to the study of the Thames basin. In 1853 he was elected F.R.S. He published in 1851 *A Geological Inquiry respecting the Water-bearing Strata of the Country around London,* which became a standard authority. With Dr. Hugh Falconer and Sir John Evans, Prestwich examined the implements discovered by Boucher de Perthes in the gravels of the Somme valley; their investigations proved that man existed contemporaneously with the Pleistocene mammalia (*Phil. Trans.* 1861 and 1864). In 1874 Prestwich was appointed to the chair of geology at Oxford. During his professorship he wrote his great work, *Geology: Chemical, Physical and Stratigraphical* (vol. i., 1886; vol. ii., 1888). He died on June 23, 1896, at Shoreham.

See *Life and Letters of Sir Joseph Prestwich,* ed. by his wife (1899).

PRESTWICH, a municipal borough in the Middleton and Prestwich parliamentary division, Lancashire, England, 5 mi. N.W. of Manchester, on the L.M.S.R. Pop. (1938) 32,410. Area 3.8 sq.mi. It has cotton factories and is a suburb of Manchester, with which (and Salford) it is contiguous. It was incorporated 1939.

PRETE, CARLO DEL (1897–1928), Italian aviator, served in World War I as a submarine officer at the age of 17. After the war, he acted for a time as observer for naval seaplanes. In 1926 he obtained his pilot's certificate for the air service, and acted as second pilot to Commander De Pinedo on his Atlantic flight. His flight with Captain Ferrarin on June 2, 1928, lasting 58 hours 37 minutes, was at the time a record of endurance; a month later (July 3–4), again with Captain Ferrarin, he exceeded the longest non-stop flight which had ever been achieved, flying from Rome to Brazil (over 4,500 miles). Del Prete died on Aug. 16, 1928, as the result of an accident while inspecting an aeroplane.

PRETORIA, administrative capital of the Union of South Africa. Pop. (1936) 76,935 Europeans, 3,392 "coloured" (mixed), 45,312 natives, and 2,982 Asiatics. The city is built in a hollow, about the Aapies river, a tributary of the Limpopo. Pretoria is laid out in rectangular blocks. At the centre is Church square, on the south side of which are the Provincial council buildings and other public offices, erected in 1892 in the Renaissance style. On the north side are the law courts and on the west the post office. The Union government building, built 1910–13 on Meintje's kop, cost £1,800,000 and overlooks the city. The lower slopes of the hill are laid out in beautiful terraced gardens. The city has several parks and sports grounds, including Burger park, and the zoological gardens. President Kruger's house was excellently restored. The Voortrekker Memorial hall, seating 650 persons, was opened in 1931. Signal hill rises 400 ft. above the plain, west of Burger park.

There is an Anglican cathedral, several high schools, a normal training college, and the University of Pretoria, which includes an agricultural faculty and an experimental farm. Cement and iron are produced locally.

Pretoria was founded in 1855 and was made the centre of a new district created at the same time. By treaty between the South African Republic (then comprising the districts of Potchefstroom, Rustenburg, Pretoria and Zoutpansberg) and the Republic of Lydenburg, concluded at Pretoria in 1860, the two republics were united and Pretoria was chosen as the capital of the whole State. In September of that year the *Volksraad* held its first meeting in the new capital. Until 1864, however, when the civil war in the Transvaal ended, Potchefstroom remained the virtual capital of the country. From that year the seat of government has always been Pretoria. As revenue flowed in from the gold mines on the Rand, many buildings were erected in the capital, which was linked by railway with Cape Town in 1893 and with Lourenço Marques and Durban in 1895. In May, 1900, Kruger fled from the town, which surrendered in June to Lord Roberts. On May 31, 1902, the articles of peace, whereby the Boer leaders recognized British sovereignty, were signed at Pretoria, and five years later there assembled here the first parliament of the Transvaal, as a self-governing State of the British empire. On the establishment of the Union of South Africa in 1910, Pretoria became its administrative capital.

PRETORIUS, the family name of two of the early leaders of the "Trek" Boers—Andries Wilhelmus Jacobus Pretorius and

Marthinius Wessels Pretorius, father and son.

1. Andries Pretorius (1799–1853), a Dutch farmer of Graaff-Reinet, Cape Colony, and a descendant from one of the earliest Dutch settlers in South Africa, left his home in the Great Trek, and by way of what is now the Orange Free State crossed the Drakensberg into Natal, where he arrived in Nov. 1838, at a time when the emigrants there were without a recognized leader. Pretorius was at once chosen commandant-general and speedily collected a force to avenge the massacre of Piet Retief and his party, who had been treacherously killed by the Zulu king Dingaan the previous February. Pretorius's force was attacked on Dec. 16 ("Dingaan's Day") by over 10,000 Zulus, who were beaten off with a loss of 3,000 men. In Jan. 1840 Pretorius with a commando of 400 burghers helped Mpande in his revolt against his brother Dingaan and was the leader of the Natal Boers in their opposition to the British. In 1842 he besieged the small British garrison at Durban, but retreated to Maritzburg on the arrival of reinforcements under Colonel (subsequently Sir) Josias Cloete and afterwards exerted his influence with the Boers in favour of coming to terms with the British.

He remained in Natal as a British subject, and in 1847 was chosen by the Dutch farmers there to lay before the governor of Cape Colony the grievances under which they laboured owing to the constant immigration of natives, to whom locations were assigned to the detriment of Boer claims. Pretorius went to Grahamstown, where Sir Henry Pottinger (the governor) then was; but Sir Henry refused to see him or receive any communication from him. Pretorius returned to Natal determined to abandon his farm and once more trek beyond the British dominions. With a considerable following he was preparing to cross the Drakensberg when Sir Harry Smith, newly appointed governor of the Cape, reached the emigrants' camp on the Tugela (Jan. 1848). Smith promised the farmers protection from the natives, and persuaded many of the party to remain, but Pretorius departed, and on the proclamation of British sovereignty up to the Vaal fixed his residence in the Magalisberg, north of that river. He was chosen by the burghers living on both banks of the Vaal as their commandant-general.

At the request of the Boers at Winburg Pretorius crossed the Vaal in July and led the anti-British party in their "war of freedom," occupying Bloemfontein on July 20. In August he was defeated at Boomplaats by Smith, and thereupon retreated north of the Vaal, where he became leader of one of the largest of the parties into which the Transvaal Boers were divided, and commandant-general of Potchefstroom and Rustenburg, his principal rival being Commandant-General A. H. Potgieter. In 1851 he was asked by the Boer malcontents in the Orange River Sovereignty and by the Basuto chief Moshesh to come to their aid, and he announced his intention of crossing the Vaal to "restore order" in the sovereignty. His object, however, was rather to obtain from the British an acknowledgement of the independence of the Transvaal Boers. The British cabinet having decided on a policy of abandonment, the proposal of Pretorius was entertained. A reward of £2,000 which had been offered for his apprehension after the Boomplaats fight, was withdrawn.

Pretorius then met the British commissioners at a farm near the Sand river, and concluded the Sand river convention (Jan. 17, 1852) by which the independence of the Transvaal Boers was recognized by Great Britain. Pretorius recrossed the Vaal, and at Rustenburg on March 16 was reconciled to Potgieter, the followers of both leaders approving the convention, though the Potgieter party was not represented at the Sand river.

Pretorius died at his home at Magalisberg on July 23, 1853. In 1855 a new district and a new town were formed out of the Potchefstroom and Rustenburg districts and named Pretoria in honour of the late commandant-general.

2. Marthinius Pretorius (1819–1901), the eldest son of Andries, was appointed in Aug. 1853 to succeed his father as commandant-general of Potchefstroom and Rustenburg, two of the districts into which the Transvaal was then divided. In 1854 he led his burghers against a chief named Makapan, who had murdered a party of 23 Boers, including ten women and children. The natives were blockaded in a great cave in the Zoutpansberg, and about 3,000 were starved to death or shot as they emerged.

Having thus chastised Makapan's clan, Pretorius created a strong central government, and from 1856 onward set to work to form one Boer state to include the Orange River burghers. In Dec. 1856 representatives of the districts of Potchefstroom, Rustenburg and Pretoria met and drew up a constitution, and on Jan. 6, the "South African republic" was formally constituted, Pretorius having been elected president on the previous day. Though the Boers of the Lydenburg, Utrecht and Zoutpansberg districts refused to acknowledge the new republic, Pretorius, with the active co-operation of Paul Kruger (*q.v.*), endeavoured (1857) to unite the Orange Free State and the Transvaal, and a commando crossed the Vaal to support Pretorius. The attempt at coercion failed, but in Dec. 1859 Pretorius was elected president of the Free State. Pretorius had just effected a reconciliation of the Lydenburg Boers with those of the other districts of the Transvaal, and he assumed office at Bloemfontein in Feb. 1860. But the anarchy in the Transvaal effectually weaned the Free State burghers from any thought of immediate amalgamation with their northern neighbours. Pretorius, however, continued to intervene in the affairs of the Transvaal and at length (April 15, 1863) resigned his Free State presidency. Acting as mediator between the various Transvaal parties Pretorius in Jan. 1864 ended the civil strife, and in May following once more became president of the South African republic—now for the first time a united community.

To Pretorius more than any other man was due the welding of the Transvaal Boers into one nation. Pretorius contemplated indefinite expansion of the Transvaal state north, east and west. In April 1868, on the report of gold discoveries at Tati, he issued a proclamation annexing to the Transvaal on the west the whole of Bechuanaland and on the east territory up to and including part of Delagoa bay. Portugal at once protested, and in 1869 its right to the bay was acknowledged by Pretorius, who in the same year was re-elected president. The Boer claim to the whole of Bechuanaland was not pressed by Pretorius in the face of British opposition, but in 1870, when the discovery of diamonds along the lower Vaal had led to the establishment of many diggers' camps, an attempt was made to enforce the claims of the Transvaal to that district.

Pretorius held repeated conferences with the Bechuana chiefs, but failed to persuade them to join the Transvaal to "save" their territory from the British. Finally, without consulting his colleagues, he agreed to refer the question of the boundary to the arbitration of R. W. Keate, then lieutenant-governor of Natal. The award, given on Oct. 17, 1871, was against the Boer claims. Pretorius loyally accepted the decision, but it aroused a storm of indignation in the Transvaal. The Volksraad refused to ratify the award and thereupon Pretorius resigned the presidency (Nov. 1871).

Pretorius then temporarily retired from politics, but after the first annexation of the state by Great Britain he acted (1878) as chairman of the committee of Boer leaders who were seeking the restoration of their independence. He was arrested in Jan. 1880 by order of Sir Garnet Wolseley on a charge of treason. (*See* the Blue Book [C. 2584] of 1880 for details of this charge.) He was admitted to bail, and shortly afterwards urged by Wolseley to accept a seat, which he declined, on the executive council. In December of the same year he was appointed, with Paul Kruger and P. Joubert, to carry on the government on the part of the insurgent Boers. He was one of the signatories to the Pretoria convention, and acted as a member of the triumvirate until the election of Kruger as president in May 1883. He then withdrew from public life; but lived to see the country re-annexed to Great Britain, dying at Potchefstroom on May 19, 1901. Within four months of his death he had visited Louis Botha and Schalk Burger, on behalf of Lord Kitchener, with the object of ending the war.

For the elder Pretorius *see* G. M. Theal, *Compendium of the History and Geography of South Africa* (3rd ed. 1878), and *History of South Africa*, vol. iv. [1834–54] (1893). For the younger Pretorius *see* vol. v. of the same series.

PRETTY, a word usually applied in the sense of pleasing in appearance, without connoting those qualities which are described as beautiful or handsome. In Old English *praettig* meant tricky, cunning or wily, and is thus used to translate the Latin *sagax, asututus, callidus,* in a vocabulary of about 1000. *Praett* meant a trick, and this word is seen in many forms in Dutch such as the obsolete *prettig,* "sportive," and *part,* "trick."

Unknown after the Old English period, the word came into use in the 15th century, when it was applied to persons considered skilful or clever and things made cleverly or ingeniously. It was used *c.* 1440 in this sense, which is archaic, in *Gesta Romanorum,* a collection of Latin tales and legends: "My son . . . woll with his praty wordis & pleys make me foryete my anger." Also archaic is the 18th-century use of the term as a synonym for a man who is a fop, dandy or affected "swell." The word was extended, especially in Scottish literature, to refer to brave or stout men. In *Waverly* (1814), Sir Walter Scott wrote, ". . . they were pretty men, meaning, not handsome, but stout warlike fellows."

Pretty may mean excellent, agreeable, satisfactory, proper, fine, etc. In his translation of *Boaystuau's Theatrum mundi, the Theatre or the Rule of the World* (1566), John Alday wrote, "There is recited a pretie historie of a noble Romane." Samuel Pepys in his *Diary,* Sept. 1667, remarked, "It is pretty to see how strange everybody looks."

The word is often used ironically; examples are "We drank hard and returned to our employers in a pretty pickle," Benjamin Malkin, translator, *Le Sage's Adventures of Gil Blas of Santillane* (1809); and "A pretty pass things are come to when hussies like this are to be . . . bepitied," William Thackeray's *Miss Tickletoby's Lectures* on English History (1842).

PREVARICATION, a divergence from the truth, equivocation, quibbling, a want of plain-dealing or straightforwardness, especially a deliberate misrepresentation by evasive answers. It is often used as a less offensive synonym for a lie. The Latin *praevaricatio* was specifically applied to the conduct in an action at law in which an advocate (*praevaricator*), in collusion with his opponent, put up a bad case of defense. *Praevaricare* meant literally to walk with the legs very wide apart, to straddle, hence to walk crookedly, to stray from the direct road, *varicus,* straddling, being derived from *varus,* bowlegged, a word which scholars connected etymologically with German *quer,* "transverse," "across," and English "queer."

The word was used by Richard Vines before 1655 in *A Treatise on the Institution of the Sacrament of the Lord's Supper:* "I . . . shall clearly without any fraud or prevarication declare my opinion." Edmund Burke in *Two (Four) Letters . . . on the Proposals for Peace with the Regicide Directory of France* (1795–97) wrote, "Fraud and prevarication are servile vices."

PREVENTIVE MEDICINE. The prevention of disease is the true ideal of medicine. Its application is twofold—the preventive medicine of the community, which is generally termed public health or state medicine, and the prevention of disease or its sequelae in the individual.

HISTORICAL DEVELOPMENT

Ancient Origins.—Hippocrates (b. 460 B.C.) classified causes of disease into those concerned with seasons, climates and external conditions and those more personal causes such as irregular food, exercise and habits of the individual. Through the middle ages the principles of preventive medicine were ignored, in spite of the scourges of leprosy and plague. Then with the Renaissance came the new learning on the nature both of health and disease, which revolutionized the whole content of medicine and gave it a fresh centre of gravity and new outlook. Leonardo da Vinci—whose genius suggested some of the great discoveries of modern science—and Andreas Vesalius of Padua were followed in the 17th century by Galileo, William Harvey, Jean Baptiste van Helmont and the experimentalists, and the great practitioners who observed the relation of the seasons, of telluric conditions and of contagion to the incidence of disease. This was followed by new knowledge of anatomy, physiology and pathology.

Practical Needs.—Concurrently with the growth of medical knowledge there was an empirical movement of practical prevention. Long before the days of Hippocrates men had sought to stem the tides of disease which threatened to overwhelm them. In Britain, also, it was the ravages of pestilence in the middle ages —of leprosy from the 12th century, of the Black Death from the 14th, of sweating sickness in the 16th and of cholera and smallpox subsequently—which compelled attention to the conditions which seemed responsible for these scourges. The great monastic orders and some of the historical cities—Rome, Venice and London—provided comfort, refuge and sustenance for the victims, and in 1388 there was passed the first Sanitary act in England, directed to the removal of nuisances. In 1443 came the first plague order recommending quarantine and cleansing; in 1518 the first rough attempts at notification of epidemic disease and isolation of the patient were made; as time passed men began to see that environment was one of the principal factors in the origin and spread of disease.

Experimental Method.—In the 17th century Harvey indicated the true experimental method; 50 years later Thomas Sydenham, another practitioner, laid the basis of epidemiology by his observation of cases, his deduction of laws of prevalence and his suggested hypothesis of "epidemic constitutions."

Bernardino Ramazzini, in Italy, published a treatise on occupational disorders in 1700. Richard Mead, an English practitioner in the first half of the 18th century, published works on poisons, on plague and methods of its prevention, on smallpox, measles and scurvy. John Fothergill described "putrid sore throat" and Haberman, chicken pox. John Huxham of Totnes, an authority on the treatment of fevers, recommended vegetable dietary in cases of scurvy and Devonshire colic. Sir George Baker traced the latter to lead in vats and cider presses. Edward Jenner introduced vaccination. James Lind issued the first treatise on scurvy and the health of seamen. John Howard pointed out the evils of typhus as a "gaol fever." Oliver Wendell Holmes demonstrated the contagiousness of puerperal fever. John Snow published his classic on cholera and William Budd on typhoid fever. P. L. Panum studied the epidemiology of measles in the Faeroe Islands.

Concurrently with these clinical discoveries, advances in related sciences, notably mathematics were occurring. John Graunt initiated the study of mortality statistics in England in the 17th century and William Farr firmly established this basic principle of preventive medicine in the 19th century. Sweden made a modern census in 1748, the U.S. in 1790, England in 1801.

Modern Era.—Louis Pasteur's discovery of the role of living microbes as the cause of infections opened a new era in preventive medicine. Robert Koch demonstrated the tubercle bacillus in 1882; Karl Joseph Eberth the typhoid bacillus in 1880. Soon many other disease-producing organisms were discovered.

In 1893 Theobald Smith established the principle of insect-borne transmission of infections. Shortly afterward Sir Ronald Ross demonstrated the *Anopheles* mosquito as a transmitter of malaria, and the team of Walter Reed, James Carroll, Jesse Lazear and Aristides Agramonte implicated the *Aëdes* mosquito in yellow fever in 1900. William Gorgas promptly employed this discovery for control of yellow fever in the Panama Canal Zone.

Serological tests were developed, such as the Widal reaction of typhoid fever (1896), Wassermann (serological) test for syphilis in 1906. An understanding of the principles of immunity led to the development of active immunization to specific diseases. The discovery and culture of viruses provided new tools for control of virus diseases. Concurrently with these laboratory discoveries epidemiology emerged as a science through the work of Charles Chapin, W. H. Frost, and Major Greenwood.

Parallel advances in treatment opened other doors for prevention—in diphtheria by antitoxin (Emil von Behring) and in syphilis by Salvarsan (Paul Ehrlich). In 1932 the sulfonamide drugs and later a group of antibiotics such as penicillin, streptomycin, aureomycin and chloromycetin afforded new opportunities of prevention and cure.

After 1900 there were many advances in medicine other than those related to infectious diseases. The use of X-ray, radium

and radioactive substances in the diagnosis and treatment of disease (*e.g.*, tuberculosis and cancer) as well as in fundamental physiological research opened new possibilities. A greater understanding of endocrine functions, with the production of prepared extracts such as insulin (Sir Frederick Banting and Charles Best, 1921), thyroid, pituitary extract and hormones, led to preventive measures in certain metabolic diseases. The apparently dramatic effects of ACTH and cortisone offered new hope in the treatment and prevention of sequelae of hitherto recalcitrant conditions.

The role of nutrition in health and disease and the isolation of many essential food factors illustrated the importance to health of adequate diet. Other advances in preventive medicine include psychiatry and psychology in relation to total health, new surgical techniques, new methods of anaesthesia, genetics and the application of statistical methods to medical problems. (*See* BACTERIAL AND INFECTIOUS DISEASES; DIET AND DIETETICS; ENDOCRINOLOGY; EPIDEMIOLOGY; IMMUNITY; MEDICINE; PSYCHIATRY; RADIOLOGY; SERUM THERAPY; VACCINE THERAPY.)

INTERNATIONAL HEALTH

International co-operation in the prevention of the spread of disease had its origin in the dim past. In 1851 France called an international conference to formulate a plan for control of cholera. This and five succeeding conferences produced no definitive results. At the Paris conference of 1903 a proposal for a permanent bureau of health was adopted. By the Rome arrangement four years later the International Office of Public Health was set up in Paris. Under its auspices international sanitary conventions were drafted in 1912–26 and 1933. Each country consistently sought to protect itself against imported disease and to aid its commerce.

The Pan American Sanitary bureau was established in 1902 sponsored by all 21 American republics. The bureau received and relayed epidemiologic information, provided technical assistance and sponsored research co-operation and fellowships.

The Health section of the League of Nations, established in 1923, acted to halt epidemics, established international standards for biologics, sponsored studies on cancer, leprosy, syphilis, nutrition, malaria and rural hygiene and assisted in the reorganization of some national health departments. The World Health organization, established in 1946, assumed the functions of the International Office of Public Health and of the Health section of the League of Nations. The Pan American Sanitary bureau became a regional office of WHO in 1949. (*See* HYGIENE; PUBLIC HEALTH.)

THE UNITED STATES

Preventive medicine in early America was concerned with epidemics, primitive sanitary conditions and the over-all problem of enough competent doctors to care for a population rapidly conquering a vast continent. Urban centres were plagued by contaminated water supplies, sewage and filth. Epidemics of exotic diseases such as cholera, yellow fever, malaria and typhus fever entered the country and spread widely. Typhoid fever and dysentery took a heavy toll. Emergency local regulations and boards of health were set up for epidemic control but lapsed when danger passed.

Lemuel Shattuck, in his "Report of the Sanitary Commission of Massachusetts" in 1850, charted a course of action in a remarkable document virtually unrecognized for two decades. C.-E. A. Winslow in 1948 said of it, "I know of no single document in the history of that science quite so remarkable in its clarity and completeness and in its vision of the future."

Prompted by recurring epidemics, advances in medical science and a growing social consciousness, city health boards were created in Baltimore (1798), Charleston, S.C. (1815), Philadelphia (1818), and elsewhere. As a result of the growing need for greater co-ordination, state boards of health were formed, Massachusetts being the first (1869). By 1919 each state had an organized department of health and the number of full-time local departments continually increased after 1914. Yet, by mid-20th century more than a third of the nation's population lived in areas without such basic full-time health services.

Concerned initially with such matters as sanitation, nuisances, acute communicable disease control, state and local health services by mid-century embraced also improved nutrition, maternal and child health services, mental hygiene, treatment of tuberculosis and the venereal diseases, control of cancer, cardiovascular and other chronic diseases. Knowledge from the biological and social sciences made it possible for medicine to shift its emphasis from cure and alleviation of illness to prevention.

Federal Program.—Prior to the creation of local and state boards of health, the congress in 1798 passed an act for the care of seamen of the merchant marine. Under its provisions, physicians were appointed in each port to furnish medical care, 20 cents being deducted from monthly wages to finance the program. Thus was initiated the earliest compulsory medical insurance in the U.S. and the basis laid for the far-flung activities of the public health service 150 years later. In 1878 authority was granted to investigate the origins and causes of epidemic diseases. In 1901 the Hygienic laboratory was established and in 1912 the title of the "United States public health service" was conferred.

The federal government assumed increased responsibility for national health in 1935 with the passage of the Social Security act which authorized a national program of grants-in-aid to states and training of health personnel. The National Cancer act, 1937, and the Venereal Disease Control act, 1938, the Mental Health act of 1946, the Hospital Survey and Construction act of the same year and a greatly expanded program of research grants have broadened the preventive concept. In 1939 the Social Security board, public health service, children's bureau, office of education, Food and Drug administration and related services were brought together under the new Federal Security agency.

Over many years, many bills have been introduced into the congress to provide a system of national medical insurance. None have been passed and opinion has been sharply divided regarding each of the diverse proposals.

Voluntary Health Agencies.—Voluntary agencies in the U.S. have played a leading role as pioneers in health promotion. They are concerned with the prevention of specific diseases (*e.g.*, tuberculosis, poliomyelitis); with disorders of specific organs (*e.g.*, eyes, heart); with health of specific groups (*e.g.*, children, mothers). They depend entirely on private contributions for their existence and range from national to local in extent. Examples are the National Tuberculosis association, American Heart association and Commission on Chronic Illness.

Other types of nongovernmental organizations which have contributed greatly to the growth of preventive medicine are: (1) foundations financed by private philanthropy such as the Rockefeller foundation, Commonwealth fund, Milbank Memorial fund and many others; (2) professional associations such as the American Public Health association; and (3) industries and insurance companies and labour unions.

The inability of most families to pay the cost of prolonged medical care has resulted in the formation of many voluntary, nonprofit, prepayment medical or hospital insurance plans to meet this unpredictable risk. The insurance principle in relation to social problems of the poor was advocated as long ago as 1697 by Daniel Defoe, yet in the U.S. prepayment of sickness costs has been recent and on a nongovernmental basis. Labour contracts with employers increasingly include sickness insurance provisions.

Schools.—Preventive medicine in the United States has been stimulated by special schools for public health education. The Rockefeller foundation financed schools at Johns Hopkins university, Baltimore, 1916; Harvard university, 1922; the University of Toronto, Ont., 1925; and has aided others at the University of Michigan, Ann Arbor, the University of California, Berkeley, and elsewhere. In 1950, 11 graduate schools of public health were accredited by the American Public Health association (California, Columbia, Harvard, Johns Hopkins, Michigan, the University of Minnesota, Minneapolis, the University of North Carolina, Chapel Hill, the University of Pittsburgh, Pa., Toronto, Tulane university, New Orleans, and Yale). The A.P.H.A. also has set up qualifications for various types of public health personnel including ac-

creditation by a specialty board for physicians especially skilled in preventive medicine and public health.

BRITISH PRACTICE

Legislative Action.—The applications of state medicine, in the 19th century, found their inspiration in England in two sources, the recurrent outbreaks of cholera and consequent commissions of inquiry, and popular demand for reform, which was realized after each of the four extensions of the franchise (1832–1918). Understandable alarm caused by ravages of cholera in 1831 led to the first steps in administrative sanitary reform; in 1849 there was a second visitation of cholera and in 1854 a third.

Concurrently with and following upon these epidemics there were various commissions of investigation. In 1838–39 the Poor Law commissioners drew attention to the prevalence of epidemic disease and its relation to poverty. The reports by Neil Arnott, Sir James Kay-Shuttleworth, Southwood Smith and Sir Edwin Chadwick were the predecessors of another famous series of investigations in 1859–65 by Edward Greenhow and his colleagues under the privy council into epidemic diarrhoea, pulmonary disease, infant mortality and ague; also into adequate food supply, sufficient house accommodation, healthful physical surroundings and wholesome industrial circumstances. They led the way to the new application of medicine for the removal of nuisances, the prevention of contagion and infection and industrial hygiene and welfare.

In 1843 Sir Robert Peel, at the instigation of Chadwick, advised appointing a royal commission to inquire into the outbreaks of disease in large towns and the best means of improving the public health, the report of which led to the passage of the comprehensive sanitary measure in 1848, the establishment of the general board of health and the appointment of medical officers of health. In 1869 the Royal Sanitary commission was appointed; on it sat Sir Thomas Watson, Sir James Paget, Sir Henry Acland, Sir Robert Christison and William Stokes, and before it Sir John Simon, Budd and Farr gave evidence. Speaking broadly, the 1843 commission found the existence of a serious national evil of insanitation and ill-health and recommended a legislative remedy, whereas the 1869 commission found that the remedy had proved ineffective and recommended that "the present fragmentary and confused sanitary legislation should be consolidated." They proposed for the first time a ministry of health; the case miscarried; the local government board was created in 1871.

Registration of Sickness and Death.—Although bills of mortality were published in London as early as the reign of Queen Elizabeth I it was not until the Births, Marriages, and Deaths Registration act of 1836 that any reasonably accurate measure of mortality was obtained. William Farr, the first registrar-general, established an efficient office of vital statistics, including in 1860 occupational mortality and morbidity analyses.

In 1889 the Infectious Disease Notification act was passed applying only to a limited number of diseases. Others have been added, such as tuberculosis in 1912. The Notification of Births act of 1907, made compulsory in 1915, required notice to the local health authority within 36 hours following birth, opening the way for more efficient maternal and infant care.

Public Health Act, 1875.—This act emerged from the labours of a royal commission. It led during 20 years to laws designed to prevent river pollution, to protect water supplies, to improve housing and isolation hospitals and to notification and prevention of infectious diseases.

Sir Robert Peel's commission in 1845 had recommended that each local governing body should have a medical officer "to ascertain the true causes of disease and death, more especially of epidemics increasing the rates of mortality, and the circumstances which . . . injuriously affect the public health." In the period 1845–75 the Vaccination acts and the elementary Education act (1870) also should be recorded.

After 1900.—In the period 1900–24 the sanitary environment improved. It must always remain a foundation of preventive medicine, and in various new departures dependent upon the principles established by the growth of medical knowledge. Typical of this era was the progress in personal hygiene as distinct from environmental hygiene. Its centre is the person rather than the premises.

In 1909 a royal commission appointed to inquire into the "Laws relating to the Relief of Poor Persons within the United Kingdom" presented majority and minority reports. The latter, signed by George Lansbury, Frances Chandler, Russell Wakefield and Beatrice Webb, contained the significant findings of this commission, with suggestions adopted almost in their entirety in 1929.

The school medical service was organized in 1907 and the National Insurance act, passed in 1911, provided a system of insurance against ill-health for a large portion of the working population, although not for dependents. The act also allowed for the use of some of the funds for medical research, and the Medical Research committee was established. In 1920 it was reconstituted as the Medical Research council under the privy council.

In 1919 a comprehensive ministry of health was entrusted with the Health and Poor law powers and duties of the local government board, duties of the Insurance commission and supervision under the Midwives act, among others. The Local Government act of 1929 produced further changes in preventive medicine. The Poor law boards of guardians were abolished, health policy was separated from "pauperism," local authorities were authorized to provide general hospitals for the sick and co-operation with voluntary hospitals was encouraged. The Public Health act (1936), which incorporated, revised or repealed certain statutes relating to public health, greatly simplified administration.

Concurrently with these developments advances were made in industrial hygiene, commencing with the Factory act of 1878. In 1898 T. M. Legge, afterward Sir Thomas Legge, the first medical inspector of factories, pioneered in the study of occupational risks in health and in preventive legislation.

In relation to mental health, the Lunacy act of 1890 was the basis of the modern attitude. A royal commission report in 1926 resulted in the Mental Treatment act, 1930, which provided for the care of mentally ill and also for voluntary care in public mental hospitals.

The relationship of preventive medicine to all the social sciences as well as to the medical sciences emerged during this early period of the 20th century. The war period of 1939–45 further emphasized the need of closer integration of all preventive medical and social services. The Beveridge report of 1942 urged full employment, family allowances and comprehensive health services as fundamental for security of the individual and the family. With this came the concept of medical care for all as a right. In 1946 the National Health Service act was passed and came into force in 1948. This act unified the health services providing hospital and specialist services, services furnished by local health authorities, general medical, dental, ophthalmic and pharmaceutical services, bacteriological and blood transfusion service as well as research. These were made available to all persons at the time of need. Other acts of importance to health are the Education act, 1944; Family Allowances act, 1945; National Insurance act, 1946; National Insurance (Industrial Injuries) act, 1946; National Assistance act, 1948; Children act, 1948; and the Housing act, 1949. These acts have resulted both from a broad concept of the role of preventive medicine and from the need to consider all aspects of the environment in relation to health.

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PRÉVEZA, or PREVESA, seaport, southern Epirus, in Greece; at the entrance to the Gulf of Arta, an inlet of the Ionian sea. Pop. (1928, last census before World War II) 8,659. The town is surrounded by dense olive groves. The harbour is small, and closed to large vessels by a bar of sand. Préveza exports dairy produce, valonia, hides and wool, olives and olive oil. About 3 mi. N. are the ruins of Nicopolis (*q.v.*).

It was seized by Ali Pasha in 1798 and recovered by Greece in 1912 during the first Balkan War. In April 1941 it was occupied by Italy.

PRÉVOST, ANTOINE FRANÇOIS (1697–1763), French author and novelist, was born at Hesdin, Artois, on April 1, 1697. He was educated at the Jesuit school of Hesdin, and in 1713 became a novice of the order in Paris, pursuing his studies at the same time at the college of La Flèche. At the end of 1716 he left the Jesuits to join the army, but he soon tired of life in barracks, and returned to Paris in 1719 with the idea, apparently, of resuming his novitiate. He is said to have travelled in Holland about this time; in any case, however, he returned to the army, this time with a commission. He joined in 1719–20 the learned community of the Benedictines of St. Maur, with whom he found refuge, he himself says, after the unlucky termination of a love affair. He took the vows at Jumièges in 1721 after a year's novitiate, and received in 1726 priest's orders at St. Germer de Flaix. He resided for seven years in various houses of the order, teaching, preaching and studying. In 1728 he was at the abbey of St. Germain-des-Prés, Paris, where he was engaged on the *Gallia christiana*, the learned work undertaken by the monks in continuation of the works of Denys de Sainte-Marthe, who had been a member of their order. His restless spirit made him seek from the Pope a transfer to the easier rule of Cluny; but without waiting for the brief, he left the abbey without leave (1728), and, learning that his superiors had obtained a *lettre de cachet* against him, fled to England.

In London he acquired considerable knowledge of English history and literature, traceable throughout his writings, and he has left an interesting account of English life in his famous memoirs. Before leaving the Benedictines Prévost had begun his most famous romance, *Mémoires et aventures d'un homme de qualité qui s'est retiré du monde*, the first four volumes of which were published in Paris in 1728, and two years later at Amsterdam. In 1729 he left England for Holland, where he began to publish (Utrecht, 1730) a romance, the material of which, at least, had been gathered in London—*Le Philosophe anglois, ou Histoire de Monsieur Cleveland, fils naturel de Cromwell, écrite par lui-mesme, et traduite de l'anglois* (Paris 1731–39, 8 vols., but most of the existing sets are partly Paris and partly Utrecht). Meanwhile during his residence at the Hague, he translated the *Historia* of De Thou, and, relying on the popularity of his first book, published at Amsterdam a *Suite* in three volumes, forming volumes v, vi and vii of the original *Mémoires et aventures d'un homme de qualité*. The seventh volume contained the famous *Manon Lescaut*, separately published in Paris in 1731 as *Les Aventures du chevalier des Grieux et de Manon Lescaut, par Monsieur D. . . .* The book was eagerly read, chiefly in pirated copies, as it was forbidden in France. In 1733 he left the Hague for London, and Miss M. Robertson gives an entry showing that he was in prison in London in December on a charge of fraud.

In the autumn of 1734 Prévost was reconciled with the Benedictines and returning to France, passed through a new, though brief, novitiate. In 1735 he was dispensed from residence in a monastery by becoming almoner to the Prince de Conti, and in 1754 obtained the priory of St. Georges de Gesnes. He continued to produce novels and translations from the English and with the exception of a brief exile (1741–1742) spent in Brussels and Frankfort, he resided for the most part at Chantilly until his death on Dec. 23, 1763.

For the bibliography of Prévost's works, which presents many complications, and for documentary evidence of the facts of his life *see* H. Harrisse, *L'Abbé Prévost* (1896); also a thesis (1898) by V. Schroeder. A critical edition by M. Robertson of the 5th vol. of the *Mémoires et Aventures* dealing with Prévost's adventures in London, was published in 1927.

PRÉVOST, EUGENE MARCEL (1862–1941), French novelist, was born in Paris on May 1, 1862. He was educated at Jesuit schools in Bordeaux and Paris, entering the École Polytechnique in 1882. He published a story in the *Clairon* as early as 1881, but for some years after the completion of his studies he applied his technical knowledge to the manufacture of tobacco. He published in succession, *Le Scorpion* (1887), *Chonchette* (1888), *Mademoiselle Jauffre* (1889), *Cousine Laura* (1890), *La Confession d'un amant* (1891), *Lettres de femmes* (1892), *L'Automne d'une femme* (1893), and in 1894 he made a great sensation by an exaggerated study of the results of Parisian education and Parisian society on young girls, *Les Demi-vierges*, which was dramatized and produced with great success at the Gymnase on May 21, 1895. *Le Jardin secret* appeared in 1897; and in 1900 *Les Vierges fortes* and a study of the question of women's education and independence in two novels, *Frédérique* and *Léa*. *L'Heureux ménage* (1901), *Les Lettres à Françoise* (1902), *La Princesse d'Erminge* (1904), *L'Accordeur aveugle* (1905) and *Lettres à Françoise Mariée* (1908) were among his later novels. In 1904 *La Plus faible* was successfully produced at the Comédie Française. In 1909 he was elected to the Academy.

PRIAM, in Greek legend, the last king of Troy (*q.v.*), son of Laomedon. According to Homer (*Iliad*, iii 184) in his youth he fought on the side of the Phrygians against the Amazons. He had fifty sons and twelve daughters, and immense wealth. He was slain by Neoptolemus, son of Achilles, during the sack of Troy.

PRIAPEIA, a collection of poems (all together about 80 in number) in various metres on the subject of Priapus. It was compiled from literary works and inscriptions on images of the god by an unknown editor, who composed the introductory epigram.

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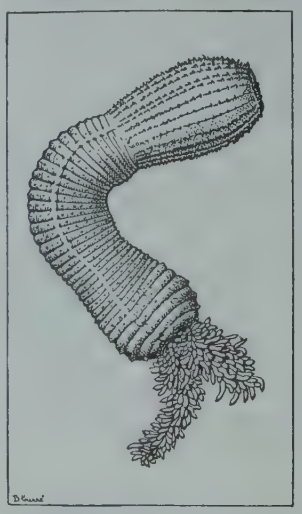
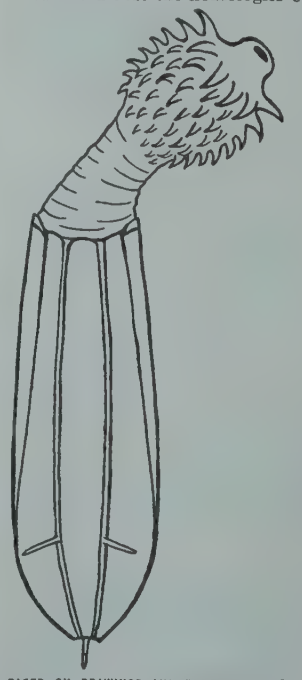


FROM THEEL, "NORTHERN AND ARCTIC INVERTEBRATES"

FIG. 1.—PRIAPULUS BICAUDATUS, A WORM-LIKE MARINE ANIMAL OF THE ARCTIC AND NORTH ATLANTIC SEAS

PRIAPULIDA, a small group of marine worms formerly included in the obsolete phylum Gephyrea. Of uncertain affinities, they are now generally conceded phyletic rank. Resemblances to the gephyrean groups Sipunculida (*q.v.*) and Echiurida (*q.v.*) appear to be of a superficial nature and the same may be said of the theory, advanced by W. Fischer, that they are related to holothurians (a class of the Echinoderma, *q.v.*). According to O. D. Hammersten, whose observations were extended by K. Lang, the larva has features in common with Rotatoria, Kinorhynca (*q.v.*) and Gastrotricha (*q.v.*). Although this hypothesis, which would place the priapuloids among pseudocoelomate phyla, is an attractive one, it must be admitted that the homologies of the body cavity are uncertain and Libbie Hyman, in *The Invertebrates: Protozoa through Ctenophora* (1940), has classified them as schizocoelous coelomates.



BASED ON DRAWINGS AND PHOTOGRAPHS BY LANG, FROM K. FYSIOGR. SÄLLSK, LUND, FÖRH, VOL. 9

FIG. 2.—LORICATE LARVA OF PRIAPULUS CAUDATUS, SHOWING PLATES CONNECTED BY FLEXIBLE MEMBRANES, FEELERS AND FOOT-LIKE CAUDAL APPENDAGE

The body is cylindrical and consists of an annulated but unsegmented trunk and a retractile proboscis. In the genus *Priapulus* there are one or two caudal appendages considered to be gills. The surface of the muscular body wall is provided with rings of spines and papillae, the latter possibly sensory in function. The epidermis secretes a thick cuticle which is shed at intervals during growth. There are 25 rows of spines on the surface of the proboscis converging toward the mouth, which is itself surrounded by several five-toothed rings of chitinous teeth, thus giving rise to the supposed resemblance to echinoderms. The mouth leads into a muscular, eversible pharynx anchored by retractor muscles originating in the trunk. The cuticular lining of the pharynx is provided with numerous small projecting teeth. The mid-gut is straight and communicates with a short hind-gut; the anus is either terminal or opens at the base of the caudal appendages when these are present. The body cavity which, in *Priapulus*, extends into the ramifications of these hollow, gill-like structures, is extensive but its developmental homologies are unknown. There is no vascular system and the coelomic fluid must subserve, in part, a respiratory function.

The nervous system, consisting of a circum-oesophageal ring and ven-

tral nerve cord, retains its primitive connection with the ectoderm. There is no evidence of segmental ganglia. A visceral plexus is connected anteriorly with the nerve ring.

The excretory system is protonephric; tufts of solenocytes discharge into the paired urinogenital ducts which lie suspended in the body cavity and open posteriorly. The sexes are usually separate but hermaphrodite individuals have been recorded; the gonads develop in the walls of blind evaginations of the urinogenital ducts. Fertilization is external. The earliest stages of development were studied by K. Lang in 1939; segmentation differs from that of polychaets and most nearly resembles that of the rotifer *Asplanchna*. Intermediate stages are unknown, but the gastrula is believed to develop, perhaps directly, into the loricate larva. This larva has a spiny, retractile proboscis and the body is protected by chitinous shields; in *Priapulus* there are two pairs of feelers and a bifurcated tail.

There are only two genera: *Priapulus* and *Halicryptus*, the latter without caudal appendages. The animals are of small to medium size and live in burrows in the sand or mud which they ingest; a secretion of the circumanal glands is used to cement the walls of the burrows. Priapuloids are found in the cold seas of both the northern and southern hemispheres, but are confined to relatively shallow coastal waters.

BIBLIOGRAPHY.—A comprehensive review of the group, published in 1931, is given by F. Baltzer in Kukenthal and Krumbach's *Handbuch der Zoologie*, Bd. 2, Hfte. 2. Larval stages are described by K. Lang, *K. Fysiogr. Sällsk. Lund, Förh.*, vol. 9. (G. E. P.)

PRIAPUS (prē-ah'poŏs, anglicized prī-ā'pus), a god of fertility, personification of the fruitfulness of nature, chief deity of Lampsacus on the Hellespont (Dardanelles). He was represented as a man, usually grotesquely ugly, with an enormous and erect sexual organ. Locally, he was thought to be the son of Dionysus and Aphrodite. His cult reached Greece somewhat late in the classical epoch, not becoming really important until Alexandrian times. Later still, it penetrated to Italy. Various legends, all of them late, bring him into connection with the gods of the Greek pantheon, particularly Aphrodite, often represented as his mother, Hermes, Dionysus, and other deities connected with fertility. In Bithynia he is a warlike god, associated with Ares. He absorbed, or was closely identified with a number of minor rustic deities of similar type; *e.g.*, Phales, Conisalus, Tychon, etc.

He is perhaps best known as a god of gardens, where his image was commonly erected, both to give supernatural protection against thieves and for practical use as a scarecrow (see, *e.g.*, Horace, *Sat.*, I., 8, 3, et seq.). But as the phallus is a common luck-bringing object, he was worshipped by persons in need of luck, such as hunters and fishermen, and also was frequently employed to keep off the evil eye (numerous examples are found in and outside of houses at Pompeii).

See Jessen in Roscher's *Lexikon, s.v.*; Herter, *De dis Atticis Priapi similibus* (Bonn, 1926).

PRIBILOF ISLANDS (often called the Fur Seal islands), a group of four islands, part of Alaska, lying in Bering sea in 56° 50′ N. and 170° W., about 180 mi. north of Unalaska and 200 mi. S.W. of Cape Newenham, the nearest point on the mainland. The principal islands are St. Paul (about 35 sq.mi.; 13 mi. long, from north-east to south-west; maximum width about six miles; named from St. Peter and St. Paul's day, on which it was discovered) and St. George (about 27 sq.mi.; 10 mi. long, maximum width, 4 mi.; probably named after Pribilof's ship) about 30 mi. south-east.

The native population in 1950 was 547. The white population act as supervisors. Only agents of the United States or Aleut natives are permitted as residents on the islands. The natives are employed in the sealing industry during the hunting season but in reality they are chiefly dependent on the U.S. government for food, clothes, schools and medical attention. They maintain their own church on each island (the Russian-Greek Church).

The islands are hilly and of volcanic origin, without harbours, and have a mean annual temperature of about 35.7° F, and a rainfall of about 35 inches. There are only two seasons—rainy summers lasting from May to October, and dry winters from November to April. The flora is restricted to ferns, mosses and grasses, though there are a number of creeping willows and small shrubs.

Fur Industry.—The seals which visit the Pribilof Islands from April until November are a distinct species (*Callorhinus ursinus*) with much better fur than that of any other. The valuable herd of seals was rapidly being killed off in 1911, when the then U.S. bureau of fisheries took over control. At that time the herd numbered about 125,000; by 1926 a census showed that it had increased to 761,281, and in 1949 it had increased further to almost 3,837,131.

Besides the fur seal there are blue and white foxes (more on St. George than on St. Paul). The natives trap foxes during the winter, when there are no sealing operations, and take about 1,000 pelts during the season. On St. George Island and the two islets there are great bird rookeries, which are the breeding places of immense numbers of gulls, sea parrots, auks and cormorants.

The islands were first sighted in 1767 by Joan Synd, and were visited in 1786 by Gerasim Pribilof, who discovered the fur seal rookeries for which they became famous. From Russia the islands passed with Alaska to the United States in 1867. From 1870 to 1890 the U.S. government leased the islands to the Alaska Commercial company.

In 1890–1910 the North American Commercial company held the monopoly, but in the meantime the industry shrank considerably because of pelagic sealing.

The Pribilof Islands were taken over by the then U.S. bureau of fisheries in 1911, as mentioned above, and after that time sealing operations were administered directly by its representatives.

PRIBRAM, ALFRED FRANCIS (1859–1942), Austrian historian, was born in London Sept. 1, 1859. He studied in London and Vienna, and in 1894 became professor of modern history at the University of Vienna, being also elected a member of the Viennese Akademie der Wissenschaften. His main works are: *Oesterreich und Brandenburg* (2 vols., 1884–85); *Der Rheinbund* (1888); *Franz von Lisola und die Politik seiner Zeit* (1894); *Das böhmische Commerzcollegium* (1898); *Oest. Staatsverträge* (England) (2 vols., 1907–13); *The Secret Treaties of Austria-Hungary 1879–1914* (English, German and French ed., 1919–23); *Austria-Hungary's Foreign Policy 1908–1918* (1923); *England and the International Policy of the Great European Powers 1879–1914* (1931). Professor Pribram also finished and issued vols. 2 and 3 of Friedjung's ambitious work *Das Zeitalter des Imperialismus*. His *Secret Treaties* threw much light on modern history in 1929.

PŘIBRAM, a town of Bohemia, lies in the upper valley of the Litavka, near the edge of the Brdy Wald highlands. In its vicinity are some of the deepest silver and lead mines in the world, several centuries old, but now zinc, antimony and bismuth are the chief ores mined. There is a home glove industry. Beside the town rises the Heiliger Berg (1,889 ft.) with a church containing a miracle-working image of the Virgin, the principal place of pilgrimage in Bohemia. Pop. (1930) 10,468. Přibram was occupied by Germany in March 1939.

PRICE, RICHARD (1723–1791), English moral and political philosopher, son of a dissenting minister, was born on Feb. 23, 1723, at Tynton, Glamorganshire. He was chaplain and companion to a Mr. Streatfield at Stoke Newington, London, by whose death and that of an uncle in 1756 his circumstances were improved. In 1757 he married Sarah Blundell.

After publishing several sermons, philosophical papers, and the *Appeal to the Public on the Subject of the National Debt* (1771) he turned his attention to the question of the American colonies, and in 1776 he published a pamphlet entitled *Observations on Civil Liberty and the Justice and Policy of the War with America*. A second pamphlet on the war with America, the debts of Great Britain, and kindred topics followed in the spring of 1777. His name thus became identified with the cause of American independence. He was the intimate friend of Franklin; he corresponded with Turgot.

Price was an intimate friend of Priestley, in spite of the fact that they took the most opposite views on morals and metaphysics. In a published correspondence between them (1778) on the subjects of materialism and necessity, Price maintained in opposition to Priestley, the free agency of man and the unity and immateriality of the human soul. The pamphlets on the

American War made Price famous. He preached to crowded congregations, and, when Lord Shelburne acceded to power, was offered the post of private secretary to the premier. In 1786 Mrs. Price died, and the remainder of his life appears to have been clouded by solitude and dejection. The progress of the French Revolution alone cheered him. On April 10, 1791, he died, worn out with suffering and disease. His philosophical importance is in the region of ethics. The *Review of the Principal Questions in Morals* (1757, 3rd ed. revised 1787) is professedly a refutation of Hutcheson, but is rather constructive than polemical. The theory he propounds is closely allied to that of Cudworth, but is interesting mainly in comparison with the subsequent theories of Kant.

Besides the above-mentioned, Price wrote an *Essay on the Population of England* (2nd ed., 1780); two Fast-day Sermons, published respectively in 1779 and 1781; and *Observations on the importance of the American Revolution and the means of rendering it a benefit to the World* (1784). A complete list of his works is given as an appendix to Dr. Priestley's *Funeral Sermon*. His views on the French Revolution are denounced by Burke in his *Reflections on the Revolution in France*. Notices of Price's ethical system occur in Mackintosh's *Progress of Ethical Philosophy*, Jouffroy's *Introduction to Ethics*, Whewell's *History of Moral Philosophy in England;* Bain's *Mental and Moral Sciences*. *See* also ETHICS, HISTORY OF, and T. Fowler's monograph on Shaftesbury and Hutcheson. For Price's life *see* memoir by his nephew, William Morgan.

PRICE, STERLING (1809–1867), American general, was born in Prince Edward county, Virginia, on Sept. 14, 1809. He was educated at Hampden Sidney college and afterwards studied law. In 1830 he removed to Missouri and from 1840 to 1844 served in the Missouri State legislature as speaker of the house of representatives. He was elected a U.S. representative in 1844 but resigned in 1846 to raise and lead the 2nd Missouri Cavalry Regiment in the Mexican War. In 1847 he was commissioned brigadier-general of volunteers and made military governor of Chihuahua. He was governor of Missouri, 1853–57, and State bank commissioner, 1857–61. In 1861 he was appointed major-general of the State militia. Upon the outbreak of the Civil War Price gathered 9,000 Confederate troops at Carthage, Mo., and defeated a small force of Union troops under Franz Sigel. Joined by other troops from Arkansas, Price fought the battle of Wilson's Creek, defeating the Union forces under Gen. Lyons. In the battle of Lexington, shortly afterward, Price captured over 3,000 Union troops, but he was forced to retreat before Gen. Frémont. In March 1862, he was commissioned major-general in the Confederate forces. He commanded under Van Dorn at the battle of Pea Ridge, Ark., on March 7, 1862, and in several engagements around Corinth, Miss. On July 4, 1863, he fought a sharp battle at Helena, Ark., and later prevented Steele's advance to the Red river. In Sept. 1864 he invaded Missouri and advanced to the environs of both St. Louis and Jefferson City, but was repulsed in his attacks at these places. After the war Price went to Mexico in the interest of a colonization project but he returned to Missouri and died at St. Louis on Sept. 29, 1867.

PRICE, THOMAS (1852–1909), Australian statesman, was born at Brymbo, North Wales, on Jan. 19, 1852. He was educated at a penny school in Liverpool, and became a stonecutter. He went to Australia for his health in 1883, where after a time he again found employment as a stonecutter, working on the parliament buildings in Adelaide. He was secretary for two years (1891–93) of the Masons' and Bricklayers' Society of South Australia, and then obtained a seat as Labour member in the House of Assembly. In 1900 he was made secretary of the Labour Party, and in 1901 became its parliamentary leader. He held office as prime minister of South Australia from 1905 until his death on May 31, 1909, at Hawthorn, near Adelaide.

PRICE. What prices are and what price, as a general conception, means would seem to be obvious enough. Yet economists, dealing with the relations of prices to different forms of economic activity and with their own interrelations find that they must take pains if they are to keep their conceptions of price clearly defined and consistent. Thus one may speak of the whole amount of money paid for a quantum of goods as their price, or—if the goods are of a homogeneous or standardized kind, sold by measure, weight, or tale—the amount of money given for each unit of the goods may be regarded as the price. Alternatively, price may be defined, not as a quantity of money but as a ratio between a quantity of money and a quantity of goods. This is generally the more useful conception, but the prices of unique goods, such as works of art, cannot be said to be ratios of quantities. The price ratio is usually stated as so many monetary units (shillings, pounds, dollars) per unit of commodity (ton, yard, bushel). In some markets, however, the ratio is expressed inversely, as so many ounces or yards per shilling, pound, or dollar. This would be a negligible difference if it were not that, as the makers of index numbers have found, where prices or percentage changes in prices are averaged or otherwise combined, precautions must be taken if the results are not to be affected by the particular form in which the price ratios are expressed.

A distinction may also be made between the conceptions of price as a ratio of quantities and as a ratio of values. If ten units of money are required to purchase one unit of a commodity, it may be inferred that a unit of the commodity is ten times as valuable as a unit of money and that the price ratio merely gives expression to that fact. That price is "value expressed in terms of money" is a standard definition. This should not be taken to mean that the values of goods are determined independently of or prior to the determination of their prices, or that the values of goods and of money are determined separately. The factors which determine the values both of goods and of money operate through the processes of exchange, and the values which are thus determined appear in the guise of money prices. It is probable, indeed, that the abstract notion of exchange value is nothing more than a generalization of the simpler idea of price. When we say that price is a ratio of values or that price is value expressed in terms of money, we logically imply, not that value is antecedent to price, but either that in respect of each particular transaction the limits within which the ratio of exchange can vary are established by the general state of the market, or that in analysing the factors which determine the price of any one commodity, the value or general purchasing power of money, may often, without too large an error, be assumed to be constant. The conception of the value of money, in turn, rests upon nothing more tangible than a broad view of all the various prices of different goods and services, but it is nevertheless a useful conception.

The Problems of Price.—The economic theory of price has two principal divisions. One division has to do with the interrelations of the prices of different goods and services, and with the way in which changes in production, consumption, and trade operate directly upon some prices and indirectly upon others. This division of price theory includes that important part of economics sometimes called the theory of value and distribution (or sometimes simply the theory of price-making) and also parts of other fields, such as the theory of international trade. It is concerned both with the tendencies which continually make for a coherent and consistent system of prices and with the subversive forces which make continuously for change. The other division of the theory of prices has to do with the causes of general movements of prices to a higher or lower level—movement which may continue gradually through a long period of years, but which may be broken by shorter movements, convulsive or cyclical in nature. The study of the long-continued general trends of price, and, in considerable measure, of their shorter movements as well, is commonly made a part of the general theory of money. The reason is not that general changes of prices are always attributable to the action of monetary factors alone, but that they are reflected in and in fact are changes of the value of money. They can be studied most conveniently and effectively by enquiring into the changing relations between the supply of money and credit and the volume of production and trade. In recent years especial attention has been given to what might be called the distortions of the whole interrelated structure of prices which accompany changes in their general level. The movements of certain classes of prices, for example, generally lag behind the movements of other classes of prices in a more or less systematic way.

Commodity prices are not the only prices with which economists

are concerned. Securities such as bonds or debentures, stocks or shares and bills or notes, have their prices. Railway rates are prices. Foreign exchange rates express the price of current funds in one market in terms of current funds in another market. Wages, of course, may be regarded as the price of labour, rent as the price of the use of land or of other durable goods, and interest as the price of advances of money. Profits, however, are not prices, for they are not proportioned in any definite way to the amounts of goods or services supplied, but are contingent upon the success of particular undertakings. Nor are taxes prices, for the governmental services for which taxes pay are diffused, and not apportioned to different taxpayers in accordance with their respective contributions. Not even the fees which are paid to Government offices for licences or for particular services are in all respects like prices, for the amount of the fee is usually proportioned very loosely, if at all, either to the value of the service to the recipient or to its cost to the Government. But the charges which Governments make for supplying such things as water, gas, electricity and transport may be governed more or less completely, according to the circumstances of the particular case, by the principles in accordance with which prices are determined.

Equilibrium Price.—This is a price at which supply and demand are equal. A distinction has to be made between a temporary equilibrium, such as would express a balancing of the immediate factors which are operative in the market at any given time, and such an equilibrium as would be reached eventually if the particular factors now known to be at work could have their full effects. Equilibrium, then, is always relative to time. All economic equilibria are unstable, but it is convenient in analysis to take separate account of the factors which, if they were neither impeded nor deflected, might finally lead to a stable equilibrium. Market price is the price which will be found in a given market at a given time. It may be regarded as the limiting form of short-time or temporary equilibrium price. Normal price is a price just high enough to cover the expenses of production, including whatever profits are necessary to induce men to undertake the risks of productive enterprise. Because some firms produce at smaller expense than others, because the expense per unit of production often varies, directly or inversely, with the volume of output, and because of the difference, at any given time, between the average expense incurred per unit of product in a given establishment and the expense of producing an additional unit, the conception of normal price is attended with serious, though not altogether insuperable difficulties.

Competitive Price.—This is the price which results from the activities of many buyers and sellers, each of whom can affect the outcome only by buying or selling larger or smaller quantities according as the price is at one point or another. Monopoly price is a price fixed with a view to his or their own advantage by a single (exclusive) seller or buyer, or by a combination of sellers or buyers acting as a unit. Class price (or differential or discriminatory price) is possible only when a monopolist seller is able to deal separately with different classes of buyers or to manage in some other way to sell his goods in what are virtually separate markets. A speculative price is a present price which is influenced by estimates of what the price of the same commodity or security will be in the future. A contract price, or what is sometimes called in speculative markets a "future," is the present price for an exchange which is to be completed by delivery or by taking delivery in the future. Mint price is the price of gold in terms of money at a Government's mint or at a bank which acts as agent for the mint. Gold price is the rather misleading name sometimes given to the result obtained by dividing a price which is quoted in terms of some depreciated paper currency by the price, in terms of the same currency, either of gold or of funds payable in some other country where a gold monetary standard is at the time effective.

Demand Price.—This is the price at which some specified quantity of a given commodity will find purchasers. A schedule of demand prices or demand schedule, exhibits the general relation between the price of a commodity and the amount of it which will be purchased. Supply price, similarly, is the price at which a specified quantity of a given commodity will be offered in the market. The form of the supply schedule depends upon the conditions under which the particular commodity is produced and also upon the period of time which is taken into account. Thus a sudden general increase in demand (in the sense of a general upward movement of a schedule of demand prices) would have the effect of increasing the price at which a specified quantum of a given commodity would be offered for sale. But if the commodity is produced under conditions of increasing returns (*i.e.*, if the output can be increased without a proportionate increase of costs), an increase of demand, continued over a period of years, will have an opposite effect upon its supply price. Indeed, the gradual lowering of the supply prices of commodities produced under conditions of increasing returns need not wait upon a general increase of demand. It is necessary only that demand should be elastic, *i.e.*, that the demand price of successively larger quantities should not fall off too rapidly. It follows that when an adequate period of time is taken into account, a schedule of supply prices may show that larger quantities will be supplied at lower instead of higher prices. A corresponding schedule of supply prices for a commodity produced under conditions of diminishing returns (*i.e.*, with increased output procurable only at a more than proportionate increase of costs) would, of course, like a schedule of short-period or "instantaneous" supply prices, show higher prices associated with larger quantums of supply. (*See* also ECONOMICS, SUPPLY AND DEMAND, and VALUE.) (A. Yo.)

PRICE-CUTTING, the term used to indicate the practice of selling standard merchandise at a price below that advertised by the manufacturers. With many trade-marked articles the manufacturer attempts to maintain the price at which his products are sold to consumers. The idea is that both wholesalers and retailers should make a profit on his merchandise; otherwise they might refuse to handle it. When an article becomes so well known that it is widely accepted as a standard, it is a common practice for retailers having similar goods that they sell under the store label to reduce the price of the trade-marked article and use it in their advertising as a special attraction. Their clerks are instructed to try to sell the substitute bearing the store label instead of the trade-marked article requested. This practice is disadvantageous to the manufacturers inasmuch as the cut-price often makes the article unprofitable for other retailers and they also attempt to substitute other brands for the one advertised. When the distributor departs from the usual practice and sells for cash where most stores would extend credit, and when he refuses to deliver goods and requires the customers to carry their own purchases, he is expected to sell at a lower price because he gives less service. The reduced price of the "cash and carry" stores is not usually included in the term price-cutting. In most countries price-cutting is prevented by contract between the manufacturer and distributors. That form of contract was not legal in the U.S. until the passage of fair trade laws by most of the separate states. Price maintenance remained illegal, by contract, except in states having these enactments.

In 1951 the U.S. supreme court held that state fair trade laws did not apply to retailers who would not make pricing agreements with manufacturers. (H. E. A.; X.)

PRICE MAINTENANCE. The subject of price maintenance, or, more specifically, resale price maintenance, is one that demands special consideration among the various types of price fixing, both from the legal and the economic aspects. Other forms of price fixing are treated elsewhere. For agreements and understandings as to prices among competing manufacturers, wholesalers or retail dealers, *see* TRADE ORGANIZATION, and also POOLS, IN INDUSTRY and CARTEL; for concentrations of industry in monopolistic, or quasi-monopolistic, forms, *see* TRUSTS; for price fixing by legal monopolies, such as railroads and other privately owned public utilities, *see* PUBLIC UTILITIES. The following discussion relates to resale price maintenance exclusively.

Resale price maintenance is the term applied to various devices by which individual manufacturers or distributors of particular trade-marked, branded, or otherwise identified articles fix minimum resale prices. The most widespread and important manifes-

tation of resale price control is seen where the manufacturer of an article, by contract, fixes a price below which retailers shall not sell it to the public.

The practice has been fostered in the United States by manufacturers who sell trade-marked and well advertised commodities such as breakfast foods, toilet goods, proprietary medicines, books and musical instruments, and has been supported by trade associations of manufacturers and dealers in various lines of products. Supporting dealer organizations have the further objective of inducing the fixing of minimum prices high enough to insure a margin satisfactory to the dealer. In Great Britain there exists an association, known as the Proprietary Articles Trade Association, whose main object is to encourage and enforce this system. A similar association was founded in Canada in 1925 but was later disbanded when it was adjudged to be a combination in restraint of trade.

It is contended by the advocates of resale price maintenance that the maker of an article which bears a trade-mark that he has made valuable by extensive advertising should be entitled to stipulate the price at which it shall be sold by dealers to the public. It is claimed that the manufacturer cannot adequately protect his intangible property—the good will attaching to his trade-mark or brand—unless he restrains dealers who sell his products at a lower price than he suggests, sometimes less than cost, as a "leader" or a "draw" to customers. This use of "leaders," it is maintained, sometimes causes competing retailers to refuse to handle the goods because they can neither make a profit by meeting the low prices, nor sell at the manufacturers' higher resale prices, thus destroying good will of the dealer and reducing the number of dealer outlets.

In England, the legal status of resale price maintenance is based largely upon court application of common law rules respecting freedom of contract and the reasonableness of agreements in restraint of trade. The courts interpret the right of contract broadly and permit manufacturers to make resale price maintenance agreements among themselves and with their distributors provided undue restraint of trade is not shown. Resale price maintenance was considered by official committees in 1920 and again in 1931. The report of 1931 neither condemned, nor did it give unqualified approval to the practice.

Canadian policy follows quite closely that of England but is somewhat more restricted. In certain cases resale price maintenance has been declared to be against public policy, but the practice itself has not been passed upon. Resale price control by a combination of manufacturers, jobbers, and retailers of drugs was condemned in 1927, and a similar combination to control prices of tobacco products was likewise condemned as a combine within the meaning of the Canadian Combines Investigation Act.

In the United States prior to 1936, in cases coming before the U.S. Supreme Court, resale price maintenance was permitted in cases of goods distributed through bonafide agents rather than independent dealers, but otherwise goods sold under a trade name or mark were not exempted from the common law and statutory provisions against monopolies and restraints of trade. As early as 1907 the courts held that a system of contracts entered into by the manufacturer of a proprietary medicine with a large part of the wholesale and retail druggists stipulating the resale price of the product was unlawful and unenforceable on the grounds that it restrained trade (*Park and Sons* v. *Hartman*, 153 Fed. 24), and in 1911 the U.S. Supreme Court rendered a similar decision in the Dr. Miles case (*Dr. Miles Medical Co.* v. *Park and Sons Co.*, 220 U.S. 373). Patented and copyrighted articles have also been held to be within the scope of the Dr. Miles case, and agreements to maintain resale prices thereon declared unlawful.

In 1915, the Federal courts refused to issue an injunction restraining the manufacturer of a breakfast food from carrying out the policy of refusing to sell to those dealers unwilling to maintain resale prices. In 1922, the U.S. Supreme Court held that a corporation may have and announce a policy of refusing to sell to cut-rate dealers and withhold its goods but may not consistently go beyond this act and by contracts or combinations, express or implied, unduly hinder or obstruct the free and natural flow of commerce (*F.T.C.* v. *Beech-Nut Packing Co.*, 257 U.S. 441).

Throughout the period from the Dr. Miles decision in 1911 to the enactment of the National Industrial Recovery Act in June 1933 (48 Stat. 195), bills to legalize resale price maintenance in interstate commerce in the United States were continually presented to the Congress, but all failed of passage. In 1931, however, the State of California enacted a law legalizing resale price maintenance by contract between manufacturers or distributors and retail dealers within the State of California. With the setting up of the National Recovery Administration under the National Industrial Recovery Act, interest in the enactment of further State laws waned due to the fact that numerous codes contained price control provisions and a number provided for some form of resale price maintenance. Following the decision of the U.S. Supreme Court in the Schechter case (*Schechter Poultry Corp.* v. *U.S.*, 295 U.S. 495) which declared portions of the National Recovery Act unconstitutional, the movement to enact State resale price maintenance laws again gained momentum. By the end of 1935, ten States had enacted such laws, generally similar to the 1931 California act. Late in 1936, the U.S. Supreme Court declared the State laws of California and Illinois to be constitutional (*Old Dearborn Distributing Co.* v. *Seagram Distillers Corp.*, 299 U.S. 183, and *The Pep Boys, Manny, Moe & Jack of California, Inc.* v. *Pyroil Sales Co., Inc.*, 299 U.S. 198). These decisions provided such a stimulus that by 1939 44 of the States had legalized resale price maintenance, by laws commonly designated as Fair Trade Acts.

In 1937, the Tydings-Miller Act amended the Sherman Anti-trust Act by exempting from the application of that act, "contracts or agreements prescribing minimum prices for resale of a commodity which bears, or the label or container of which bears the trade mark, brand, or name of the producer of such commodity, and which is in fair and open competition with commodities of the same general class produced or distributed by others when contracts or agreements of that description are lawful as applied to intrastate transactions, under any statute, law, or public policy now or hereafter in effect in any State, Territory, or the District of Columbia," and further declared that the making of such contracts "shall not be an unfair method of competition under the Federal Trade Commission Act." This exemption, however, is specifically stated in the act not to make lawful "horizontal" agreements or understanding on prices between competitors, whether they be manufacturers or distributors, and such "horizontal" agreements are still a violation of law when in restraint of trade or commerce among the States.

While resale price maintenance appears presently to find legal sanction in the United States and in the United Kingdom, consumer organizations and economists generally are opposed to the practice from the standpoint of its effects on the public, and many in the United States advocate returning to former policies on the ground that the evils inherent in a system of fixed retail prices outweigh the benefits of resale price maintenance to manufacturers of some lines of merchandise and a segment of the retail trade.

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(R. E. F.)

PRICES, STATISTICS OF. In the United Kingdom and the United States, and in some other countries, price quotations for a number of important commodities are available from the middle of the 19th century; there are some quotations in earlier periods. However, there have been many changes in the nature and quality of the commodity and in the type of price quotation; in only a few cases have the changes been small enough to permit the compilation of a continuous series of prices on a reasonably comparable basis. A series of single prices, however interesting they may be, cannot be taken as indicating general movements in

TABLE I.—*Wholesale Price Movements of Specified Commodity Groups, United States, Selected Years, 1890–1949*
(1926=100)

Year	(1) Farm products	(2) Foods	(3) Hides and leather products	(4) Textile products	(5) Fuel and lighting	(6) Metals and metal products	(7) Building materials	(8) Chemicals and allied products*	(9) House-furnishing goods	(10) Miscellaneous	(11) Raw materials	(12) Semi-manufactured articles	(13) Manufactured products	(14) All commodities other than farm products and food	(15) All commodities
1890	50.4	56	48	59	38	105	46	73	50	98	—	—	—	—	56
1896	40	44	45	43	40	71	39	65	43	90	—	—	—	—	46
1913	72	64	68	57	61	91	57	80	56	93	69	75	69	70	70
1920	151	137	171	165	164	149	150	165	142	168	152	198	150	161	154
1929	105	100	109	90	83	100	95	94	94	83	98	94	94	92	95
1930	88	90	100	80	78	92	90	89	93	78	84	82	88	85	86
1931	65	75	86	66	68	84	79	79	85	70	66	69	77	75	73
1932	48	61	73	55	70	80	71	74	75	64	55	59	70	70	65
1933	51	60	81	65	66	80	77	72	76	62	56	65	70	71	66
1934	65	70	87	73	73	87	86	75	82	70	69	73	78	78	75
1935	79	84	90	71	74	86	85	79	81	68	77	74	82	78	80
1936	81	82	95	72	76	87	87	79	82	70	80	76	82	80	81
1937	86	86	105	76	78	96	95	83	90	78	85	85	87	85	86
1938	68	74	93	67	76	96	90	77	87	73	72	75	82	82	79
1939	65	70	96	70	73	94	90	76	86	75	70	77	80	81	77
1940	68	71	101	74	72	96	95	77	88	77	72	79	82	83	79
1941	82	83	108	85	76	99	103	84	94	82	84	87	89	89	87
1942	106	100	118	97	78	104	110	96	102	90	101	93	99	96	99
1943	123	107	118	97	81	104	111	95	103	92	112	93	100	97	103
1944	123	105	117	98	83	104	116	95	104	94	113	94	101	98	104
1945	128	106	118	100	84	105	118	95	104	95	117	96	102	100	106
1946	149	131	137	116	90	116	133	101	112	100	135	111	116	110	121
1947	181	169	182	142	109	145	180	127	131	116	166	149	146	135	152
1948	188	179	189	149	134	164	199	135	144	120	178	158	159	151	165
1949	166	161	180	140	132	170	193	119	145	112	164	150	151	147	155
1948 indexes as a per cent of indexes in selected years															
1890	374	323	397	255	352	155	428	185	290	123	—	—	—	—	204
1896	476	406	418	348	340	230	512	209	333	134	—	—	—	—	355
1913	263	279	277	261	219	180	351	169	257	129	259	211	230	216	237
1920	125	130	110	91	82	110	133	82	102	72	118	80	106	94	107
1926	188	179	189	150	134	164	199	136	144	120	178	158	159	151	165
1932	391	294	259	273	191	204	279	184	192	187	324	266	227	215	255
1939	288	254	197	215	184	173	220	179	167	161	254	205	198	186	214

Source: Bureau of Labor Statistics.
*In Jan. 1940 the group of "Chemicals and allied products" was substituted for the group of "Chemicals and drugs." The revision was made by years from 1926.

prices. What is required for this purpose is a set of indicators showing the general course of prices, in convenient major groups of commodities, over time in a particular country. Such indicators can only be constructed in the form of index numbers (*see* INDEX NUMBERS) which are generally averages of the changes in prices of certain commodities selected to represent the various groups. The averages can be computed in various ways giving different results. Moreover, the index numbers depend on the accuracy and continuity of the price quotations used and any one compilation is generally limited to comparisons of prices in a relatively short period, perhaps no more than 10 or 20 years. For longer-run comparisons, different index numbers need to be "spliced" together and the results are more approximate.

The most obvious feature in the general world picture is the effect of major wars on wholesale prices. During the French Wars (1793–1815) prices rose rapidly and were then maintained at a high level, though with considerable oscillations. Prices fell after Waterloo but it was not until the 1820s that they had fallen to the level of the years before 1793. The American Civil War (1861–65) gave rise to the second major peak in wholesale prices in the U.S. but the effect in the U.K., and in many other countries, was much smaller. World Wars I and II exercised an even sharper effect on prices. Moreover, the course of prices was broadly similar in the two wars, at least in the United Kingdom and the United States—an immediate and pronounced rise, followed by a slower increase as measures of price control became effective and finally another sharp rise after the close of hostilities. The main difference between the two wars was that price control was effective sooner in World War II, and the postwar increase in prices was more protracted.

Between wars the trend of prices was generally downward and, at the outbreak of one war, the level of prices was little different from that immediately before the previous war. Closer inspection, however, reveals major fluctuations disturbing the general course of prices. One cause of disturbance was the discovery of new gold fields or the rapid development of gold production. A growth in the supplies of gold coming forward pushes up prices in domestic currencies which are based on gold. The discovery of gold in California and Australia raised wholesale prices after 1850 and prices did not sink below the level of 1849 until about 1880. The effect of the new gold supplies on prices is to be seen clearly in the series for the U.K. where the American Civil War was a very minor disturbing factor. The development of the South African gold fields was the main influence in the steady rise in prices following the low point attained in 1896, a rise which continued until the outbreak of World War I.

Other major fluctuations, generally working themselves out in a period of less than ten years, are those associated with booms and depressions. The pattern is boom, commercial crisis, recession and recovery. Commercial crises generally appear as peaks in the course of wholesale prices; *e.g.*, those of 1839 and 1847 in the first half of the 19th century and that of 1907 at the beginning of the 20th. No earlier depression, however, had quite the same catastrophic effect as that following the crisis of 1929. Both in the U.K. and in the U.S., wholesale prices in 1929 stood about 35% higher than in 1913; by 1932–33, prices had fallen to nearly 10% below the 1913 level; *i.e.*, a decline of more than 30% in less than four years.

A remarkable feature of the course of prices over 150 years is the broad similarity between the movements in the U.K. and the U.S. There are, of course, many factors which exert little more than a local influence. For example, the Franco-Prussian and South African wars had relatively little effect on prices in the U.S. and the American Civil War influenced prices outside the U.S. to a relatively small extent. However, major wars, severe commercial crises and gold discoveries are events which are international in their impact on economic affairs and they affect prices everywhere. For this reason it can be said that there has been a level of world prices, the movements of which can be distinguished in a broad historical survey.

In an index of the general level of wholesale prices, the movements in the prices of commodities of many different kinds are averaged. Individual price quotations are to be expected to show greater fluctuations than the general average, as is well illustrated by the price of English wheat (Table III and fig. 3). Up to about 1880, imports of wheat into the U.K. were small and the price was largely dependent on the supplies of domestic wheat available and hence on the condition of the harvest. The price of wheat showed very large fluctuations, many of which did not correspond at all with movements in the general price level. After 1880, with increasing supplies of wheat coming in from the western hemisphere and other overseas areas, the price of English wheat was determined more by world prices than by the British harvest. The result was, first, that the price was reduced in

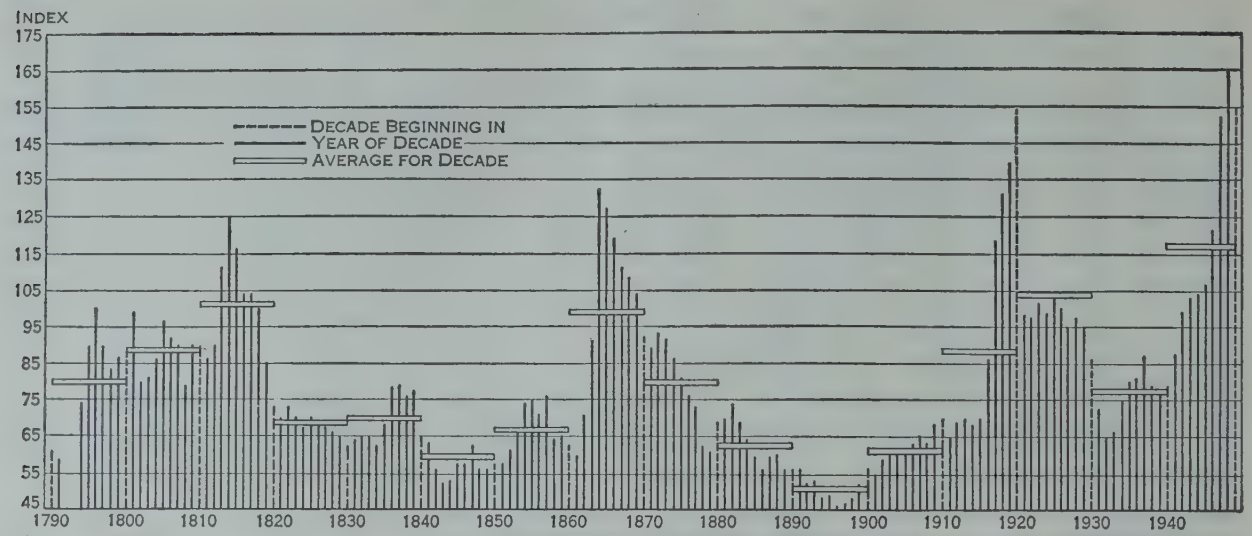

FIG. 1.—MOVEMENTS OF WHOLESALE COMMODITY PRICES IN THE UNITED STATES, 1790-1949. FROM 1790 TO 1889 THE WARREN-PEARSON-STOKER INDEX (STOKER BEFORE 1797) IS USED; FROM 1890 TO 1949 THE OFFICIAL INDEX OF THE BUREAU OF LABOR STATISTICS. 1949 IS PRELIMINARY

relation to other prices and, second, that there were less violent fluctuations in price. Though still showing wider variations than the general price level, the price of English wheat followed fairly closely the general course of prices. (R. G. D. A.)

UNITED STATES

In the United States, as in other countries, statistics of prices became available in greater quantity and in more varied forms than data reflecting other major aspects of the economy such as production and employment. The wealth of price data was steadily enhanced by the contributions of government departments and private business and research groups, and information about historical prices and price movements was expanded by the painstaking work of individual scholars.

In this article three main tasks are undertaken. First, an effort is made to indicate the nature and sources of the price data available in the United States. Secondly, the data are drawn upon to describe the movement of the general price level in the period between the founding of the republic and the middle of the 20th century, and to analyze changes in the relationships of prices for different kinds of goods within the last 50 or 60 years of this period. Finally, a summary is presented of the cyclical behaviour of the price level and of price relationships.

NATURE AND SOURCES OF U.S. PRICE DATA

Statistics on prices are available in two forms: (1) price quotations for specified commodities, services or securities; and (2) index numbers which usually are designed to summarize the average amount of change in the prices for a specified group of commodities, services or securities between two or more dates. Despite the careful efforts of price statisticians in business and government who supervise the collection of price data and the compilation of price indexes, the numerous practical and theoretical difficulties involved in their work cannot be completely overcome. Although these problems need not be considered in detail here, some understanding of their general nature is essential to proper interpretation of the price data discussed below.

The central problem of price collection is to gather a sample of prices representative of the various price quotations for each of the commodities under study. Sampling is almost always necessary because it is not feasible to obtain a record of every single transaction. Price collection must be planned so that observed differences between the prices of any two dates (any two places, when place-to-place rather than time-to-time price differences are being studied) will reflect changes in price and price alone. In order to exclude the influence of variation in quality, commodity prices are frequently collected in accordance with detailed specifications (*i.e.*, descriptions) such as "wheat, no. 2 red winter, bulk, carlots, f.o.b. Chicago, spot market price, average of high and low, per bushel."

When the correct average prices for a commodity for successive dates have been determined, they may be expressed as percentages of the price for a particular date or "base period." These percentages are called "price relatives." The problem of constructing price index numbers is to combine either the prices themselves or the price relatives in such a way that the central tendency of the movement of the whole group of prices from one period to another is accurately described. Although a number of problems are encountered at this stage, the one that is perhaps the most important to an understanding of the limitations of price indexes is the weighting problem. This arises because not all commodities for which prices have been obtained are of equal importance in the price universe under study. The price of wheat, for example, should be given more weight in an index of wholesale prices in the domestic economy than the price of pepper, because either in physical terms or in value terms wheat is much more important in trade. The difficulty is that the relative importance of commodities changes over time. Furthermore, some commodities drop out of use and new ones appear, and often a good changes so much in composition and design that it is doubtful whether it can properly be considered the same commodity.

Under these conditions, the pattern of weights selected can correspond accurately to the relative importance of the various commodities in only one of the periods for which the index numbers have been calculated. The greater the lapse of time between the period of the weighting pattern and other periods, the less relevant the pattern is likely to be for one of the periods, and therefore the less meaningful the price comparisons become. Price indexes thus can give relatively accurate measures of price change only for periods close together in time. F. C. Mills found also that the dispersion of price relatives computed on a given base year tends to increase with time; this means that the price index numbers become less representative of the central tendency of the whole distribution of the price relatives for the various commodities.

Sources of Data on Actual Prices.—The most important single source of price statistics in the United States at mid-20th century was the bureau of labour statistics (BLS) of the U.S. department of labour. The BLS was publishing monthly prices for about 900 different commodities at the primary market level (*i.e.*, the stage of marketing at which the goods were first sold), and for approximately 50 foods and for various types of fuels at the retail level. All the retail prices and roughly half of the wholesale prices were obtained directly from sellers. Most retail prices

were collected during store visits by price agents trained to price goods in accordance with established specifications. A few retail prices, such as those for fuel and those primary market prices obtained directly from sellers, were secured by mail. The other primary market prices were obtained from such recognized trade journals as *Iron Age* and the *Oil, Paint and Drug Reporter.*

Another important governmental source of price data was the department of agriculture, collecting both "local market prices" and "wholesale prices" of farm products, the latter referring to prices at central markets. Estimates of Dec. 1 crop prices and Jan. 1 farm values of livestock are available since 1867, monthly prices of commodities sold by farmers since 1908 or 1910. Prices of articles bought by farmers were published annually from 1910 to 1922 and quarterly (for most items) subsequently. At mid-century, the department was receiving reports on farm product prices from about 9,000 respondents (mostly buyers or dealers) and reports on prices paid by farmers from about 17,000 respondents (mainly independent retailers serving the farm population). The prices thus obtained were available in the department's publication *Crops and Markets.*

The trade journals were, perhaps, the most readily available nongovernmental source of commodity price data. Prices for highly standardized commodities traded on organized markets (*e.g.*, wheat, coffee and sugar) and prices for stocks and bonds were also reported in the financial pages of many metropolitan newspapers.

Survey of Available Price Indexes.—The prices from all these sources were being used to compute a wide variety of index numbers at mid-century. The most generally used index numbers were those computed by the bureau of labour statistics, particularly its wholesale price and consumers' price indexes. Before describing these indexes, it may be well to survey the more important price indexes in the U.S., taking into consideration first commodity price indexes at both wholesale and retail levels, and then indexes of the prices of services, construction and securities.

TABLE II.—*Movements of Various Price Indexes, Selected Years, United States, 1913–49 (1935–39=100)*

Year	Wholesale prices	Consumers' prices				Hourly earnings	Prices received by farmers	Prices paid by farmers	Construction costs	Stock prices
		All items	Food	Apparel	Rent					
1913	87	71	80	69	92	37*	95	81	45	71
1920	192	143	169	201	121	80†	196	161	113	68
1929	118	122	132	115	141	95	139	123	93	201
1930	107	119	126	113	138	92	119	117	91	158
1931	91	109	104	103	130	86	84	101	81	100
1932	80	98	86	91	117	75	63	86	71	51
1933	82	92	84	88	101	74	67	86	76	67
1934	93	96	94	96	94	89	84	98	89	77
1935	99	98	100	97	94	92	102	100	89	83
1936	100	99	101	98	96	93	106	99	94	118
1937	107	103	105	103	101	104	114	105	106	118
1938	98	101	98	102	104	105	90	99	106	88
1939	96	99	95	100	104	106	88	97	106	95
1940	98	100	97	102	105	110	93	98	109	88
1941	108	105	106	106	106	122	116	105	116	80
1942	123	116	124	124	108	143	148	122	125	69
1943	128	124	138	130	108	161	179	134	131	92
1944	129	126	136	139	108	170	182	141	134	100
1945	131	128	139	146	108	171	188	144	139	122
1946	150	139	160	160	109	181	217	162	158	140
1947	189	159	194	186	111	204	259	197	188	123
1948	205	171	210	198	117	222	267	212	209	124
1949	192	170	202	190	126	234	233	204	214	121
1948 indexes as percentage of indexes in selected years										
1913	236	242	263	286	127	595*	281	261	464	175
1920	107	119	125	98	97	278†	136	131	185	183
1926	165	135	153	164	78	242	197	170	223	118
1932	255	175	243	218	100	297	422	245	295	243
1939	214	172	221	197	113	210	302	218	197	131

Sources: Wholesale and consumers' price series are the BLS indexes described in text. Hourly earnings are BLS series for production workers in manufacturing. Prices paid (for living and production) and received by farmers are from Department of Agriculture. The construction cost index is from the *Engineering News-Record* and the stock prices are the Standard and Poor's composite index numbers of more than 400 stock prices.
*1914. †1919.

In the group of predominantly commodity price indexes were the department of agriculture indexes of prices received and prices paid by farmers. These indexes, based on the department's price data collection described above, were used in the determination of parity prices.

Among the more widely known nongovernmental price indexes being published in 1950 were Moody's index of staple commodity prices (available since 1928 in *Moody's Stock Survey*), Dun and Bradstreet's wholesale food price index (available since 1916 and published in *Dun's Statistical Review*) and the *Journal of Commerce* daily and weekly price indexes (available since 1933). The National Bureau of Economic Research computed wholesale price indexes based on BLS prices but combined according to a different commodity classification (F. C. Mills, *The Structure of Postwar Prices* [1948]). A number of the privately computed indexes of the 1920s and 1930s were abandoned as the government indexes came into greater use.

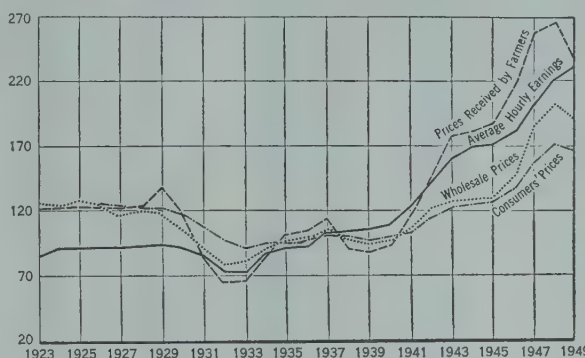

FIG. 2.—MOVEMENTS OF VARIOUS PRICE INDEXES 1913-49 (1935-39=100) (GRAPH LINES FOR CONSUMERS' PRICES AND PRICES RECEIVED BY FARMERS ARE IDENTICAL BETWEEN 1923 AND 1925)

A large number of wholesale price index numbers of more limited commodity coverage were available in the trade journals. *Iron Age*, for example, published an index of finished steel prices which was a weighted average of the prices (in cents per pound) of ten major finished steel products.

In addition to these and similar commodity price indexes that were in the realm of public information, a number of business firms computed special-purpose price indexes for their own uses, especially in connection with marketing and purchasing activities.

At the retail level, a distinction must be made between those indexes including services and those including commodity prices only. The consumers' price indexes of the BLS and the National Industrial Conference board were in the former category, while the U.S. department of commerce and Fairchild Publications indexes of retail prices were examples of the latter group. The National Industrial Conference board index, available since 1914, was similar to the BLS index (described below) but included a number of small cities not in the BLS sample and was based on prices obtained by mail questionnaires. The department of commerce index of prices at retail stores, which was available for 1929 and 1933 and since 1939, differed from the BLS consumers' price index in that it omitted services (medical care, transportation, recreation, etc.) and included building materials, farm machinery and other nonconsumer goods sold through retail stores. The index of the Fairchild Publications, available since 1930, covered the prices of piece goods, apparel and home furnishings. All four of the retail and consumers' price indexes just mentioned were being published monthly at mid-century.

Different in concept from any of the indexes treated thus far was Carl Snyder's "index of the general price level." This was designed to measure changes in prices of commodities at all levels from primary to retail markets and shifts in the prices of services and property as well as of commodities. The index was extended from 1938 back to 1791 (*Review of Economic Statistics*, p. 25 [Feb. 1934] and p. 40 [Feb. 1928]). Comprehensive price indexes embracing both services and commodities were also derived, largely with the aid of existing price index numbers, in the course of estimating national income in terms of constant prices. Such indexes were available for 1919–38 in S. Kuznets and others, *National Income and Its Composition, 1919–1938*, pp. 141 ff. (1941). Similar series, referring to price changes in the gross national product and 10 or 12 of its major segments were made available for the period 1929–50 in *National Income, 1951 Edition: A Sup-*

plement to the Survey of Current Business, p. 146, U.S. department of commerce. These series will be carried on and, if the past custom is followed, will be found each year in the July issue of the *Survey of Current Business.*

Aside from the services included in the consumers' price index, the most readily available indicators of the changing price of services were indexes of hourly earnings and wage rates. The BLS series on average hourly earnings of production workers in manufacturing industries, available since 1909, was the most general of these series. Indexes of wage rates were restricted to particular groups of workers such as organized workers in the building and printing trades.

A field in which it was necessary to combine wages and commodity prices to derive indexes was construction. These were not price indexes in the strict sense, but construction cost indexes. A number of these indexes were being published at mid-century by private business groups in or servicing the construction industry; in addition, government agencies were publishing index numbers of construction costs in such fields as railroad, highway and farm construction. Most construction cost index numbers went back to the 1910–13 period. Mention may be made of the construction cost indexes of the *Engineering News-Record,* the Aberthaw Co., the American Appraisal Co., the Associated General Contractors of America, Inc., and E. H. Boeckh and Associates, Inc.

The last category of price indexes deserving consideration here consists of the indexes of security prices. Among the leading indexes of stock prices at mid-century were those prepared by the New York Stock exchange, Moody's Investors Service, Standard and Poor's Corp. and Dow Jones & Co. The first of these indexes was based on the average price obtained by dividing the market value of all listed stocks at the end of the month by the number of shares. The other indexes were based on a more limited but more constant group of sample stocks selected to represent different groups of stocks. The Dow Jones averages, for example, were based on 30 industrials, 20 railroads and 15 utilities; the Standard and Poor's indexes, based on more than 400 stocks, were available for a more detailed industrial classification. Indexes of bond prices were also computed by the New York Stock exchange, Standard and Poor's and others; such indexes generally derived the bonds prices from average yields.

The general user of price indexes could find data for almost all of the price index series mentioned above in the *Survey of Current Business,* monthly publication of the department of commerce. Sources of the statistics for former years and brief descriptions of many of the indexes were available in *Historical Statistics of the United States, 1789–1945, A Supplement to the Statistical Abstract of the United States,* and in the *Statistical Supplement to the Survey of Current Business.*

The BLS Indexes.—The BLS official wholesale price index numbers dated from 1890. The methods of computation and the number of commodities included in the index varied from time to time but the revisions were made to retain comparability of the series. As computed in the 1940s, the index was derived from the prices of 800 to 900 commodities; in the first years for which the index was available only a few more than 250 commodities were included. The expanded list of prices collected was designed to be representative of all primary markets not only in respect to the commodity sample but also with regard to specifications, markets and reporting firms. A program of revision for 1947–50 entailed the improvement of the samples of prices, particularly for certain subgroups of commodities. Previously each price series had been weighted by the quantity of that commodity marketed in 1929–31 with minor alterations to reflect changing patterns of trade. The revision program involved the further modification of these weights to correspond with the situation prevailing after World War II.

Since the index included the primary market price of goods of all degrees of fabrication, the same commodity was often priced at several stages of production. For example, cotton was priced in the form of raw cotton, cotton yarn, cotton grey goods, cotton piece goods and cotton clothing. Indexes were published monthly for each of the commodities, for 49 subgroups of commodities, 10 major commodity groups and 5 economic classifications (*e.g.,* raw materials). Prices for one day a week were averaged to obtain monthly prices for most commodities.

In addition to the monthly index, the BLS computed a weekly index of wholesale prices. As issued in 1948–50, this was intended as a weekly counterpart of the monthly index. It was based on a comprehensive sample of approximately 125 commodities out of nearly 900 used for the monthly index. Beginning in 1940, the BLS also issued a daily index of the prices of 28 commodities traded on organized exchanges or markets. This was intended to provide a sensitive gauge of changes in market conditions. At mid-century the daily index was being published on

TABLE III.—*Wholesale Prices, United Kingdom, 1790–1949*

Year	Wheat price* (*s* per qtr.)	Statist index† (1913=100)	Year	Wheat price* (*s* per qtr.)	Statist index† (1913=100)
1790	54.7	127	1870	46.8	113
1791	48.6	130	1871	56.7	118
1792	43.0	136	1872	57.0	128
1793	49.2	145	1873	58.7	131
1794	52.2	144	1874	55.7	120
1795	75.2	171	1875	45.2	113
1796	98.6	183	1876	46.2	112
1797	53.7	161	1877	56.7	111
1798	51.8	173	1878	46.4	102
1799	69.0	190	1879	43.8	98
1800	113.8	206	1880	44.3	104
1801	119.5	224	1881	45.3	100
1802	69.8	174	1882	45.1	99
1803	58.8	187	1883	41.6	96
1804	62.2	179	1884	35.7	89
1805	89.7	199	1885	32.8	85
1806	79.1	195	1886	31.0	81
1807	75.3	193	1887	32.5	80
1808	81.3	218	1888	31.8	82
1809	97.3	236	1889	29.7	85
1810	106.4	240	1890	31.9	85
1811	95.2	215	1891	37.0	85
1812	126.5	217	1892	30.2	80
1813	109.7	218	1893	26.3	80
1814	74.3	224	1894	22.8	74
1815	65.6	193	1895	23.1	73
1816	78.5	160	1896	26.2	72
1817	96.9	176	1897	30.2	73
1818	86.2	198	1898	34.0	75
1819	74.5	171	1899	25.7	80
1820	67.8	155	1900	26.9	88
1821	56.1	138	1901	26.7	82
1822	44.6	129	1902	28.1	81
1823	53.3	130	1903	26.7	81
1824	63.9	129	1904	28.3	82
1825	68.5	151	1905	29.7	85
1826	58.7	132	1906	28.2	91
1827	58.5	132	1907	30.6	94
1828	60.4	119	1908	32.0	86
1829	66.2	116	1909	36.9	87
1830	64.2	119	1910	31.7	92
1831	66.3	120	1911	31.7	94
1832	58.7	114	1912	34.8	100
1833	52.9	110	1913	31.8	100
1834	46.2	114	1914	35.0	100
1835	39.3	117	1915	53.9	127
1836	48.5	126	1916	58.4	160
1837	55.8	123	1917	75.7	206
1838	64.6	123	1918	72.7	226
1839	70.7	135	1919	72.9	242
1840	66.3	127	1920	80.6	295
1841	64.3	125	1921	72.7	182
1842	57.2	110	1922	47.8	154
1843	50.1	104	1923	42.2	151
1844	51.2	101	1924	49.3	164
1845	50.8	108	1925	52.2	160
1846	54.7	108	1926	53.3	147
1847	69.7	112	1927	49.3	144
1848	50.5	92	1928	44.7	140
1849	44.2	87	1929	42.2	134
1850	40.2	91	1930	34.3	113
1851	38.5	88	1931	24.0	96
1852	40.8	92	1932	25.0	93
1853	53.2	112	1933	22.8	92
1854	72.4	120	1934	20.2	95
1855	74.7	119	1935	22.2	98
1856	69.2	119	1936	30.8	104
1857	56.3	124	1937	40.0	120
1858	44.2	107	1938	28.9	106
1859	43.7	111	1939	21.4	111
1860	53.3	116	1940	42.8	151
1861	55.3	115	1941	62.8	167
1862	55.4	119	1942	68.5	178
1863	44.7	121	1943	69.7	182
1864	40.2	124	1944	63.9	188
1865	41.8	119	1945	61.8	193
1866	49.9	120	1946	63.6	219
1867	64.4	118	1947	71.8	271
1868	63.7	116	1948	90.0	306
1869	48.2	115	1949	99.6	323

*Wheat price: English *Gazette* price of wheat, in shillings per quarter of 480 lb. †Statist index: from 1847, index compiled by the *Statist* newspaper, London, continuing the original calculations of A. Sauerbeck, with base shifted from 1867–77=100 to 1913=100; before 1847, index compiled by W. S. Jevons (*Journal* of the Royal Statistical Society, London, 1865) equated to the *Statist* index at the average of the decade 1853–62.

an Aug. 1939 base while the weekly and monthly indexes were being published on a 1926 base.

The BLS wholesale price index had been extended back to 1801 on the basis of price indexes for 1801–40 computed by A. H. Hansen (*Publications* of the American Statistical association, pp. 804–12 [Dec. 1915], and BLS *Bulletin No. 367*, pp. 235–48) and data for 1841–89 contained in the Aldrich committee's comprehensive report, "Wholesale Prices, Wages and Transportation,"

TABLE IV.—*Wholesale and Retail Prices, United Kingdom, 1880–1938*

Year	Wholesale prices* (1913=100)			Retail prices† (July 1914=100)		
	Food	Textile materials	Coal	Food	Clothing	Fuel
1880	122	96	71	115	86	86
1881	118	92	79	111½	86	89½
1882	116	95	79	111	85	85
1883	116	83	84	111½	83	88
1884	103	81	77	103½	82	87
1885	96	77	77	94	81	87
1886	94	75	74	91	81	85
1887	91	77	74	88	81	84
1888	94	76	77	89	80	85
1889	97	83	82	91	79	86
1890	95	79	88	90	81	93
1891	100	70	88	92	81	91
1892	95	68	86	93	80	91
1893	94	70	91	88	79	99
1894	86	63	77	85	78½	85
1895	83	62	69	82	78	82½
1896	81	64	69	82	78½	84
1897	84	61	73	85	78	85
1898	88	61	78	88	77	85
1899	84	69	86	85	76	92
1900	90	79	109	89	79	116
1901	87	71	93	89	72	103½
1902	87	73	86	90	73	99
1903	86	79	77	92	79	94
1904	88	85	76	91	86	92
1905	90	86	71	92	86½	91
1906	90	95	77	91	96	92
1907	94	92	92	94	93	103½
1908	94	74	84	95½	74½	100
1909	95	76	82	96½	77	98
1910	96	87	80	97	88	98
1911	97	90	83	97	94	99
1912	105	90	101	102	94	101
1913	100	100	100	103	101	100
1914	105	96	99	100	100	100
1915	139	110	143	131	122	122
1916	169	154	128	160	157½	134
1917	219	229	128	198½	207	145
1918	226	264	156	215	311	174
1919	240	271	210	219	361	193
1920	304	312	148	256	416	212
1921	205	167	150	229½	303	242½
1922	169	160	159	176	238	202
1923	158	167	150	169	222½	184
1924	169	202	128	170	225	186
1925	166	196	138	171	229	182
1926	155	158	141	164	221	205
1927	148	156	107	160	214	183
1928	148	162	99	157	219	169
1929	143	145	108	154	218	171
1930	125	100	115	145	211	172½
1931	108	75	114	131	196	174
1932	103	76	108	126	189	172
1933	96	80	105	120	184	170
1934	100	86	94	122	186	170
1935	99	95	94	125	187	170
1936	105	99	107	130	189	174
1937	121	111	113	139	202	178
1938	109	89	119	140½	209	181

*Wholesale prices: constituents of *Statist* index (*see* Table IV); food and textile materials are group index numbers, coal is a single price quotation (Wallsend Hetton in London to 1916, then Best Yorkshire house). †Retail prices: estimates by A. L. Bowley, *Wages and Income in the United Kingdom Since 1860* (Cambridge University Press, 1937), continued by constituents of the cost of living index compiled from 1914 by the Ministry of Labour, London.

Senate Report No. 1394, 52nd congress, 2nd session, part i, p. 9. Hansen's data were based on prices published in Boston, Mass., newspapers for the period 1801–25 and for the period 1825–40 on New York prices published in the "Report of the Secretary of the Treasury on the State of Finances" for the year ending June 30, 1863.

The BLS index was also extended by G. F. Warren and F. A. Pearson back to 1797, and H. Stoker extended it to 1720. This work was based primarily on New York city prices obtained directly or indirectly from newspaper sources and from the treasury report mentioned above (Warren and Pearson, *Prices* [1933]).

Although not directly linked to the BLS index, mention should be made also of a series of careful investigations of early price records in New York city, Boston, Philadelphia, Pa., Charleston, S.C., New Orleans, La., and Cincinnati, O. A summary of the results of these studies was prepared by A. H. Cole (*Wholesale Commodity Prices in the United States, 1700–1861* [1938]).

The BLS consumers' price index was designed to measure changes in prices of a fixed list of living essentials, not changes in the total amount families spend for living. (*See* COST OF LIVING). The living essentials relevant for purposes of the index were those of urban wage earners and lower salaried clerical workers. The sample of items and the weights for the various prices were derived from a 1934–36 survey of the incomes and expenditures of 14,500 such families. The weighting pattern of the index was modified from time to time on the basis of later though more limited family expenditure surveys. Methods of computation, the number of items priced and the number of cities covered varied after the index was initiated in World War I but the revisions were made so as to maintain the continuity of the series as far as possible. At mid-century the index was being published on a 1935–39 base and the sample of items included 49 foods, 58 articles of clothing, 10 fuels, 23 housefurnishings, 49 miscellaneous goods and services and rent. Food prices were collected in 56 cities and other prices in 34 cities but not all cities were surveyed each month. Prices were collected so as to refer to a date near the 15th of each month.

Although consumers' price indexes, or cost-of-living indexes as they were formerly called, were calculated for the 100 years preceding the beginning of the BLS series (1913), most of these estimates were based on wholesale price changes in whole or part. Several of these indexes were linked together by the Federal Reserve Bank of New York to form a single series for the period 1820–1913.

THE LONG-TERM MOVEMENT OF PRICES

It is difficult to describe the movement of prices because, as is evident from the preceding survey of prices and price indexes, there are many different kinds of prices in the economy. It is true that such broad groups of prices as primary market prices, retail prices, wages and security prices could be combined in some way to give an index of prices in general. Carl Snyder's "index of the general price level" represented such an attempt. However, it is hard to interpret the meaning of changes in such an index; it is composed of elements that are too heterogeneous. What is required for most business and public purposes is a knowledge of the behaviour of one or more of the broad groups of prices and sometimes of the major or minor subgroups or even of particular items, depending upon the nature of the specific problem.

It happens that data on wholesale commodity prices, which represent a group of prices of strategic importance in the economy, are available for a longer period than information about other broad groups of prices. Hence, discussion of the long-term movements of prices in the United States may most conveniently run in terms of wholesale prices.

Changes in the Price Level.—The course of these prices during the period 1790–1950 was characterized by relatively moderate changes except for the violent fluctuations associated with war and postwar periods in U.S. history. This statement is based on the BLS wholesale price index which was previously discussed and is charted in fig. 1; before 1890, the Warren-Pearson-Stoker index is used.

It is easy to pick out the major price peaks from fig. 1, but the troughs are more difficult to select. This is due to the fact that periods of high prices were confined almost entirely to well-defined short spans of war years, while relatively low prices generally characterized the long interwar periods. From 1820 to 1919 more than half of the years had index averages between 50 and 70. During 8 of the 15 decades following 1800 the index averaged 77 or less (*see* fig. 1).

For the period preceding 1800 the data summarized by Cole (*op. cit.*, pp. 106–107) seem to indicate a slowly rising trend from 1720 to a peak associated with the Revolutionary War. Cole suggested, however, that the period 1720–45 was characterized by level or moderately declining prices and that it was followed by a long price upswing to a Revolutionary War peak with the subsequent trough coming in 1789. By 1796, prices had recovered to a higher level which was only slightly above that of 1801 when the figures of fig. 1 pick up the story.

How may these historical movements in wholesale commodity prices be summarized? Bearing in mind the approximate nature of price comparisons over long periods of time and the more arbitrary nature of the selection of particular troughs among years of generally low prices, the extremes of the variations (taking 1926 as 100) may be set down as shown in the table above.

Troughs		Peaks		Trough to peak		Peak to trough*	
Year	Index	Year	Index	Total period	Annual rate	Total period	Annual rate
1789	59	1814	125	+112%	+3.1%	—	—
1843	52	1864	132	+154%	+4.5%	−58%	−2.9%
1896	46	1920	154	+235%	+5.2%	−65%	−3.2%
1932	65	1948(?)	165	+154%	+6.0%	−58%	−6.9%

*1814–43, 1864–96 and 1920–32.

TABLE V.—*Wholesale and Retail Prices, United Kingdom, 1929–49 (1938=100)*

	Wholesale prices*						Retail prices†				
Year	Total	Food and tobacco	Coal	Iron and steel	Cotton	Wool	Total	Food	Drink and tobacco	Fuel and light	Clothing and household goods
1929	113	118	83	73	152	133	—	110	100	95	—
1935	88	89	83	72	104	89	—	89	101	94	—
1936	93	94	87	77	106	104	—	92	100	96	—
1937	107	105	101	93	117	126	—	99	100	98	—
1938	100	100	100	100	100	100	100	100	100	100	100
1939	101	100	98	95	106	104	102	102	107	101	102
1940	135	136	114	114	150	155	119	116	141	114	126
1941	150	150	129	130	165	168	130	123	160	121	155
1942	157	161	139	131	169	171	139	125	197	128	173
1943	160	164	151	131	164	175	143	125	225	128	171
1944	164	162	170	132	184	181	146	125	237	133	175
1945	167	162	192	136	194	181	148	127	235	139	176
1946	173	163	198	150	207	184	150	129	241	142	175
1947	189	169	204	159	239	209	160	137	274	147	182
1948	216	186	241	169	359	272	173	149	311	161	196
1949	227	202	247	182	384	301	178	157	308	164	205

*Wholesale prices: index compiled by the Board of Trade, London, with base switched from 1930=100 to 1938=100.
†Retail prices: estimates by London and Cambridge Economic Service, London School of Economics, (see *Bulletin* for Feb. 1949); clothing and household goods is a combination of three groups (clothing; household durables; miscellaneous goods) in the interim index of retail prices compiled since 1947 by the Ministry of Labour, London.

The annual rates of change suggest that the amplitude of the later swings was greater. It is, however, impossible to generalize on the basis of so limited a number of long swings, particularly since there is such a great margin of error in the earlier index numbers.

Furthermore, it must be borne in mind that the calculations are based on the differences between the index numbers at the terminal dates of each period and do not necessarily characterize the period as a whole. Thus, for example, while it is true that the decline in the index from 154 in 1920 to 65 in 1932 represented an annual rate of decline of 6.9%, the significant declines in the index came in 1920–21 and 1929–32; the computed average decline is a poor description of the behaviour of prices during the period as a whole, particularly for 1921–25 when the index rose slightly. The figures showing the fluctuations in the index from trough to peak and peak to trough must therefore be interpreted in the light of the original data in fig. 1.

The periods of upswing from the troughs to the peaks correspond to what have sometimes been referred to as long periods of "predominantly good times" and the downswings from peaks to troughs to what have been described as long periods of "predominantly bad times." There is, indeed, some evidence that the contraction phase of business cycles was shorter during the long upswings both in terms of absolute length of time and as a proportion of length of the full cycle. Despite the likely existence of this relationship, however, it is impossible to state any simple causal connection between the duration of business cycles and the long-term movement of prices.

The first of the upswings indicated above, 1789–1814, was associated with the effects of the Napoleonic Wars and the Industrial Revolution; the second, 1843–64, with the discovery of gold, the building of railroads and the Civil War; and the third, 1896–1920, with electrification and motorization and World War I. The fourth, 1932–48 (if, indeed, 1948 proved to mark the end of this upswing), reflected World War II and the greatly expanded sphere of governmental activity in the economy. The downswings were generally explained in terms of the eventual loss of impetus in the technological innovations which played the major role in the preceding upswing.

Changes in Price Relationships.—The amplitude of fluctuations in the individual price series may have been greater than that of the composite index; unless the peaks and troughs of the various constituent prices come simultaneously, an index representing the average of all the prices would not reveal fully the extremes of the actual fluctuation in prices. Furthermore, the over-all index cannot show the changing relative positions of individual commodity prices or groups of prices in the whole system of prices. In any given movement of the price index, all prices will not, of course, change in the same proportion. Some idea of the changes in price relationships that occurred during the various shifts of the over-all index may be obtained by studying Table I, which shows the index numbers for the ten major commodity groups in the BLS wholesale price index.

In the lower part of Table I, the 1948 group indexes have been expressed as percentages of the same indexes for 1890 (the first year for which the BLS official group indexes were available), for each peak and trough year (1896, 1920 and 1932), and for an intermediate year between each trough and peak (1913, 1926 and 1939). The results show that the major difference in the structure which prevailed after World War II from the price structures of the 50 years preceding that war was the rise in the prices of farm products and foods relative to other commodity prices. This shift in exchange values in favour of farm products was the result of government agricultural policies, high domestic incomes and large exports.

Another group index that rose by a much greater percentage than the over-all index was the building materials price index. This was attributable chiefly to the sharp rise in the price of lumber between 1939 and 1948; lumber prices approximately tripled while most of the other types of building materials (cement, brick and tile, etc.) did not even double in price. The commodity groups that had low values in terms of other goods in 1948 relative to their exchange values of former years were metals and metal products and chemicals (comparisons for this group were of limited validity because its composition was not the same before and after 1926). Hides and leather products and fuel and lighting materials had lower relative prices in the first 10 or 20 years of the period 1890–1949 than in the rest of the period. Among the major economic classes of commodities, the greater rise in raw material prices relative to manufactured product prices reflected to a large extent the substantial rise in farm-product prices.

These changes and the even greater diversity of changes in relationships among individual commodity prices both influence the price level and are influenced by the price level. Changes in the supply and demand conditions for the individual commodities or for groups of commodities may be active factors in affecting the general level of prices. On the supply side, one of the most important factors affecting prices is technological change. Because the rate of technological change is uneven and affects particular industries rather than all industries at once, relative prices are often altered. This is illustrated by the behaviour of prices of tires and tubes in 1939–48. In 1948 these prices were not much different in dollar terms from 1939; since they failed to keep pace with the rise of other commodity prices during this ten-year period, tire and tube prices fell relative to other commodity prices. An example of the influence of demand upon relative prices during the same period was provided by the great increase in lumber

TABLE VI.—*Exchange Rates, 1921–49*
(U.S. cents per unit of national currency)

Year	Czecho-slovakia (koruna)	Denmark (krone)	France (franc)	Italy (lira)	Nether-lands (guilder)	Spain (peseta)	Sweden (krona)	Switzer-land (franc)	U.K. (£)	Aus-tralia (£A)	Canada ($)	S. Africa (£[S.A.])	Egypt (£E)	India (rupee)	Japan (yen)	Argen-tina (peso)	Peru (sol)
1913 (parity)	20.30	26.8	19.3	19.30	40.2	19.3	26.8	19.3	487	487	100	487	—	—	49.8	42.4	48.7
1921	1.26	17.8	7.46	4.30	33.6	13.5	22.6	17.4	385	379	89.6	—	—	—	48.7	32.1	37.6
1922	2.41	20.9	8.19	4.75	38.5	15.5	26.2	19.1	443	441	98.6	449	—	—	48.1	36.0	38.5
1923	2.96	18.4	6.07	4.60	39.1	14.5	26.6	18.1	457	460	98.0	466	—	—	48.6	34.6	41.6
1924	2.95	16.7	5.23	4.36	38.2	13.3	26.5	18.2	442	450	98.7	454	—	—	41.2	34.3	41.0
1925	2.97	21.1	4.77	3.98	40.2	14.3	26.9	19.3	483	489	100.0	484	—	—	41.0	40.2	40.6
1926	2.96	26.2	3.25	3.89	40.1	14.9	26.8	19.3	486	486	100.0	483	—	—	47.1	40.5	37.5
1927	2.96	26.7	3.92	5.15	40.1	17.1	26.8	19.3	486	485	100.0	484	—	—	47.4	42.3	37.4
1928	2.96	26.7	3.92	5.26	40.2	16.6	26.8	19.3	487	485	99.9	484	—	—	46.4	42.4	39.7
1929	2.96	26.7	3.92	5.24	40.2	14.6	26.8	19.3	486	483	99.3	483	—	—	46.1	41.8	40.0
1930	2.96	26.7	3.92	5.24	40.2	10.4	26.8	19.4	486	471	99.8	484	—	—	49.4	36.5	36.1
1931	2.96	24.7	3.92	5.22	40.2	9.5	24.9	19.5	486*	411	99.3	483*	—	—	48.9	28.9	27.9
1932	2.96	18.7	3.93	5.14	40.3	8.0	18.4	19.4	350	306	88.1	482	—	—	28.1	25.7	21.3
1933	3.68	18.5	4.86	6.44	49.8	10.3	21.5	24.2	422	277	92.0	482	—	—	25.2	30.9	18.8
1934	4.23	22.3	6.57	8.56	67.6	13.5	25.9	32.4	504	390	101.0	501	—	—	29.5	25.3–33.6†	23.0
1935	4.15	21.8	6.60	8.24	67.6	13.6	25.2	32.5	490	392	99.5	487	—	—	28.6	26.3–32.7	23.9
1936	3.98	22.1	5.98	7.03	68.0*	13.5	25.6	32.7*	497	394	99.9	494	510	37.4	29.0	27.8–33.2	24.9
1937	3.49	22.0	3.98	5.26	54.9	11.7	25.4	22.9	494	393	100.0	492	507	37.2	28.8	30.0–33.0	25.3
1938	3.46	21.8	2.86	5.26	54.9	11.6	25.1	22.9	489	396	99.4	486	501	36.4	28.5	25.5–32.6	22.4
1939	3.41*	20.3	2.64*	5.20	53.2	10.7	24.0	22.5	467*	376	99.6*	443	457	33.0	26.0	23.1–30.6	18.7
1940	—	19.3	2.28*	5.05	53.2	9.3	23.9	22.7	403	328	90.5	403	413	30.1	23.4	22.0–29.8	16.2
1941	—	19.3	2.28	5.07	53.2*	9.1	23.9	23.2	403	322	90.5	403	413	30.1	23.4*	20.3–29.8	15.4
1942	—	20.9*	2.28	5.26	—	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1943	—	20.9	2.28	1.00*	—	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1944	—	20.9	2.28	1.00	—	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1945	2.00*	20.9†	2.01	1.00	37.7*	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1946	2.00	20.8	.84	—	37.7	9.1	23.9*	23.3	403	322	100.0*	403	413	30.1	—	20.3–29.8	15.4
1947	2.00	20.8	.84	—	37.7	9.1	27.8	23.3	403	322	100.0	403	413	30.1	—	20.3–29.8	15.4
1948	2.00	20.8	.47*	.18	37.7	9.1	27.8	23.3	403	322	100.0	403	413	30.1	—	20.0–29.8	15.4
Aug. 1949	2.00	20.8	.47	.18	37.7	9.1	27.8	23.3	403	322	100.0	403	413	30.1	—	20.0–29.8	15.4
Sept. 1949	2.00	14.4	.29	.16	26.3	—	19.3	23.1	280	223	90.5	280	287	20.9	—	—	15.4

Figures are officially established rates or market rates (mid-point between buying and selling rates). From 1928, data from International Monetary Fund quoted in U.N. *Statistical Yearbook*; before 1928 from League of Nations *Statistical Yearbook*.
*Relating to part of year only. †Argentina, from 1934: different rates used for various transactions and a range (lowest—highest rate) shown.

prices noted above; these increases might be attributed to the large quantities of lumber demanded during the war and postwar construction booms.

Relative prices are also influenced by changes in the price level, because some goods and groups of goods respond more readily than others to such changes. In this connection, it is interesting to contrast the price behaviour of the farm-product group and metals and metal-product group in Table I. In the 60-year period 1890–1949, the latter index numbers (annual averages) fell within a 30-point range (80 to 110) in 41 of the years; only 27 of the annual farm-product price index numbers could be found in any 30-point range, and even the range in which this number of observations was found (40 to 70) was typical only of the early years of the period. Such differences in price fluctuations are discussed below in connection with cyclical changes in prices.

F. C. Mills, studying the period 1893–1926 in *The Behavior of Prices*, estimated that about 40% of the shifts in relative prices could be attributed to changes in the general level of prices (assuming that the causal relation runs from price-level change to alterations of price relationships), while the other 60% would have occurred even if the general level of prices had been constant.

So much for the pattern of wholesale commodity prices, and how this pattern altered between 1890 and 1950. What happened to the relationship of wholesale commodity prices to other prices in the economy? The data required to answer this question, available only since 1913, may be found in Table II. In the lower part of this table, the 1948 indexes have been expressed as percentages of the indexes for five earlier years in order to facilitate the comparison of the 1948 price structure with former ones.

The relative increase in farm-product prices noted in connection with the analysis of wholesale commodity prices is reflected in Table II in two ways: (1) the prices received by farmers had increased more between almost any of the five base dates and 1948 than any other wholesale or retail commodity price series in the table; and (2) among the consumers' price groups, food was relatively more expensive, compared with other living essentials, than it had been in the 50 years before World War II.

Perhaps the most significant fact is the notably greater rise in average hourly earnings of production workers in manufacturing compared with the rise in consumers' prices; the spread between these two increases is a measure of the rise in average hourly earnings in real terms (*i.e.*, power to buy goods). The total increase in real earnings is not, of course, fully indicated in these figures; less unemployment existed in 1948 than in some of the base periods.

The wholesale price index had wider amplitude of fluctuation than the consumers' price index (by about 50%). Both types of commodity prices were high in 1948 relative to prices of common stocks, an interesting phenomenon in view of the high profit levels that prevailed. Rentals paid by consumers increased less than any other series in Table II. Construction costs had not increased as much as wholesale commodity prices since 1939, but their increase was greater if any of the earlier base periods is used.

THE CYCLICAL BEHAVIOUR OF PRICES

There is a close correspondence between the movements of commodity prices and the business cycle turning points used by A. F. Burns and W. C. Mitchell (*Measuring Business Cycles*, p. 78 [1946]). Mills, who studied 209 price series for cyclical variation during the ten cycles from the revival of 1892 to the revival of 1924, found that an average of 71% of the series had upturns during revivals and downturns during the succeeding recessions (*op. cit.*, pp. 387–389). Of course, some individual price series do not conform to the general business cycle at all, and there have been times when even the over-all wholesale price index moved in a different direction from business activity (*e.g.*, 1938–39).

The fluctuations observed in the business cycle are, of course, in the broadest sense changes in aggregate values produced, traded or consumed; these changes in values may be regarded as the net results of changes in prices and quantities. Thus even as a symptom of what is transpiring in the business cycle, price changes must be considered in connection with concomitant changes in quantity.

The price and quantity movements of 64 commodity series during business cycles were analyzed by Mills in *Price-Quantity Interactions in Business Cycles* (1946). For the composite of all 64 commodities and of all cycles, the movement of prices and quantities at various points in the general business were summarized by expressing each of these series as a percentage of its average for the whole cycle:

	Prices	Quantities
Initial trough	94	90
Peak	112	112
Final trough	90	94

TABLE VII.—*Wholesale* and Retail† Prices, Certain Countries, 1913–14 and 1921–38*

Year	Czechoslovakia		Denmark		France		Italy		Netherlands		Spain		Sweden		Switzerland	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail
1913	—	—	100	—	100	—	100	—	100	100	100	—	100	—	—	—
1914	100	100	—	100	102	100	—	100	109	—	101	100	116	100	100	100
1921	—	—	—	225	345	309	531	559	182	202	190	189	222	247	200	200
1922	—	—	—	199	327	296	508	515	160	182	176	181	173	198	158	164
1923	—	—	—	207	419	334	512	499	151	174	172	177	163	178	170	164
1924	986	695	—	216	489	369	512	527	156	177	182	184	162	174	171	169
1925	997	724	210	211	550	400	596	611	155	179	185	189	161	176	161	168
					‡											
1926	944	716	163	184	695	505	603	654	145	168	175	187	149	172	145	162
1927	968	747	153	177	642	514	495	588	148	168	168	189	146	171	142	160
								‡								
1928	969	748	153	175	645	519	462	558	149	169	163	176	148	172	145	161
1929	913	744	150	173	627	556	446	570	142	168	168	181	140	170	141	161
							‡		‡							
1930	811	727	130	165	554	581	399	552	128	161	167	186	122	165	127	158
1931	738	695	114	155	502	569	348	497	109	151	169	194	111	159	110	150
1932	682	682	117	155	427	526	326	473	92	141	167	187	109	157	96	138
1933	658	675	125	161	398	520	297	455	90	139	159	180	107	153	91	131
1934	678	667	137	167	376	516	290	430	90	140	164	184	114	155	90	129
1935	704	687	140	172	338	483	319	437	88	136	165	179	116	156	90	128
1936	706	693	146	175	411	507	358	471	91	132	167	—	120	158	95	130
1937	748	702	165	181	581	619	416	516	108	137	189	—	137	163	111	137
1938	742	734	156	183	653	698	447	558	102	139	212	—	130	167	107	137

Year	Australia		Canada		S. Africa		Egypt		India		Japan		Argentina	Peru	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Wholesale	Retail
1913	100	—	100	—	100	—	—	—	—	—	100	—	100	100	100
1914	106	100	102	100	97	100	100	100	100	100	97	100	101	104	104
1921	175	165	172	165	160	162	173	196	178	173	200	—	143	205	199
1922	162	146	152	152	128	135	146	176	176	164	196	236	130	190	190
		‡													
1923	179	145	153	152	127	131	132	162	172	154	199	221	135	189	180
1924	173	143	155	148	129	133	143	161	173	157	207	221	145	192	187
1925	170	144	160	150	128	133	152	165	159	155	202	218	147	202	200
1926	168	146	156	152	123	131	132	160	148	155	179	199	133	203	201
1927	167	145	153	149	124	131	121	153	148	154	170	189	130	203	194
1928	165	146	151	150	120	131	120	152	145	147	171	184	131	192	181
1929	166	149	149	151	116	131	116	151	141	149	166	181	128	186	177
1930	147	141	135	150	103	128	104	148	116	137	137	155	122	178	169
1931	131	127	113	136	99	123	97	138	96	110	116	136	118	175	158
1932	130	121	104	123	92	118	84	132	91	109	122	137	119	170	151
1933	130	117	105	117	93	115	71	125	87	102	136	146	114	180	148
1934	131	119	112	119	102	116	87	127	89	97	134	149	130	188	150
1935	134	121	112	120	95	116	95	130	92	101	140	151	129	189	152
1936	140	123	116	122	99	116	85	130	92	102	149	159	132	192	160
1937	148	127	132	126	101	119	88	128	102	107	180	174	150	205	171
1938	148	130	123	127	104	123	92	131	96	107	190	199	140	205	173

*Wholesale prices: official index numbers, based on or with base switched to average 1913 or 1914=100 with two exceptions, the index for Italy being computed by Riccardo Bachi (1921–29) and that for Japan by the Bank of Japan. The index numbers relate to general wholesale prices except for Australia (Melbourne only), Egypt (Cairo only), India (Calcutta only) and Japan (Tokyo only).

†Retail prices: official index numbers of the cost of living or retail prices to working-class families based on or with base switched to average 1914 or July 1914=100 except those for the Netherlands (average 1911–13=100) and Peru (average 1913=100). The index for Japan computed by the Bank of Japan. Some index numbers relate to the principal city, others to a group of large towns in the country concerned. All index numbers comprise prices of food, rent, fuel and clothing except those for Spain (food and fuel only) and Japan (rent excluded). Data extracted from the League of Nations *Statistical Yearbook*.

‡Important break in the comparatibility of series of index numbers.

The average amplitude of each phase of the composite cycle was thus 20% for both prices and quantities. However, in expansion, prices rose only 80% as much as quantities did, but in contraction they declined 23% more than quantities. Also, quantities tended to rise in the final stage of contraction while prices were still falling. About five-sixths of the commodities studied conformed to the cycle, but with wide diversity in amplitude of price and quantity movements. For farm products, foods, consumers goods and nondurable goods, prices varied more than quantities during the course of the cycle, but the combined variation of both price and quantity (*i.e.*, value) was characteristically low. On the other hand, for durable goods, capital equipment and nonfarm products, prices were relatively stable and cyclical influences were reflected in relatively large changes in quantities.

Mills pointed out that the groups of commodities with flexible prices are those close to the initial extractive stages or those close to the final stage of consumption. The stability of output in the extractive industries and the relatively stable character of consumption (especially of nondurables) throws the burden of cyclical adjustment upon price.

Although there is general agreement that certain industries adjust to falling demand primarily through reduction in output with prices remaining relatively stable while in others the reverse is true, not all students interpreted the underlying factors in the same terms as Mills. G. Means, for example, attributed the inflexibility of certain prices mainly to control over prices placed in the hands of business administrators in industries characterized by a relatively small number of sellers. Means' measure of price flexibility was based on frequency of price change. According to this criterion, most commodity prices during the period 1926–33 were either very flexible or very inflexible; few fell in the middle range ("Industrial Prices and Their Relative Inflexibility," *Senate Document No. 13*, 1st session, 74th congress [1935]). Those prices changing least frequently were found to have the smallest amplitude of fluctuation (S. Nelson and W. Keim, "Price Behavior and Business Policy," Temporary National Economic Committee, *Monograph No. 1*, p. 170 [1940]).

Price Changes in World War II.—Some aspects of the impact of World War II on the U.S. price structure have already been mentioned. The peak year of the price swing associated with World War II was in 1948 when the wholesale price index averaged 165 (1926=100). (With the outbreak of the Korean war in the middle of 1950, the index began another upswing.) This was almost double the level of 1941, the year of Pearl Harbor, and more than double the average for 1939, the year of the beginning of hostilities in Europe. The rise in the index associated with World War I and with the Civil War was similar in magnitude to that of World War II, but the more than doubling of the index occurred over a somewhat shorter span of years (1861–64 and 1915–20). The consumers' price index rose by more than 70% between 1939 and 1948; it had doubled between 1914 and 1920. The price decline in the year following the peak year was much more moderate after World War II than it was after World War I. The record of the later of the two wars was also unique in that price increases were held in check with remarkable success by price controls during the four years of actual hostilities despite the shortages of materials and labour involved in the unprecedented production of the war economy; in 1945, the year hostilities ended, the wholesale price index averaged 106 compared with 87 in 1941 and 77 in 1939, and the

increases in the consumers' price index were comparable.

As a matter of fact, the wartime price increase in the United States was less than that of almost all other countries (Canada, and if consumers' prices are taken into account, possibly Australia and New Zealand, were the chief exceptions). The great inflation in U.S. prices came in the three years after the end of the fighting, particularly after the abandonment of price controls in mid-1946. This rise brought the total increase in U.S. prices since 1939 beyond the increases that had occurred in most nations of the British Commonwealth, the Scandinavian countries and Switzerland. Elsewhere, the 1939–48 price inflation was generally greater than in the U.S.

BIBLIOGRAPHY.—U.S. Bureau of Labor Statistics, Annual Bulletins on Wholesale Prices; F. C. Mills, *The Behavior of Prices* (1927), *Price-Quantity Interactions in Business Cycles* (1946); W. C. Mitchell, "The Making and Using of Index Numbers," U.S. Bureau of Labor Statistics *Bulletin 284*, part 1 (reprinted as *Bulletin 656*); A. C. Neal, *Industrial Concentration and Price Inflexibility* (1942); U.S. Department of Commerce, *Historical Statistics of the United States, 1789–1945* (1949). (I. B. K.)

UNITED KINGDOM

The movement of the general level of wholesale prices in the U.K. during the 19th century, between the close of the French Wars and the South African War, can be summarized best by reference to three periods. Between 1820 and 1850 there was a general downward movement, combined with considerable fluctuations, from about 155 in 1820 to about 90 in 1850 (1913=100). From 1850 to 1870 the price level was first raised and then maintained, apart from fluctuations, as a result of great economic developments (in industry, transport, etc.) backed by the new supplies of gold from California and Australia. The earlier downward trend was resumed after 1870, when the level was around 115 (1913=100), until a low point of a little over 70 was reached in 1896. Before the end of the century, therefore, wholesale prices in general were less than half the level ruling immediately after Waterloo.

Following the South African War and the development of the South African gold fields, wholesale prices moved upward fairly steadily until 1914. The immediate effect of the outbreak of war in 1914 was a sharp rise in prices. In the first three years, Aug. 1914 to Aug. 1917, wholesale prices rose by an average amount of 2% a month. Control of prices then began to take effect and there was even some decline after the armistice in Nov. 1918. The postwar rise, however, was the most rapid recorded to that date; wholesale prices increased by more than 40% in the year April 1919–April 1920. The reaction was just as spectacular and prices generally were halved by the end of 1921. The subsequent further fall, between 1924 and 1929, was caused at least in part by the restoration of the gold standard (May 13, 1925). The depression following the crisis of 1929 was severe, though the effect on wholesale prices was somewhat offset by the abandonment of the gold basis (Sept. 21, 1931). The period of 25 years 1913–38 was marked by price fluctuations of the most violent kind; but at the end of the period wholesale prices in general were little more than 5% above the level of 1913.

There were differences of great significance between the movements of wholesale prices of different groups of commodities, and between wholesale prices on the one hand and retail prices of comparable commodities on the other. The broad comparisons of greatest interest are those between the prices of foodstuffs and the prices of textiles and clothing. The relevant data for the period of nearly 60 years up to 1938 are shown in Table IV.

In the period of booms, depressions and war, 1880–1938, there is one broad conclusion which stands out—foodstuffs tended to become relatively cheaper and textiles and clothing relatively dearer. Moreover, this divergence is greater in retail prices than in wholesale prices. Retail and wholesale prices of food (and also of textiles and clothing) marched together quite closely up to 1914 but, in the general decline of prices between 1924 and 1938, wholesale prices fell more rapidly than retail. The increased margin between wholesale and retail prices arose, at least in part, because of the greater importance of distributive and marketing services. This was particularly true of textiles and clothing: in 1937–38 wholesale prices of textile materials stood approximately at the level of 1913 but retail clothing prices were more than double those of 1913. A similar comparison for foodstuffs shows a less marked difference: retail food prices in 1937–38 were about 40% above 1913 while wholesale prices of foodstuffs had risen by about 10% in the same period.

Wholesale prices of coal and retail prices of fuel showed a similar divergence. Wholesale prices of coal increased in the late 19th century but, at the end of the 1920s, they stood little higher than they were before World War I. On the other hand, retail prices of coal, gas and electricity were 70% higher in 1928–29 than in 1913. The 1930s were characterized by an upward movement in fuel prices, while other prices generally tended to fall.

The movement of prices during World War II and the postwar period can be followed with the aid of index numbers of more elaborate construction than those used for earlier periods. The data are summarized in Table V. Changes in the general level of wholesale prices in the two World Wars were broadly similar (*see* fig. 3). According to the index shown in Table V, there was a rapid rise in prices, amounting to about 55% in the first three years of war, 1939–42. This was followed by a period of slowly rising prices, as price control became effective, and prices at the close of the war were generally only 5%–10% higher than in 1942. The price rise was accelerated in the postwar period and amounted to 30% in the three years 1945–48. The increases shown by the index of Table V are less than those recorded by the *Statist* index (fig. 3). The latter comprises mainly the prices of basic commodities whereas the former includes prices of many manufactured products which were subject to price control and, in particular, to the effect of subsidies. The general comparison with World War I, however, is clear. Though the price movements were similar in general direction, the initial rise in prices after 1939 was more moderate, price controls were more effective and operated more quickly and there was no repetition after 1945 of the postwar crisis of 1920.

The feature of price control, in the postwar period of 1945–48 as much as during the war, was the effect of subsidies (including trading losses in government purchasing) in moderating the rise in prices. Subsidies were largely, though by no means entirely, concentrated on the main foodstuffs and they affected both wholesale and retail prices. If a range of prices of food products is taken for comparison at wholesale and at retail, the following results (in round figures) are obtained:

Prices in 1948 (1938=100)		
	Wholesale	Retail
Prices of food products before subsidies . .	255	200
Prices of food products after subsidies . .	175	150

Source: R. G. D. Allen, "Wholesale Prices, 1938–48," *Economic Journal* (London, 1949).

A similar result is found for clothing prices in the period before the removal of clothing subsidies at the beginning of 1948. Subsequently, the continued operation of the "utility" clothing scheme acted as a cushion in absorbing part of the rise in prices of textile materials. Another effective group of subsidies was that on iron and steel products, taking the form of trading losses in government purchases of imported ores, scrap, pig iron and steel.

The general upward movement in prices continued until the middle of 1948 when there were definite signs of a downturn in the world prices of foodstuffs and raw materials. The easing of world prices continued into 1949 but the effect on British prices, at wholesale and at retail, was more than counterbalanced by two particular factors. The first was the policy of limiting the cost of subsidies, introduced early in 1949 with increases in the price of iron and steel products and of certain foodstuffs. The second was the devaluation of sterling (Sept. 18, 1949) which was followed by rises in the sterling prices of many imported commodities and then by rising domestic prices, both wholesale and retail.

OTHER COUNTRIES

The course of prices in various countries can only be assessed and compared after reference to the rates of exchange between national currencies. A suitable standard of comparison is the course of prices in the U.S. and the rates of exchange required are then the rates between various national currencies and the U.S. dollar (*see* Table VI).

As an illustration of the relevance of rates of exchange, prices in France, expressed in terms of the French franc and related to 1913 as a base year, should be considered. At parity in 1913 the French franc was equivalent to 19.3 U.S. cents. The rate of exchange varied after World War I before settling down, in 1927–31, at the devalued rate of 3.92 cents per franc. Later, on the devaluation of the dollar, the franc appreciated and the rate of exchange in 1934–35 was 6.60 cents per franc. Wholesale prices in the U.S. varied as follows: 1913, 100; 1929, 137; 1935, 115.

If wholesale prices in France had followed the same course, except that they were denominated in French francs instead of U.S. dollars, then the index figure in 1929 would have been nearly five times as great as that for the U.S. (19.3 divided by 3.92) and in 1935 nearly three times as great (19.3 divided by 6.60). Wholesale price index numbers for France would then be: 1913, 100; 1929, 675; 1935, 340. The recorded levels of wholesale prices in France (in round figures)

were: 1913, 100; 1929, 630; 1935, 340.

There are many factors, such as changes in freight rates, domestic costs and taxes or subsidies, that operate to make domestic prices diverge from world or import prices. In most important countries, however, wholesale prices are in fact largely determined by world prices, and particularly by prices in the U.S., at least during periods of stable rates of exchange. The correspondence between French wholesale prices in francs and U.S. wholesale prices was close in 1929 and 1935, each year being related to 1913.

In the period between World Wars I and II the pound sterling diverged little from parity with the U.S. dollar, except during the period before the restoration of the gold standard in the United Kingdom in 1925, and again briefly about 1932 when the gold standard was suspended 18 months before the U.S. took similar action. The general movements of prices, *e.g.*, a comparison of prices in 1929 or 1938 with those of 1913, are broadly comparable in the U.K. and the U.S. without modification for changes in the sterling-dollar exchange rates. The validity of the foregoing account of price changes in the two countries is based on this fact. The same is true of other countries, such as Canada or South Africa, Denmark or Sweden, whose currencies were more or less closely related to the dollar or sterling.

In some countries, however, there were limited depreciations or appreciations of the national currencies in terms of sterling and the U.S. dollar. Australia depreciated the Australian pound in terms of sterling in 1930. In any comparison of periods before and after 1930, therefore, prices in Australia will be found to have risen more than corresponding prices in the U.K. On the other hand, the Netherlands and Switzerland did not follow the U.S. off the gold standard in 1933 and when their currencies were revalued in 1936 they did not depreciate them as far as the U.S. did. After 1933 the Netherlands and Switzerland had currencies which were appreciated relative to sterling and the U.S. dollar and their price levels were correspondingly lower. There are still other countries in which inflation following World War I proceeded much further than elsewhere. The interwar years in such countries—France and Italy being among the more important—were characterized by periods of instability followed by currency reforms and periods of greater stability. The exchange rate in terms of the U.S. dollar fluctuated between stability and instability, but always much depreciated as compared with the rate in 1913. The course of prices showed similar fluctuations but always around much higher levels (as compared with 1913) than reached in the U.K. or the U.S.

The year of highest prices after World War I was generally 1920. There was a general fall in wholesale prices from 1921, steep at first and then more gradual. In most countries the fall continued slowly until 1929, though there was a subsidiary rise in prices around 1924, followed by a fall in 1926–27. This is, in fact, the broad pattern set by the movement of prices in the U.K. and the U.S. The closeness of correspondence of price movements was greater for countries on the gold standard and these included, by 1925, the U.K., the British dominions, Sweden, the Netherlands, Switzerland and others, in addition to the U.S. There were some important deviations from the general pattern. In France and Italy in particular, depreciation of the currency relative to sterling and the U.S. dollar was resumed in 1922 and continued in the following years; the French franc and Italian lira were not stabilized until 1927–28. The fall in wholesale prices in France and Italy was halted in 1922 and prices then rose rapidly in France, and more moderately in Italy, until 1926, in which year the price level was above that reached immediately after the war. From 1926, prices in both countries, as in other countries, decreased slowly until 1929. In Japan prices remained high in the whole period from 1921 to 1925 and only began to fall with the stabilization of the currency in 1926.

After the stock market crash in the U.S. late in 1929, wholesale prices declined everywhere, following to a greater or less extent the rapid fall in prices in the U.S. The gold standard was suspended in the U.K. in Sept. 1931, and in the U.S. in March 1933. The devaluations of the two currencies were approximately equal in amount so that they bore about the same relation to each other after 1933 as in 1929. In both countries, wholesale prices fell to a low point in 1932–33 when their level was not quite 70% of the 1929 level. The effect of the world-wide depression on prices in other countries was varied but three broad groupings can be distinguished.

In a first group are countries which devalued their currencies about the same time as the U.K. in 1931. Some countries devalued to the same extent but others, like Sweden and Denmark, and also Australia, decided upon a greater devaluation. The currencies of these latter countries depreciated in terms of the U.S. dollar, not only in 1931–33, but also after the devaluation in the U.S. in 1933. This depreciation of national currencies offset to some extent the fall in world prices and, though the low point of wholesale prices was still reached about 1932, the level was 75%–80% of 1929 rather than 70% or less. Japan followed much the same course; but wholesale prices had already fallen to 70% of the 1929 level by 1931 (before devaluation) and then recovered immediately.

In a second group of countries, represented in Tables VI–VIII by Spain, Argentina and Peru, the national currencies were depreciated in terms of the U.S. dollar almost continuously from 1929 to 1932–33. The offset to the fall in world prices was greater, though the currency depreciation was in no case quite sufficient to prevent wholesale prices in the national units from falling. Low points in the level of wholesale prices were reached, in 1932–33, at 90%–95% of the 1929 figures.

The last group of countries comprises those which did not devalue their currencies with the U.K. and the U.S. in 1931–33. Devaluation was postponed, generally until 1936. The Netherlands, France and Switzerland belong to this group and, despite some differences, Italy can be added to the list. The governing fact here is that national currencies appreciated in terms of sterling from 1931 and in terms of the U.S. dollar from 1933. The fall in world prices was amplified in translation into wholesale prices in national units. The fall in domestic wholesale prices was of greater extent and operated over a longer period than in the U.K. and the U.S. Low points were reached generally about 1935 and at levels between 55% and 65% of 1929.

The recovery in prices from the bottom of the depression was almost as rapid as the preceding fall and, except in France and Italy, it had come to an end by 1937. In that year wholesale prices in the U.K. and the U.S. stood about 20% above the level of 1913 and a

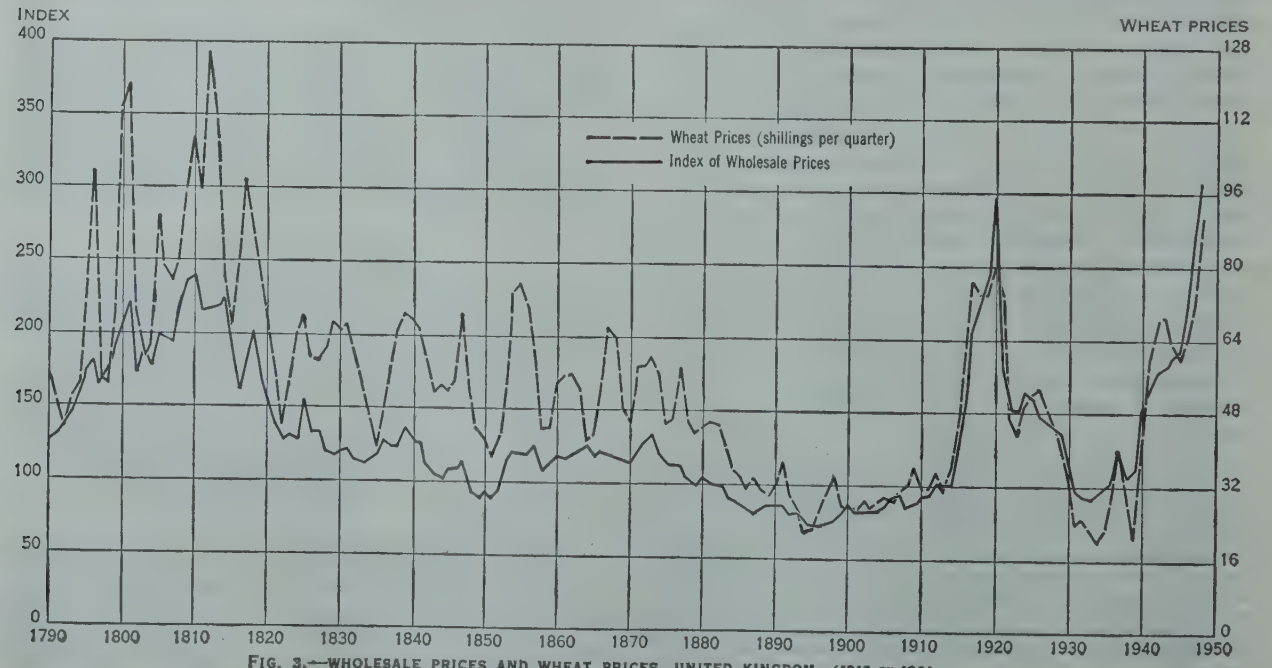

FIG. 3.—WHOLESALE PRICES AND WHEAT PRICES, UNITED KINGDOM, (1913 = 100)

TABLE VIII.—*Wholesale* and Retail† Prices, Certain Countries, 1929, 1932 and 1935–49*
(1937 = 100)

Year	Czechoslovakia		Denmark		France		Italy		Netherlands		Spain		Sweden		Switzerland	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail
1929	124	106	91	96	108	107	107	110	131	122	89	—	102	104	127	118
1932	88	97	71	89	74	94	78	92	85	102	88	—	80	96	86	101
				‡									‡	‡		
1935	93	98	84	95	58	73	76	84	81	99	87	—	88	96	81	94
1936	94	99	88	97	71	92	86	96	84	96	89	100	89	97	86	95
										‡						
1937	100	100	100	100	100	100	100	100	100	100	100	—	100	100	100	100
					‡	‡		‡								
1938	99	105	94	102	112	100	107	100	94	101	112	—	97	102	96	100
1939	113	115	99	104	118	—	112	—	97	102	128	154	101	104	100	101
1940	137	141	145	130	156	—	130	—	120	117	153	178	128	116	129	110
1941	147	165	171	150	192	—	145	—	138	134	181	232	151	133	165	127
1942	150	179	179	156	226	—	163	—	145	143	199	247	166	143	188	141
1943	152	177	180	158	263	—	245	—	148	149	222	246	172	146	196	149
1944	153	178	182	160	298	—	918	—	151	153	239	257	172	145	200	152
1945	170	188	179	162	422	—	2,203	—	167	176	265	275	170	145	198	153
							‡									
1946	297	341	176	161	728	723	3,085	2,823	232	192	318	361	163	146	193	152
1947	312	326	195	165	1,112	1,161	5,518	4,575	250	199	374	424	175	150	201	159
1948	325	322	213	170	1,924	1,842	5,824	4,644	259	205	400	453	188	157	209	164
1949	—	—	219	171	2,155	—	5,460	4,920	273	—	429	478	190	160	199	162

Year	Australia		Canada		S. Africa		Egypt		India		Japan		Argentina		Peru	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail
1929	112	118	113	120	115	110	132	117	149	—	92	—	86	108	91	104
1932	92	95	79	98	91	99	95	102	93	—	68	85	79	84	83	88
				‡			‡									
1935	90	95	85	95	94	97	101	100	93	94	78	94	86	89	92	89
1936	95	97	88	97	98	98	94	101	92	95	83	96	88	98	94	94
									‡		‡	‡				
1937	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
						‡										
1938	100	103	93	101	103	104	99	102	90	100	106	108	94	99	101	101
1939	100	105	89	100	101	104	100	102	95	100	117	119	96	101	105	100
								‡								
1940	110	110	98	104	112	107	124	112	113	106	131	141	110	103	119	107
1941	117	115	106	110	123	112	156	137	122	117	139	145	129	106	140	117
1942	132	125	113	116	138	122	200	183	149	148	149	151	107	112	175	131
														‡		
1943	138	129	118	117	150	129	254	240	215	218	158	162	180	113	201	143
1944	139	129	121	117	155	133	300	276	227	224	176	—	188	113	208	164
1945	140	129	122	118	158	137	318	291	231	222	250	—	193	135	218	182
1946	141	131	128	122	161	139	308	285	252	244	—	—	208	159	234	199
									‡							
1947	150	136	153	134	169	145	292	277	297	263	—	—	222	180	315	258
1948	170	148	181	153	181	153	316	279	367	286	—	—	—	—	396	337
1949	189	162	186	159	190	159	—	—	381	290	—	—	—	—	550	388

*Wholesale prices: official index numbers, based on or with base switched to average 1937 = 100. The index numbers relate to general wholesale prices except for Argentina (Buenos Aires only), Peru (Lima only), Egypt (Cairo only in 1929, 1932) and Japan (Tokyo only).

†Retail prices: official index numbers of the cost of living or retail prices to working-class families, based on or with base switched to average 1937 = 100, except that for Spain (July 1936 = 100). Some index numbers relate to the principal city, others to a group of large towns in the country concerned. All index numbers comprise prices of food, rent, fuel, clothing and miscellaneous items except that for France (food only, large towns). Data extracted from the U.N. *Statistical Yearbook*.

‡Important break in the comparability of series of index numbers.

little below the 1929 figures. In some countries, like the Netherlands and Switzerland, whose currencies appreciated in relation to sterling and the U.S. dollar in the 1930s, the 1937 level of wholesale prices was rather lower—a little above the 1913 level but 20%–25% below 1929. On the other hand, in countries like Spain, Argentina and Peru where the national currency continued to depreciate in the late 1930s, wholesale prices in 1937 stood higher, often at levels about double that of 1913 and well above 1929. The price situation in France, and to a lesser extent in Italy, was exceptional in the years immediately before World War II. As in the Netherlands and Switzerland, the rise in prices began late because of postponed devaluations of currency. But in France and Italy the revaluation of the currency was much more drastic and the price rise from 1936 was rapid and also continued beyond 1937. By 1939, the level of wholesale prices was above that of 1929 but the process of adjustment was not complete and prices would probably have risen further even if war had not intervened.

Early in World War II, most countries devalued their currencies or allowed them to depreciate in terms of the U.S. dollar; after the war there were many adjustments, a few upward but most downward in relation to the dollar. The position in 1948 was that a small group of countries, including Canada, Sweden and Switzerland, had maintained or restored their currencies to parity with the U.S. dollar. Another group, including the Netherlands and Denmark as well as the countries of the sterling area, had devalued to a moderate amount in relation to the U.S. dollar. The difference was larger in Spain and many countries of Latin America, following long periods of almost continuous depreciation in terms of the dollar. The most drastic devaluations of all were in the French franc and Italian lira, occurring for the most part after the war.

The relative levels of wholesale prices in the various countries after the war were quite largely dependent on these currency adjustments, though there were considerable divergencies from the general pattern. Prices rose during the war and even more sharply in the early postwar years. By 1948 wholesale prices in the U.S. were rather less than double those in 1937; in the U.K. the change was somewhat greater, the 1948 price level being a little more than double that of 1937. The position in the British dominions, Denmark, Sweden and Switzerland was broadly the same, though there were some variations; for example, the price increase from 1937 in Australia was relatively small and in Switzerland relatively large. In the Netherlands, the price level in 1948 was higher, about two and one-half times the 1937 figure, following a rapid rise after liberation of the country. In Spain, and in some Latin American countries for which data were available, wholesale prices in 1948 were between three and four times the level of 1937, as were prices in Egypt and India. The most striking effects of inflation and currency devaluation are to be seen in price changes in France and Italy. French wholesale prices in 1945 were already more than 4 times those of 1937, but in 1948 they were about 20 times the 1937 figure and still rising. It was not until 1949 that prices in France were brought under control. The inflation was even more rapid in Italy, particularly between 1944 and 1947, and wholesale prices in lire reached a level nearly 60 times that of 1937. A greater degree of stability in Italian prices was attained in 1948 and 1949; despite some fluctuations, the general rise in prices was halted in these years.

The countries of the sterling area, following the lead of the U.K., devalued their currencies in terms of the U.S. dollar in Sept. 1949. The currencies of most countries in western Europe were devalued at the same time, although not all to the same extent as sterling (*see* Table VI). Wholesale prices in these countries rose immediately, reversing a tendency toward lower prices which had become evident earlier in 1949, and which continued throughout the year in the U.S.

There is much less correspondence between retail prices in different countries (allowance being made for exchange rates) than between prices at wholesale. Many prices at retail are less dependent upon world prices of commodities and some are almost completely insulated against price changes outside the country concerned. Retail prices of commodities are influenced by domestic costs, controls, subsidies and taxation, and index numbers of retail prices, generally relating to the cost of living of working-class families, include rent and other services. A general pattern, however, does emerge. Following the boom and collapse after World War I, retail prices were generally higher (relative to 1913–14) than wholesale prices and the difference was accentuated during the interwar period. On the other hand, retail prices generally rose less between 1937 and 1948 than wholesale prices. This

was largely the result of price controls, particularly on rents as well as important commodities, and to the continuation after World War II of wartime policies of subsidizing foodstuffs and other commodities purchased by working-class families. In those countries where wholesale prices in 1948 were about double those in 1937, retail prices had generally increased by about 50%–80% in the same period.

International comparisons of the purchasing power of national currencies are peculiarly difficult to make. The level of retail prices in one country needs to be compared, with allowance for the exchange rate, with the level of retail prices in another country; it is not sufficient to compare the movements of retail prices over time in one country with similar movements in another country. The most complete calculations are those made by Colin Clark (see *The Conditions of Economic Progress,* [London, 1940]). The following figures are his computations, taken from *Review of Economic Progress* (Queensland Bureau of Industry, published by Macmillian & Co., Ltd., Jan. 1949):

Comparative retail price levels (U.S.A.=100)

	1929	1946-47
Denmark	85½	103
France	73	—
Italy	95	—
Netherlands	74	85
Sweden	100	119
Switzerland	104½	118
United Kingdom	85	77½
Australia	115	72
Canada	89	81
South Africa	101½	90
Argentina	—	75

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PRICHARD, JAMES COWLES (1786–1848), English physician and ethnologist, was born on Feb. 11, 1786, at Ross, Herefordshire. He adopted medicine as a profession mainly because of the facilities it offered for anthropological investigations. He took his M.D. at Edinburgh, afterwards reading for a year at Trinity College, Cambridge, whence, joining the Church of England, he migrated to St. John's College, Oxford, afterwards entering as a gentleman commoner at Trinity College, Oxford, but taking no degree in either university. In 1810 he settled at Bristol as a physician, and in 1813 published his *Researches into the Physical History of Man.* The central principle of the book is the primitive unity of the human species, acted upon by causes which have since divided it into permanent varieties or races.

In 1843 was published his *Natural History of Man.* Prichard may fairly be called the founder of the English branch of the sciences of anthropology and ethnology. In 1811 he was appointed physician to St. Peter's hospital, Bristol, and in 1814 to the Bristol infirmary. In 1822 he published a *Treatise on Diseases of the Nervous System,* and in 1835 a *Treatise on Insanity and other Disorders affecting the Mind,* in which he advanced the theory of the existence of a distinct mental disease, "moral insanity." In 1842, following up this suggestion, he published *On the different forms of Insanity in relation to Jurisprudence designed for the use of Persons concerned in Legal Questions regarding Unsoundness of Mind.* In 1845 he was made a commissioner in lunacy, and removed to London. He died there on Dec. 23, 1848. At the time of his death he was president of the Ethnological Society and a fellow of the Royal Society.

See Memoir by Dr. Thomas Hodgkin (1798–1866) in the *Journal of the Ethnological Society* (Feb. 1849); Memoir read before the Bath and Bristol branch of the Provincial Medical and Surgical Association (March 1849) by Dr. J. A. Symonds *Journ. Eth. Soc.,* (1850); *Prichard and Symonds in Special Relation to Mental Science,* by Dr. Hack Tuke (1891).

PRICKLY ASH (*Zanthoxylum americanum*), a North American shrub or small tree of the rue family (Rutaceae), called also toothache tree, found in woods and thickets from Quebec to Minnesota and southward to Virginia and Missouri. While usually a shrub, it sometimes attains a height of 25 ft. and a trunk diameter of 6 inches. It bears alternate, pinnate leaves, composed of from 5 to 11 ovate, dark green, somewhat pointed leaflets, with the twigs and leaf-stalks usually prickly. The small greenish flowers, which appear before the leaves in early spring, are borne in short axillary clusters; the fruit is a black ellipsoid capsule about ⅛ in. long, containing one or two seeds.

The similar but larger Herculesclub (*Z. clavaherculis*), known also as sea ash and pepperwood, occurs along streams from southern Virginia to Florida west to Kansas and Texas.

PRICKLY LETTUCE (*Lactuca scariola*), an annual or biennial herb of the family Compositae, closely allied to the garden lettuce (*q.v.*), native to Europe and widely distributed in temperate regions as a naturalized weed. It is a whitish green, usually smooth plant, with a stiff, erect stem, 2 to 7 ft. high, bearing oblong, more or less toothed or cut leaves, with spiny midribs and edges, usually clasping the stem by a more or less eared or heart-shaped base. The very numerous heads of yellow flowers are borne in a large open panicle.

The plant is noteworthy in that the leaves exhibit a marked tendency to become vertical. Moreover, when growing in open places, equally exposed to the sun during either half of the day, the vertical leaves often assume a north and south direction. Because of this characteristic the designation compass-plant is sometimes applied to this species of lettuce, as it also is to various other plants of similar habit.

PRICKLY PEAR, the name given to cacti of the genus *Opuntia,* from the appearance of their fruit. There are about 250 species, all originally American, but several have been introduced elsewhere and, in some places (*e.g.,* Australia), have overrun the countryside. Most species have flattened, jointed stems, and the flowers are white or red. The prickly pear proper is *O. vulgaris; O. Ficus-indica* is Indian fig. The fruit of both of these forms is edible. *O. subulata* is remarkable in that the leaves are large and functional. From *O. tuna,* the tuna hedges are grown in the West Indies, where it is also used as a food plant for the cochineal insect (*Coccus cacti*). (*See* CACTUS.)

PRIDE, THOMAS (d. 1658), Parliamentarian general in the English Civil War, is stated to have been brought up by the parish of St. Bride's, London. Subsequently he was a drayman and a brewer. At the beginning of the Civil War he served as a captain under the earl of Essex, and was gradually promoted to the rank of colonel. He distinguished himself at the battle of Preston, and with his regiment took part in the military occupation of London in December 1648, which was the first step towards bringing the king to trial. Pride is chiefly remembered for the expulsion (Dec. 6, 1648) of the Presbyterian and Royalist elements in the House of Commons. This, resolved by the army council and ordered by the lord general, Fairfax, was carried out by Colonel Pride's regiment. Taking his stand at the entrance of the House of Commons with a written list in his hand, he caused the arrest or exclusion of the obnoxious members, who were pointed out to him. After about a hundred members had been thus dealt with ("Pride's Purge"), the mutilated House of Commons proceeded to bring the king to trial. Pride was one of the judges of the king and signed his death-warrant, appending to his signature a seal showing a coat of arms. He commanded an infantry brigade under Cromwell at Dunbar and Worcester. He took no conspicuous part in Commonwealth politics, except in opposing the proposal to confer the kingly dignity on Cromwell. He was knighted by the Protector in 1656, and was also chosen a member of the new House of Lords. He died at Nonsuch House, Surrey, on Oct. 23, 1658. After the Restoration his body was ordered to be dug up and suspended on the gallows at Tyburn along with those of Cromwell, Ireton and Bradshaw, though it is said that the execution of this sentence was evaded.

See Noble, *Lives of the Regicides;* Bate, *Lives of the Prime Actors and Principal Contrivers of the Murder of Charles I.;* Carlyle, *Cromwell's Letters and Speeches.*

PRIDEAUX, HUMPHREY (1648–1724), English divine and Oriental scholar, born at Place, Cornwall, on May 3, 1648, was educated at Westminster School and Christ Church, Oxford. His

account of the famous Arundel marbles just given to the university, *Marmora Oxoniensia* (1676), won for him the favour of Heneage Finch, who secured his rapid preferment. Prideaux held several livings, was Hebrew lecturer at Christ Church (1679–86), and dean of Norwich (1702–24). He died on Nov. 1, 1724.

Prideaux's most important work was *The Old and New Testament connected in the History of the Jews* (1716), which not only displayed but stimulated research.

A volume of his letters to John Ellis, some time under-secretary of state, was edited by E. M. Thompson for the Camden Society in 1875; they contain a vivid picture of Oxford life after the Restoration. For a complete list of his printed and ms. work see *Bibliotheca Cornubiensis* (ii., 527–533 and iii. 1319).

PRIDE OF CALIFORNIA (*Lathyrus splendens*), a name given to a North American plant of the pea family (Leguminosae), native to the mountains of southern California, called also campo pea. It is closely allied to the sweet pea of the gardens, and bears showy clusters of brilliant red flowers.

PRIENE (mod. *Samsun kale*), an ancient city of Ionia on the foot-hills of Mycale, about 6 m. N. of the Maeander. It was formerly on the sea coast, but now lies some miles inland. It is said to have been founded by Ionians under Aegyptus, a son of Neleus. Sacked by Ardys of Lydia, it revived and attained great prosperity under its "sage," Bias, in the middle of the 6th century. Cyrus captured it in 545; but it was able to send twelve ships to join the Ionian revolt (500–494). Disputes with Samos, and the troubles after Alexander's death, brought Priene low, and Rome had to save it from the kings of Pergamum and Cappadocia in 155. Orophernes, the rebellious brother of the Cappadocian king, who had deposited a treasure there and recovered it by Roman intervention, restored the temple of Athena as a thank-offering. Under Roman and Byzantine dominion Priene had a prosperous history. It passed into Muslim hands late in the 13th century. The ruins, which lie on successive terraces, were excavated mainly in the late 19th century. The city, as rebuilt in the 4th and 3rd centuries, was laid out on a rectangular scheme. It faced south, its acropolis rising nearly 700 ft. behind it. The whole area was enclosed by a wall 7 ft. thick with towers at intervals and three principal gates. On the lower slopes of the acropolis was a shrine of Demeter. The town had six main streets, about 20 ft. wide, running east and west and fifteen streets about 10 ft. wide crossing at right angles, all being evenly spaced; and it was thus divided into about 80 *insulae*. Private houses were apportioned four to an *insula*. The systems of water-supply and drainage can easily be discerned. The houses present many analogies with the earliest Pompeian. In the western half of the city, on a high terrace north of the main street and approached by a fine stairway, was the temple of Athena Polias, a hexastyle peripteral Ionic structure built by Pythias, the architect of the Mausoleum. Under the basis of the statue of Athena were found in 1870 silver tetradrachms of Orophernes, and some jewellery, probably deposited at the time of the Cappadocian restoration. Fronting the main street is a series of halls, and on the other side is the fine market place. The municipal buildings, Roman gymnasium, and well preserved theatre lie to the north, but, like all the other public structures, in the centre of the plan. Temples of Isis and Asclepius have been excavated. At the lowest point on the south, within the walls, was the large stadium, connected with a gymnasium of Hellenistic times.

See Society of Dilettanti, *Ionian Antiquities* (1821), vol. ii.; Th. Wiegand and H. Schrader, *Priene* (1904); on inscriptions (360) *see* Hiller von Gärtringen, *Inschriften von Priene* (Berlin, 1907), with collection of ancient references to the city.

PRIEST, the contracted form of "presbyter" (*πρεσβύτερος*, "elder"; *see* PRESBYTER), a name of office in the early Christian Church, already mentioned in the New Testament. But in the English bible the presbyters of the New Testament are called "elders," not "priests"; the latter name is reserved for ministers of pre-Christian religions. The reason of this will appear more clearly in the sequel; it is enough to observe at present that, before our English word was formed, the original idea of a presbyter had been overlaid with others derived from pre-Christian priesthoods, so that it is from these and not from the etymological force of the word that we must start in considering historically what a priest is. The theologians of the Greek and Latin churches expressly found the conception of a Christian priesthood on the hierarchy of the Jewish temple, while the names by which the sacerdotal character is expressed—*ἱερεύς, sacerdos*—originally designated the ministers of sacred things in Greek and Roman heathenism, and then came to be used as translations into Greek and Latin of the Hebrew *kōhēn*. *Kōhēn, ἱερεύς, sacerdos,* are, in fact, fair translations of one another; they all denote a minister whose stated business was to perform, on behalf of the community, certain public ritual acts, particularly sacrifices, directed Godwards. Such ministers or priests existed in all the great religions of ancient civilization.

Early Priesthoods.—Among the Babylonians and Assyrians magic and soothsaying were intertwined with priestly functions, as was the case in early Hebrew pre-exilian days with the *Kōhēn*. The *barû* (from *barû* to see, inspect) was a soothsaying priest who was consulted whenever any important undertaking was proposed, and addressed his inquiries to Samaš the sun god (or Adad) as *bêl bîri* or lord of the oracle (accompanied by the sacrifice of lambs). (*See* OMEN and DIVINATION.)

As contrasted with the *barû* or soothsaying priest we have the *ašipu,* who was the priest-magician who dealt in conjurations (*šiptu*), whereby diseases were removed, spells broken, or in expiations whereby sins were expiated. Now, as the conjurations were addressed to the deity, *ašipu,* according to the definition given above, comes more reasonably under the category of priest. In Babylonia priesthoods were endowed with great wealth and power, and even the king stood in awe of them. (*See* Johns, *Babylonian and Assyrian Laws, Contracts and Letters,* p. 212 *sqq.*) These powerfully-organized priesthoods, as well as the elaborate nature of their ritual and apparatus of worship, must have deeply and permanently impressed the exiled Jewish community. Thus arose the more developed system of Ezekiel's scheme (xl.–xlviii.) and of the Priestly code and the high dignity which became attached to the person of the High Priest (reflected in the narrative of Uzziah's leprosy in 2 Chron. xxvi. 16–20).

Among the ancient Egyptians the local god was the protector and lord of the district. Consequently it was the interest and duty of the inhabitants to maintain the cultus of the patron-deity of their city who dwelt in their midst. Moreover, in the earlier times we find the prince of the nome acting as the High Priest of the local god, but in course of time the state, represented by the king, began to an ever-increasing degree to take oversight over the more important local cults. Thus we find that the Egyptian monarch was empowered to exercise priestly functions before all the gods. We constantly see him in the wall-paintings, portrayed as a priest in the conventional attitudes before the images of the gods. In the chief sanctuaries the chief priests possessed special privileges, and it is probable that those in the immediate entourage of the king were elected to these positions. The highest nobility in the nome sought the honour of priesthood in the service of the local deity. One special class called *kher heb* was charged with reciting the divine formulae, which were popularly held to possess magical virtue. In the middle empire (VIIth to XIIth Dynasties) the lay element maintains its position in religious cultus despite its complexity. But under the new empire (Dynasties XVIIIth and following) the professional priest had attained to ominous power. Priests increased in number and were divided into ranks; temples possessed larger estates and became more wealthy.

Ancient Greece.—Homer speaks of special priests who preside over ritual acts in the temples to which they are attached; but his kings also do sacrifice on behalf of their people. The king, in fact, both in Greece and in Rome, was the acting head of the state religion, and when the regal power came to an end his sacred functions were not transferred to the ordinary priests, but either they were distributed among high officers of state, as archons and prytanes, or the title of "king" was still preserved as that of a religious functionary, as in the case of the *rex sacrorum* at Rome and the *archon basileus* at Athens. In the domestic circle the union of priesthood and natural headship was never

disturbed; the Roman paterfamilias sacrificed for the whole family. On the other hand, *gentes* and *phratriae,* which had no natural head, had special priests chosen from their members; for every circle of ancient society, from the family up to the state, was a religious as well as a civil unity, and had its own gods and sacred rites. We cannot speak of priestly power and hardly even of a distinct priestly class.

In Greece the priest, so far as he is an independent functionary and not one of the magistrates, is simply the elected or hereditary minister of a temple charged with "those things which are ordained to be done towards the gods" (*see* Aristotle, *Pol.* vi. 8), and remunerated from the revenues of the temple, or by the gifts of worshippers and sacrificial dues. The position was often lucrative and always honourable, and the priests were under the special protection of the gods they served. But their purely ritual functions gave them no means of establishing a considerable influence on the minds of men, and the technical knowledge which they possessed as to the way in which the gods could be acceptably approached was neither so intricate nor so mysterious as to give the class a special importance. There was, indeed, one sacred function of great importance in the ancient world in which the Greek priests had a share. As man approached the gods in sacrifice and prayers, so too the gods declared themselves to men by divers signs and tokens, which it was possible to read by the art of Divination (*q.v.*). In many nations divination and priesthood have always gone hand in hand; at Rome, for example, the augurs and the *XV. viri sacrorum,* who interpreted the Sibylline books, were priestly colleges. In Greece, on the other hand, divination was not generally a priestly function, but it did belong to the priests of the Oracles. (*See* Oracle.) The great oracles, however, were of Panhellenic celebrity and did not serve each a particular state, and so in this direction also the risk of an independent priestly power within the state was avoided.

In Rome, again, where the functions of the priesthood were politically much more weighty, where the technicalities of religion were more complicated, where priests interpreted the will of the gods, and where the pontiffs had a most important jurisdiction in sacred things, the state was much too strong to suffer these powers to escape from its own immediate control: the old monarchy of the king in sacred things descended to the inheritors of his temporal power; the highest civil and religious functions met in the same persons (*cf.* Cic. *De dom.* i. 1); and every priest was subject to the state exactly as the magistrates were, referring all weighty matters to state decision and then executing what the one supreme power decreed. And it is instructive to observe that when the plebeians extorted their full share of political power they also demanded and obtained admission to every priestly college of political importance, to those, namely, of the pontiffs, the augurs, and the *XV. viri sacrorum.* The Romans, it need hardly be said, had no hereditary priests.

Aryan Religions.—In historical times the priesthood in India is rigidly confined to members of the Brahman caste. But at an earlier date the warrior caste often became priests. The power of the priesthood began with the delegation by the king of his sacrificial duties to an appointed official. This power grew with the growing importance of the sacrifice and the complication of its ceremonial. In the post-Vedic period "right" or "wrong" simply meant the exact performance or the neglect, whether intentional or unintentional—of all the details of a prescribed ritual, the centre of which was the sacrifice. At this period the priestly caste gained its unbounded power over the minds of men. For further details as to the development of the priestly caste and wisdom in India the reader must refer to Brahmanism.

Among the Zoroastrian Iranians, as among the Indian Aryans, the aid of a priest to recite the sacrificial liturgy was necessary at every offering (Herod. i. 132), and the Iranian priests (âthravans, later *Magi*) claimed, like the Brahmans, to be the highest order of society; but they did not acquire the powers of the Indian priesthood; in particular, the priesthood, as it was not based on family tradition, did not form a strict hereditary caste. Nevertheless, it formed a compact hierarchy not inferior in influence to the clergy of the Christian middle ages, had great power in the state, and were often irksome even to the great king. But the monarchs had one strong hold on the clergy by retaining the patronage of great ecclesiastical places.

The Persian religion throughout all its multitude of purifications, observances and expiations was a constant warfare against impurity, death and the devil. Amid all the ceremonialism of its priesthood there were also high ideals set forth in Zoroastrian religion of what a priest should be. Thus we read in Vendidâd xviii., "Many there be, noble Zarathustra, who bear the mouth bandage, who have yet not girded their loins with the law. If such a one says 'I am an Athravan' he lies, call him not Athravan, noble Zarathustra, said Ahura Mazda; but thou shouldst call him priest, noble Zarathustra, who sits awake the whole night through and yearns for holy wisdom that enables man to stand on death's bridge fearless and with happy heart, the wisdom whereby he attains the holy and glorious world of paradise."

Semitic Races.—Among the nomadic Semites there was no developed priesthood. Religion partook of the general simplicity of desert life; apart from the private worship of household gods and the oblations and salutations offered at the graves of departed kinsmen, the ritual observances of the ancient Arabs were visits to the tribal sanctuary to salute the god with a gift of first-fruits or the like (*see* Nazarite and Passover), and an occasional pilgrimage to discharge a vow at the annual feast and fair of one of the more distant holy places. (*See* Mecca.) These acts required no priestly aid; each man slew his own victim and divided the sacrifice in his own circle; the share of the god was the blood which was smeared upon or poured out beside the stone set up as an altar or perhaps as a symbol of the deity. We find therefore no trace of a sacrificial priesthood, but each temple had one or more doorkeepers, whose office was usually hereditary and who had the charge of the Temple and its treasures.

The sacrifices and offerings were acknowledgments of divine bounty and means used to ensure its continuance; the Arab was the "slave" of his god and paid him tribute, as slaves used to do to their masters, or subjects to their lords; and the free Bedouin, trained in the solitude of the desert to habits of absolute self-reliance, knew no master except his god. The decision of the god might be uttered in omens which the skilled could read, or conveyed in the inspired rhymes of soothsayers, but frequently it was sought in the oracle of the sanctuary, where the sacred lot was administered for a fee by the *sādin.* The sanctuary thus became a seat of judgment, and here, too, compacts were sealed by oaths and sacrificial ceremonies. These institutions, though known to us only from sources belonging to an age when the old faith was falling to pieces, are certainly very ancient. The fundamental type of the Arabic sanctuary can be traced through all the Semitic lands, and so appears to be older than the Semitic dispersion.

With the beginning of a settled state the sanctuaries rose in importance and all the functions of revelation gathered round them. A sacrificial priesthood arose as the worship became more complex (especially as sacrifice in antiquity is a common preliminary to the consultation of an oracle), but the public ritual remained closely associated with oracle or divination, and the priest was, above all things, a revealer. That this was what actually happened may be inferred from the fact that the Canaanite and Phoenician name for a priest (*kōhēn*) is identical with the Arabic *kāhin,* a "soothsayer." Soothsaying was no modern importation in Arabia; its characteristic form—a monotonous croon of short rhyming clauses—is the same as was practised by the Hebrew "wizards who peeped and muttered" in the days of Isaiah. The *kāhin,* therefore, is not a degraded priest but such a soothsayer as is found in most primitive societies, and the Canaanite priests grew out of these early revealers. In point of fact some form of revelation or oracle appears to have existed in every great shrine of Canaan and Syria, and at Hierapolis it was the charge of the chief priest, just as in the Levitical legislation.

The Hebrews, who made the language of Canaan their own, took also the Canaanite name for a priest. But the earliest forms of Hebrew priesthood are not Canaanite in character; the priest, as he appears in the older records of the time of the Judges,

Eli at Shiloh, Jonathan in the private temple of Micah and at Dan, is more like the *sādin* than the *kāhin*. The whole structure of Hebrew society at the time of the conquest was almost precisely that of a federation of Arab tribes, and the religious ordinances are scarcely distinguishable from those of Arabia, save only that the great deliverance of the Exodus and the period when Moses, sitting in judgment at the sanctuary of Kadesh, had for a whole generation impressed the sovereignty of Jehovah on all the tribes, had created an idea of unity between the scattered settlements in Canaan such as the Arabs before Mohammed never had. But neither in civil nor in religious life was this ideal unity expressed in fixed institutions, the old individualism of the Semitic nomad still held its ground. Thus the firstlings, first-fruits and vows are still the free gift of the individual which no human authority exacts, and which every householder presents and consumes with his circle in a sacrificial feast without priestly aid.

As in Arabia, the ordinary sanctuary is still a sacred stone set up under the open heaven, and here the blood of the victim is poured out as an offering to God. (*See* especially 1 Sam. xiv. 34, and *cf.* 2 Sam. xxiii. 16, 17.) The priest has no place in this ritual; he is not the minister of an altar, but the guardian of a temple, such as was already found here, and there in the land for the custody of sacred images or other consecrated things (the ark at Shiloh, 1 Sam. iii. 3; images in Micah's temple, Judges xvii. 5; Goliath's sword lying behind the "ephod" or plated image at Nob, 1 Sam. xxi. 9; no doubt also money, as in the Canaanite temple at Shechem, Judges ix. 4). Such treasures required a guardian; but, above all, wherever there was a temple there was an oracle, a kind of sacred lot, just as in Arabia (1 Sam. xiv. 41, lxx.), which could only be drawn where there was an "ephod" and a priest (1 Sam. xiv. 18, Sept., and xxiii. 6 *seq.*). The Hebrews had already possessed a tent-temple and oracle of this kind in the wilderness (Exod. xxxiii. 7 *seq.*), and ever since that time the judgment of God through the priest at the sanctuary had a greater weight than the word of a seer, and was the ultimate solution of every controversy and claim (1 Sam. ii. 25; Exod. xxi. 6, xxii. 8, 9, where for "judge," "judges," of A.V. read "God" with R.V.).

The temple at Shiloh, where the ark was preserved, was the lineal descendant of the Mosaic sanctuary and its priests claimed kin with Moses himself. In the divided state of the nation, indeed, this sanctuary was hardly visited from beyond Mt. Ephraim; and every man or tribe that cared to provide the necessary apparatus (ephod, teraphim, etc.) and hire a priest might have a temple and oracle of his own at which to consult Jehovah (Judges xvii., xviii.); but there was hardly another sanctuary of equal dignity. The priest of Shiloh is a much greater person than Micah's priest Jonathan; at the great feasts he sits enthroned by the doorway, preserving decorum among the worshippers; he has certain legal dues, and, if he is disposed to exact more, no one ventures to resist (1 Sam. ii. 12 *seq.*, where the text needs a slight correction). The priestly position of the family survived the fall of Shiloh and the capture of the ark, and it was members of this house who consulted Jehovah for the early kings until Solomon deposed Abiathar.

Ultimately, indeed, as sanctuaries were multiplied and the priests all over the land came to form one well-marked class, "Levite" and legitimate priest became equivalent expressions, as is explained in the article Levites. But between the priesthood of Eli at Shiloh or of Jonathan at Dan and the priesthood of the Levites as described in Deut. xxxiii. 8 *seq.* there lies a period of the inner history of which we know almost nothing. It is plain that the various priestly colleges regarded themselves as one order, that they had common traditions of law and ritual which were traced back to Moses, and common interests which had not been vindicated without a struggle. The kingship had not deprived them of their functions as fountains of divine judgment (*cf.* Deut. xvii. 8 *seq.*); on the contrary, the decisions of the sanctuary had grown up into a body of sacred law, which the priests administered according to a traditional precedent. According to Semitic ideas the declaration of law is quite a distinct function from the enforcing of it, and the royal executive came into no collision with the purely declaratory functions of the priests. The invective of Hos. iv. equally with the eulogium of Deut. xxxiii. proves that the position which the later priests abused had been won by ancestors who earned the respect of the nation as worthy representatives of a divine Torah.

The ritual functions of the priesthood still appear in Deut. xxxiii. as secondary to that of declaring the sentence of God, but they were no longer insignificant. With the prosperity of the nation, and especially through the absorption of the Canaanites and of their holy places, ritual had become much more elaborate, and in royal sanctuaries at least there were regular public offerings maintained by the king and presented by the priests. (*Cf.* 2 Kings xvi. 15.) Private sacrifices, too, could hardly be offered without some priestly aid now that ritual was more complex; the provision of Deut. xviii. as to the priestly dues is certainly ancient, and shows that besides the tribute of first-fruits and the like the priests had a fee in kind for each sacrifice, as we find to have been the case among the Phoenicians according to the sacrificial tablet of Marseilles. Their judicial functions also brought profit to the priests, fines being exacted for certain offences and paid to them (2 Kings xii. 16; Hos. iv. 8; Amos ii. 8). The greater priestly offices were therefore in every respect very important places, and the priests of the royal sanctuaries were among the grandees of the realm (2 Sam. viii. 18; 2 Kings x. 11, xii. 2); but there is not the slightest trace of an hereditary hierarchy officiating by divine right, such as existed after the exile. The sons of Zadok, the priests of the royal chapel, were the king's servants as absolutely as any other great officers of state; they owed their place to the fiat of King Solomon, and the royal will was supreme in all matters of cultus (2 Kings xii., xvi. 10 *seq.*); indeed the monarchs of Judah, like those of other nations, did sacrifice in person when they chose down to the time of the captivity (1 Kings ix. 25; 2 Kings xvi. 12 *seq.*; Jer. xxx. 21).

The detailed steps which prepared the way for the post-exile hierarchy, the destruction of the northern sanctuaries and priesthoods by the Assyrians, the polemic of the spiritual prophets against the corruptions of popular worship, which issued in the reformation of Josiah, the suppression of the provincial shrines of Judah and the transference of their ministers to Jerusalem, the successful resistance of the sons of Zadok to the proposal to share the sanctuary on equal terms with these new-comers, and the theoretical justification of the degradation of the latter to the position of mere servants in the Temple supplied by Ezekiel soon after the captivity, need not here be dealt with. Already in the time of Josiah altar service and not the judicial or "teaching" function had become the essential thing in priesthood (Deut. x. 8, xviii. 7); the latter, indeed, was not forgotten (Jer. ii. 8, xviii. 18), but by the time of Ezekiel it also has mainly to do with ritual, with the distinction between holy and profane, clean and unclean, with the statutory observances at festivals and the like (Ezek. xliv. 23 *seq.*). What the priestly Torah was at the time of the exile can be seen from the collection of laws in Lev. xvii.–xxvi., which includes many moral precepts, but regards them equally with ritual precepts from the point of view of the maintenance of national holiness. The holiness of Israel centres in the sanctuary, and round the sanctuary stand the priests, who alone can approach the most holy things without profanation, and who are the guardians of Israel's sanctity, partly by protecting the one meeting-place of God and man from profane contact, and partly as the mediators of the continual atoning rites by which breaches of holiness are expiated. In the old kingdom the priests had shared the place of the prophets as the religious leaders of the nation; under the second Temple they represented the unprogressive traditional side of religion, and the leaders of thought were the psalmists and the scribes, who spoke much more directly to the piety of the nation.

But, on the other hand, the material influence of the priests was greater than it had ever been before; the Temple was the only visible centre of national life in the ages of servitude to foreign power, and the priests were the only great national functionaries, who drew to themselves all the sacred dues as a

matter of right and even appropriated the tithes paid of old to the king. When the high priest stood at the altar in all his princely state, when he poured out the libation amidst the blare of trumpets, and the singers lifted up their voices and all the people fell prostrate in prayer till he descended and raised his hands in blessing, the slaves of the Greek or the Persian forgot for a moment their bondage and knew that the day of their redemption was near (Ecclus. l). The high priest at such a moment seemed to embody all the glory of the nation, as the kings had done of old, and when the time came to strike a successful blow for freedom it was a priestly house that led the nation to the victory which united in one person the functions of high priest and prince. From the foundation of the Hasmonean state to the time of Herod the history of the high priesthood merges in the political history of the nation; from Herod onward the priestly aristocracy of the Sadducees lost its chief hold over the nation and expired in vain controversy with the Pharisees.

The influence of the Hebrew priesthood on the thought and organization of Christendom was the influence not of a living institution, for it hardly began till after the fall of the Temple, but of the theory embodied in the priestly code of the Pentateuch. Two points in this theory were laid hold of—the doctrine of priestly mediation and the system of priestly hierarchy. The first forms the text of the principal argument in the Epistle to the Hebrews, in which the author demonstrates the inadequacy of the mediation and atoning rites of the Old Testament, and builds upon this demonstration the doctrine of the effectual high priesthood of Christ, who, in His sacrifice of Himself, truly "led His people to God," not leaving them outside as He entered the heavenly sanctuary, but taking them with Him into spiritual nearness to the throne of grace.

The idea that presbyters and bishops are the successors of the Old Testament priesthood first appears in full force in the writings of Cyprian. The further development of the notion of Christian priesthood was connected with the view that the Eucharist (*q.v.*) is a propitiatory sacrifice which only a consecrated priest can perform. It is sufficient to remark here that the presentation of the sacrifice of the mass came to be viewed as the essential priestly office, so that the Christian presbyter really was a *sacerdos* in the ancient sense. Protestants, in rejecting the sacrifice of the mass, deny also that there is a Christian priesthood "like the Levitical," and have either dropped the name of "priest" in reference to any specific office, or use it in a quite emasculated sense.

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PRIESTLEY, JOSEPH (1733–1804), English chemist and Nonconformist minister, was born on March 13, 1733, at Fieldhead, a hamlet in the West Riding of Yorkshire. From the age of 16 to nearly 20 he worked at Chaldee and Syriac, began to read Arabic, and mastered 's Gravesande's *Natural Philosophy*. He also learned French, German and Italian. In 1752 he went to Daventry to attend the Nonconformist academy there.

In 1755 he was appointed to a small congregation at Needham Market, in Suffolk. In 1758 he obtained a more congenial congregation at Nantwich, where he opened a school. Three years later he moved to Warrington as classical tutor in a new academy, and there he attended lectures on chemistry by M. Turner of Liverpool and pursued the studies in electricity which gained him the fellowship of the Royal society in 1766 and supplied him with material for his *History of Electricity*. In 1767 he was appointed to the charge of Mill Hill chapel at Leeds, where he wrote many political tracts attacking the government policy toward the American colonies. He also began his researches into "different kinds of airs," getting a plentiful supply of "fixed air" from a brewery next door to his house. His *Directions for Impregnating Water with Fixed Air* (1772) announced his invention of soda water.

In 1772, the year in which he was chosen a foreign associate of the French Academy of Sciences, Priestley accepted the position of librarian and literary companion to Lord Shelburne (afterward 1st marquess of Lansdowne) at Calne, with a salary of £250 a year and a house. He travelled with his patron on the continent and in Oct. 1774 he met Antoine Lavoisier and his friends in Paris and gave them an account of the experiment by which on the previous Aug. 1 he had prepared "dephlogisticated air" (oxygen). In 1780 he left Lord Shelburne, who allowed him an annuity of £150 for life, and settling at Birmingham was appointed junior minister of the New Meeting society. There he found friends in Matthew Boulton, James Keir, James Watt and Erasmus Darwin. On July 14, 1791, the Constitutional Society of Birmingham arranged a dinner to celebrate the anniversary of the fall of the Bastille. Priestley, according to his own account, "had little to do with it." But his predilections in favour of the revolutionists were notorious, and the mob seized the occasion to burn his chapel and sack his house at Fairhill. He and his family escaped, but his possessions were destroyed and the labour of years annihilated. He retreated to London, where he felt safe, though even the fellows of the Royal society shunned him. He received an invitation to become morning preacher at Gravel Pit chapel, Hackney, and there he remained until 1794, when he determined to emigrate to America. Settling at Northumberland, Pa., he lived there for nearly ten years, until his death on Feb. 6, 1804. A collection of his scientific apparatus is preserved at this "Priestley house." The American Chemical society was founded there.

Priestley made very important contributions to pneumatic chemistry—the study of gases—and was the inventor of the "pneumatic trough," which allowed gases to be collected and examined. By heating spirits of salt he obtained "marine acid air" (hydrochloric acid gas), and he was able to collect it because he happened to use mercury, instead of water, in his pneumatic trough. Then he treated oil of vitriol in the same way, but got nothing until by accident he dropped some mercury into the liquid, when "vitriolic acid air" (sulphur dioxide) was evolved. Again he heated fluorspar with oil of vitriol, as K. W. Scheele (*q.v.*) had done, and because he was employing a glass vessel he got "fluor acid air" (silicon fluoride). Heating spirits of hartshorn, he was able to collect "alkaline air" (ammonia), again because he was using mercury in his pneumatic trough; then, trying what would happen if he passed electric sparks through the gas, he decomposed it into nitrogen and hydrogen, and "having a notion" that mixed with hydrochloric acid gas it would produce a "neutral air," perhaps much the same as common air, he synthetized sal ammoniac. He prepared dephlogisticated air (oxygen) in Aug. 1774 by heating red oxide of mercury with a burning glass, and he found that in it a candle burned with a remarkably vigorous flame and mice lived longer than in an equal volume of ordinary air. He concluded that it was not common air, but the substance "in much greater perfection" that rendered common air respirable and a supporter of combustion. Of the analogy between combustion and respiration—both true phlogistic processes in his view—he had convinced himself three years before, and his paper "On Different Kinds of Air" (*Phil. Trans.,* 1772) described experiments which showed that growing plants are able to "restore" air which has been vitiated, whether by being breathed or by having candles burned in it. He noted that when hydrogen and oxygen were exploded together a mist or dew coated the inside of the vessel, but it was Henry Cavendish who showed that the dew consisted of water.

Priestley had an unusual gift, as well as a passion, for experimenting, although he had received no scientific education. Probably for this reason he supported the doctrine of phlogiston to the very last in spite of the fact that his own researches had probably given Lavoisier (*q.v.*) the clue to the oxygen theory of combustion. He was heterodox in religion but orthodox in chemistry. Although his theoretical knowledge was weak his observations and experiments had a profound influence on the development of chemistry.

Priestley was a most voluminous writer, and his works (excluding his scientific writings) as collected and edited by his friend J. T. Rutt in 1817–32 fill 25 octavo volumes. His chief theological and philosophical works were *Institutes of Natural and Revealed Religion,* 3 vol. (1772–74), *An History of the Corruptions of Christianity,* 2 vol. (Birmingham, 1782), *A General History of the Christian Church to the Fall of the Western Empire,* vol. i and ii (Birmingham, 1790), vol. iii and iv (Northumberland, 1802–03) and *Disquisitions Relating to Matter and Spirit* (1777).

His chief books on chemistry were *Experiments and Observations on Different Kinds of Air,* 6 vol. (1774–86); *Experiments on the Generation of Air from Water* (Birmingham, 1793); *Experiments and Observations Relating to the Analysis of Atmospherical Air* (1796); and *The Doctrine of Phlogiston Established, and That of the Composition of Water Refuted* (Birmingham, 1800). He also published a treatise on the *History and Present State of Electricity, with Original Experiments* (1767), which embodies some original work, and *The History of the Present State of Discoveries Relating to Vision, Light, and Colours,* 2 vol. (1772), which is a mere compilation.

See also T. E. Thorpe, *Joseph Priestley* (1906); O. Lodge, "Joseph Priestley," in J. H. Muirhead (ed.), *Nine Famous Birmingham Men* (1909). His *Memoirs,* written by himself to 1795, and continued to his death by his son, Joseph, was reprinted in 1904. *See* also H. B. Hammond, "Priestley and Lavoisier," in his *Stories of Scientific Discovery* (1924); P. Hartog, "Priestley's Place in the History of Science," *Proc. Royal Institution* (1931), "The Newer Views of Priestley and Lavoisier," *Annals of Science* (1941); A. Holt, *Life of Joseph Priestley* (1931); D. H. Peacock, *Joseph Priestley* (1919); E. F. Smith, *Priestley in America, 1794–1804* (1920). (R. E. O.; X.)

PRIEUR, PIERRE (*c.* 1626–*c.* 1676), French enamel painter. He married Marie (1610–1677), sister of Jean Petitot, as her second husband. In 1669 he was in England, painting a miniature of Charles II and another of Lady Castlemaine, both after Cooper, for the king of Denmark. In 1670 he was in Poland, painting for the Danish monarch a portrait of King Michael, and in the following year was in Denmark executing a remarkable series of portraits of the children of Frederick III. All these, with some beautiful enamel badges for the Order of the Elephant, are in the Danish royal collection. By Christian V he is said to have been sent to Spain and Russia, where several examples of his work, dated 1676, are to be seen in the Hermitage, Leningrad. He died in Denmark, in 1676. He was a Huguenot, and was said to possess secret colours in enamel, especially a blue, which were not known to his Petitot relations. (G. C. W.)

PRIEUR DE LA MARNE [Pierre Louis Prieur] (1756–1827), French politician, was born at Sommesous (Marne) on Aug. 1, 1756. He practised as a lawyer at Châlons-sur-Marne until 1789, when he was elected to the states-general. He became secretary to the assembly, and the violence of his attacks on the *ancien régime* won him the nickname of "Crieur de la Marne." In 1791 he became vice-president of the criminal tribunal of Paris and in May 1796 president of the convention, hiding from May 1795 until the amnesty proclaimed in the autumn of that year. In 1816 he was banished as a regicide. He died in Brussels on May 31, 1827.

See Pierre Bliard, *Le Conventionnel Prieur de la Marne en mission dans l'ouest 1793–1794 d'après des documents inédits* (1906).

PRIEUR-DUVERNOIS, CLAUDE ANTOINE, Comte (1763–1832), French politician, was born at Auxonne on Dec. 2, 1763, and was known as Prieur de la Côte d'Or. He was a member of the legislative assembly and of the convention. In 1793 he was employed in breaking up the Federalist movement in Normandy, but he was arrested by the Federalist authorities of Caen, and only released in July 1793 after the defeat of their forces at Vernon. On Aug. 14, 1793, he became a member of the committee of public safety, allying himself with L. N. M. Carnot in the organization of national defense. Under the directory he sat in the Council of the Five Hundred, retiring after the coup d'état of 18 Brumaire (Nov. 9, 1799). In 1808 he was created a count of the empire, and in 1811 retired from the army with the grade of *chef de brigade.* He was one of the founders of the École Polytechnique, and shared in the establishment of the Institute of France; the adoption of the metric system and the foundation of the bureau of longitude were also due to his efforts. Prieur died at Dijon on Aug. 11, 1832.

See J. Gros, *Le Comité de salut public* (1893); and E. Charavay, *Correspondance de Carnot,* vol. i, which includes some documents drawn up by Prieur.

PRILEP, a town in southern Serbia, Yugoslavia. Pop. (1931) 21,405. The town owes its chief importance to a large annual fair. The town is famous in Serbian history as the birthplace and capital of Marko Kralyevich, one of the favourite national heroes, who held his kingdom, after the fall of Serbia in 1389, as a vassal of the Turks. Legend says that before his death he buried his sword deep in the rocks of Prilep and left his magic horse Sharatz to nibble the moss near by, with the promise of reappearing in his country's hour of need. In the Balkan Wars (1912–13) the Serbs successfully stormed the heights, reputed to be impregnable. In 1941 the town was occupied by Bulgaria.

PRIM, JUAN, Marquis de los Castillejos, Count de Reus (1814–1870), Spanish soldier and statesman, was born at Reus, Catalonia, on Dec. 12, 1814. He served in the volunteers of Isabella II in 1834, becoming lieutenant-colonel during the Carlist war. In 1839, as a progressist opposed to the dictatorship of Espartero, he was exiled. Elected deputy for Tarragona in 1843, he defeated Espartero at Bruch and entered Madrid in triumph with Serrano. The regent Maria Christina made him major-general and count of Reus. Narvaez, the prime minister, who did not understand what constitutional freedom meant, sentenced Prim to six years' imprisonment in the Philippine Islands; the sentence was not executed, and until the amnesty of 1847 Prim remained an exile in England and France. On his return he was made captain-general of Porto Rico and military representative with the sultan during the Crimean War. Elected to the *cortes* in 1854, he supported O'Donnell, who promoted him lieutenant-general in 1856. He was made marquis de los Castillejos and a grandee of Spain for his valuable services in Morocco (1860). A member of the opposition against Narvaez, at his death (1868) Prim and Serrano raised the standard of revolt at Cadiz, with Admiral Topete commanding the fleet. In July 1869 Serrano was elected regent, and Prim became president of the council and was made a marshal. He was shot by unknown assassins on leaving the chamber of the *cortes* on Dec. 28, 1870.

See F. Jiménez y Guited, *Historia militar y política del general D. Juan Prim . . .,* 2 vol. (1860); L. Blairet, *Le Général Prim et la situation actuelle de l'Espagne* (1867); Guillaumot, *Juan Prim et l'Espagne* (1870); H. Leonardon, *Prim,* bibl. (1901); F. González Llanos, *Biografiá política y militar del . . . general . . . Prim . . .* (1860).

PRIMARIES are meetings of voters at which the first steps are taken toward the nomination of candidates for office. They may be informal gatherings or elections held under the same safeguards as final elections. They may be partisan in the sense that participation is limited to persons affiliated with the same party, or nonpartisan, in that nominees are chosen without regard to party affiliation. Partisan primaries may be indirect or direct. In the former, delegates are chosen to nominating conventions and the primary is equivalent to a caucus, but in the direct primary the rank and file of the party choose the nominees and the primary becomes a trial heat in the electoral process.

The formalized, legally regulated primary election and the direct primary are peculiar to the United States. Nominating conventions, instituted by the parties as reform measures, became subject to abuses which led first to their regulation and ultimately to their elimination for most offices. Early laws relating to selection of delegates were optional, parties being permitted but not required to conform to their provisions, and were limited to certain areas. After 1890, mandatory regulations of a sweeping character transformed the primary into an election conducted by public officers at public expense. Even before these laws were tested direct nominations were demanded. The direct primary was used by the Democratic party in Crawford county, Pa., as early as 1842, but it was not until the 20th century, when the Progressive movement tended to divide both parties that the system came into general use. In 1903, Wisconsin, under the leadership of Gov. Robert M. LaFollette, passed the first mandatory, state-wide direct primary law. The movement spread so rapidly that by 1917 all but four states had adopted the direct primary for some or all state-wide nominations. The adoption of direct primary laws by Utah in 1937, New Mexico in 1938 and Rhode Island in 1947 left Connecticut the only state in which nominations for all state offices continued to be made by convention.

The trend was toward mandatory laws covering all state and county offices, but by mid-century optional primaries survived in Alabama, Delaware, Georgia and a few other southern states, and the convention was used for some state offices in Michigan, New York and Indiana. In most states provisions applied only to parties polling a fixed minimum at the last election.

Beyond this few generalizations are possible; direct primaries had been forged in 48 states and varied widely in detail. In some states the date had been fixed in the spring and in others in the fall. Various methods had been used to place names on the ballot. The simplest, used in a dozen states, was a declaration of candidacy, with or without a filing fee. The more popular method was by petition signed by a certain number of political supporters of the aspirant. Some states had required a certain geographic distribution of the signers. An interesting variant was the use of preprimary conventions. In Colorado the names of all persons receiving 10% or more of the votes in the convention appeared on the ballot. Additional names might be added by petition. A law adopted in Nebraska in 1943 provided that the names of all candidates receiving at least 25% of the preprimary vote should appear on the ballot, the two highest being designated "endorsed" candidates. The elaborate South Dakota law, in effect 1917–29, was unique in its attempt to emphasize principles and policies and its frank recognition of factions within the party. Under a Massachusetts law, adopted by popular referendum in 1932 and repealed after a short and stormy trial in 1937, a single list of candidates for all state offices was proposed by the convention. Other names could be added by petition.

Important variations were found in the requirements for participation in the primary at mid-century. In the open primary no declaration of party affiliation was required and the voter might vote in the Republican or Democratic primary as he chose and might move freely from one party to another in succeeding primaries. In Wisconsin, Michigan, Montana and Utah he received the ballots of all parties and in the privacy of the voting booth decided which he wished to use. Minnesota, Idaho and North Dakota, however, used a single "blanket" ballot with the names of the candidates of all parties arranged in columns. In 1935 Washington adopted an open primary which made it possible for a voter to participate in all primaries; *i.e.*, at the same primary he might vote for a Republican candidate for the gubernatorial nomination and cast his vote for a Democrat for United States senator.

In the closed primary, used by most states, tests of party affiliation are provided. The most common method has been to require the voter to enrol as a member of a party at the time of registration and to limit his participation to the selection of the nominees of that party. Other states have defined party membership and required the voter, if challenged, to swear that he meets the test. In a few cases the only requirement is that the voter publicly ask for the ballot of the party with which he wishes to affiliate.

The relative merits of open and closed primaries have been hotly debated. Independents have argued that the open primary permits secrecy of party affiliation, prevents intimidation and does not bar those unwilling to declare a party affiliation. Critics have charged that it destroys party responsibility by permitting nominations to be controlled by those with no continuing allegiance to the party, and that it permits voters of one party to "raid" the primaries of the other party. Although in a few southern states the primary has included a pledge to support the party's nominees in the general election, voters who participate in the primaries of a party usually have been free to vote for the candidates of any party in the final election.

In most states the candidate polling the highest number of votes has received the nomination. If there are more than two candidates this may allow a minority candidate to win, and various devices have been introduced to assure a majority choice. In the south, where a Democratic nomination is equivalent to election, the second or "run-off" primary has been adopted by an increasing number of states. By 1950 ten states had such provisions. Preferential voting, tried by several states, had been abandoned by all of them.

In the United States an attempt was made to extend the idea of direct nominations to the presidency. By election of delegates to the nominating conventions, and by preference votes for president, or both, some states attempted to bring the national conventions within the control of the rank and file of the party members. The first presidential primary law was adopted by Wisconsin in 1905 and by 1916 laws varying widely in type and effectiveness were in operation in 24 states. After that the movement lost ground and by 1948 mandatory laws were retained by only 14 states.

Nonpartisan primaries have been widely used for judicial and local offices in the United States, and have been extended to members of the state legislature in Minnesota and Nebraska. In reality a double election system in which party labels play no part, nonpartisan elections and primaries were introduced in an attempt to remove these offices from the arena of national party politics. Although nonpartisan in form they frequently become partisan in fact.

The closest parallel to the U.S. primary has been the "preselection" ballot of the Australian Labour party, in which candidates in each locality have been selected by party members in that locality from those offering themselves for the preselection vote.

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PRIMARY EDUCATION: *see* ELEMENTARY EDUCATION.

PRIMATE, a title applied during the 4th and 5th centuries A.D. to both secular and ecclesiastical officials. The Theodosian code mentions primates of towns, districts and fortified places (*Primates urbium, vicorum, castellorum*). A pragmatic sanction of Justinian also mentions primates governing a district, *primates regionis;* and in this sense the title survived, under Turkish rule, in Greece until the 19th century. An official called "primate of the palace" is mentioned in the laws of the Visigoths. Primas also seems to have been used loosely during the middle ages for "head" or "chief." Charles du Fresne, Sieur du Cange cites *primas castri.* The title has been more generally used to denote a bishop with special privileges and powers. It was first employed almost synonymously with metropolitan to denote the chief bishop of a province having his see in the capital and certain rights of superintendence over the whole province. At the Council of Nicaea (A.D. 325) the metropolitan constitution was assumed as universal, and after this the terms metropolitan, and primate, to denote the chief bishop of a province, came into general use. The title of primate was used more generally in Africa, while elsewhere metropolitan was more generally employed.

At a later date primate became the official title of certain metropolitans who obtained from the pope a position of episcopal authority over several other metropolitans and who were, at the same time, appointed vicars of the Holy See. This was done in the case of the bishops of Arles and Thessalonica as early as the 5th century. The archbishop of Reims received the title of *primas inter primates.* By the False Decretals an attempt was made to establish such a primacy as a permanent institution, but the attempt was not successful and the dignity of primate became more or less honorary. The overlapping of the title is illustrated by the case of England, where the archbishop of York still bears the title of primate of England and the archbishop of Canterbury that of primate of all England.

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PRIMATES, an order of mammals, including man, the apes, monkeys, tarsiers and lemurs. The name, meaning "chiefs," was given by Carolus Linnaeus in 1758. Linnaeus also included the bats, assigned to a separate order by modern zoologists.

Structure and Habits.—Primates are primarily arboreal animals with hands and feet adapted for climbing. The fingers and toes are provided with nails (rarely compressed as claws). The great toe of the hind foot is usually more or less divergent and the foot functions as a grasping organ, branches of trees being seized between the great toe and the four outer toes. The hands serve both for climbing and for manipulating food. The limbs are relatively long and slender, with free movements of rotation and supination. The lower primates (lemurs) are practically quadrupeds that run and leap in the trees but in the more advanced monkeys and apes there is an increasing tendency to climb with the arms extended above the head and the weight of the body suspended beneath the branches (brachiation). On the other hand, in the baboons the limbs plainly show secondary adaptation for running on the ground, both in their somewhat dog-like proportions and in the reduction of the great toe.

In the stem type of arboreal monkeys, vision is dominant over smell, whereas in typical ground-dwelling mammals the reverse is the case. Hence the occipital poles of the brain, which are connected with vision, are much enlarged. The adjustments for balancing in such actively climbing animals are extremely various and rapid; this requires a correspondingly complex development of the cerebellum and of the cerebral areas of the brain concerned with the movements of the limbs and body. As intelligence increases the prefrontal lobes of the brain develop. Thus the brain of monkeys is proportionately larger and more complexly convoluted than in ordinary ground-living animals. As a whole the brain of the old world monkeys presents the ground plan of the human brain without the special developments and complications connected with man's superior mentality.

The bony brain case closely follows the shape of the brain, except in front, where the large eye sockets jut forward, thus enabling the achievement of binocular, stereoscopic vision. Owing to the forward growth of the temporal lobes of the brain the greater wings of the sphenoid are moved forward to form the backwall of the orbits, which are thus separated by a bony partition from the temporal fossae.

Hearing is acute and the temporal lobes are large. A thin bony shell, the auditory bulla, on the underside of the brain case behind the socket for the lower jaw, covers the lower side of the cavity of the middle ear and is connected by a bony tube with the root of the external ear; the latter resembles that of man but usually has a point on its upper rim and lacks a lobule below.

In the more primitive primates, *e.g.* lemurs, the jaws are long and slender and the muzzle pointed. In typical monkeys, however, the jaw is shortened and deepened and the muzzle broad, the nose and lips assuming more or less the human aspect. The opposite halves of the lower jaw are fused in front even in young animals. The dentition is adapted for a mixed diet, with fruits or vegetation prevailing. The teeth in an adult old world monkey number 32, as in man. The incisors are cutting teeth, the lower ones slightly inclined forward. There are two pairs in both upper and lower jaw. The canines are sharp and adapted for biting; the upper premolars are bicuspid, *i.e.,* with single, outer and inner cusps; and the low-crowned molars are surmounted by low cusps.

The female reproductive organs are fundamentally as in man (except in details) and there is likewise only a single pair of breasts in the female. The placenta, except in the Lemuroids, is disk-shaped and intimately attached to the wall of the uterus.

Thus a typical monkey differs from an ordinary mammal such as a dog in its thorough adaptation to arboreal life, in the greater activity of the visual as compared with the olfactory powers, in its more advanced type of brain and in its much greater likeness to man in the entire ground plan of its anatomy.

Such a monkey is structurally connected on the one hand with lower primates (including new world monkeys, tarsiers and lemurs) and on the other hand with the higher primates, the anthropoid apes and man. Even the still existing species of primates form a fairly gradual transition from the tree shrews at the base to highly specialized forms like the spider monkey, the orangutan and man, which stand far out on widely divergent branches.

SUBORDER PROSIMII

Here are included the lower primates, animals very different in appearance from monkeys and apes. Structurally they also differ widely, many authors considering the lemurs distinct enough to be given ordinal rank.

Tupaioidea.—The tree shrews are often classed as Insectivora (*q.v.*) but they are undoubtedly much like the stock from which the other primates arose.

The pen-tailed tree shrew (*Ptilocercus*) of Borneo is a mouse-like arboreal animal. Its hands and feet are five-toed and provided with claws, the thumb and great toe somewhat divergent. Food includes insects and fruit; the upper molar teeth are tritubercular, the lower molars tuberculo-sectorial (*see* MAMMALIA). The skull is lemur-like, especially in the ring-shaped orbit and inflated auditory bulla, which completely encloses the ring-like tympanic bone and eardrum. The brain is primitive in having relatively unreduced olfactory parts and very feebly developed neopallium or higher part of the brain. *Tupaia* and related genera of India and the Malayan region are in many ways more advanced toward the lemur type. Fossil tree shrews not greatly different from modern forms were found in the Lower Oligocene of Mongolia.

Lemuroidea.—In the Palaeocene and Eocene of North America occur the fossil teeth and jaws of ancient primates belonging to several groups. The orbits open into the temporal fossae beneath the postorbital bar. The thumb and first toe are opposable.

Family Plesiadapidae is the earliest of these groups; it also occurred in Europe. The incisors are shrew-like, the lower one large and procumbent, while the molar teeth resemble those of Recent lemurs.

Family Adapidae lived in the European and North American Eocene. The skull was broad, with large, forward-looking orbits, massive cheek arches and high crests. The molars were four-cusped, with sharp cross-crests. These ancient primates approached in many skeletal features the modern lemurs, to which they were either ancestral or closely related.

Family Notharctidae confined to the North American Lower and Middle Eocene, included forms ranging from the size of a squirrel to that of a cat. The first and second upper molar teeth gradually evolved from a three-cusped to a four-cusped stage. Apparently the entire family then became extinct, but some of them may possibly have given rise to the ancestral South American monkeys. In *Notharctus osborni* from the Middle Eocene of Wyoming, the hands and feet were of the grasping, climbing type, much like those of existing lemurs. The skull was far less specialized than that of contemporary tarsioids, both skull and dentition retaining the primitive features of lemurs on the one hand and monkeys on the other. Thus the dental formula of *Notharctus* ($i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{4}{4}$, $m\frac{3}{3}$ x $2=40$) is the primitive one for all primates. The brain case is primitive with no great expansion of the brain and with an unreduced nasal chamber. The orbits were protected behind by a rim of bone, not by a fully developed partition. The auditory region and base of the cranium, backbone, forearm, pelvis and hind feet were like those of lemurs.

Family Lemuridae became confined in modern times to Madagascar and the smaller adjacent islands. The lemurs have a fully arboreal skeleton, with grasping hands and feet. The animals run and leap on the tops of branches. The second toe bears a claw, while the other digits are armed with flat nails. The lower incisors and much reduced lower canines are sharply inclined forward, compressed and pointed. This structure was thought a "comb," used in grooming the fur, but it is more probably used in feeding on soft fruits. The upper canines are large,

but the incisors are small, widely separated medially. The upper molars have two sharp outer cusps and a medial crescentic one; the first two molars, in addition, have two small internal cusps. The lower molars are four-cusped. The opposite halves of the lower jaw are not fused in front as in the higher primates but remain free. The placenta is diffuse, with a large allantois, and separates from the uterine wall at birth, without destruction of maternal tissue; *i. e.*, it is not deciduous. In this feature the members of this family resemble the ungulates and differ widely from the higher primates. Lemurs have only one pair of mammae situated on the breast.

The true lemurs (*Lemur*) have a dental formula $i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{3}{3}$, $m\frac{3}{3}$. The head has a fox-like muzzle and rounded occiput. The eyes are very large and protrude from their sockets, while the ears are large and movable. A long fringe of hair often surrounds their chin and cheeks. The ring-tailed lemur (*L. catta*) is one of the best known species, somewhat like a small, slender raccoon in appearance. It is ashy gray in colour, paler on the legs and sides, and white on the under parts, cheeks, ears and forehead. The blackish tail is ringed with white, giving this lemur its name. The ruffed lemur (*L. variegatus*) is characterized by the fringe of hair on the sides of the head and neck. This species varies greatly in colour. Usually the face is blackish, as are the under parts, tail and feet, while the upper parts and sides are white, cream-coloured or reddish. This species is the largest of the true lemurs. The black lemur (*L. macaco*) has tufted ears and a ruff. The male is black, while the female is said to have a white ruff and ears; the body is dark brown, lighter on the rump. Other races of this species are reddish or gray and may show stripes. The mongoose lemur (*L. mongoz*) is small, with dull reddish-brown, woolly fur; the face, chin, the middle of the forehead and a line above the eyes are black. The smooth-eared black lemur (*L. rubriventer*) lacks a fringe on the ears and has a small ruff; the female has reddish feet. The under parts are often reddish.

The gentle lemur (*Hapalemur griseus*) has a rounded head, short muzzle and small ears. Its colour is dark iron gray with a tinge of reddish. This species is said to be nocturnal and to feed on bamboo shoots and leaves. A closely related lemur was described as *H. simus*, characterized by broader muzzle, and there are no spines on the forearm above the wrist.

The weasel or sportive lemur (*Lepilemur mustelinus*) is about 10 in. long, with a tail some 14 in. The small ears are naked, while the muzzle is long and pointed. Considerable variation in colour is shown by this species. There is frequently a black stripe down the back; the general colour is gray tinged with yellow or reddish, while the under parts are grayish or yellowish white. The upper incisors are generally lost in adults, but a single small pair may persist. *L. ruficaudus*, the red-tailed sportive lemur, is smaller than the preceding, the head shorter and broader, with the ears short-haired.

Subfamily Cheirogaleinae includes the mouse lemurs, referable to three genera. The face is short and the bony palate extends behind the last cheek tooth. *Cheirogaleus major* is about 8 in. long, with the tail about 9 in. The base of the tail becomes swollen with fat stored there during the summer and the animal hibernates in a nest in a hollow tree. The silky fur is grayish brown, often fawn-coloured or washed with rufous. A blackish ring surrounds the eyes, while between them the fur is pale. The eyes are large, while the ears are moderate in size, oval and sparsely haired. The heel bone is lengthened, while the hind limbs are larger than the fore. In habits the mouse lemur is nocturnal; it feeds on fruits and possibly honey. Several smaller species are known. *Microcebus* has four mammae, two on the breast, two on the abdomen. In the skull the brain case is high, while the facial region is reduced. The foot is long, the result of a lengthening of the cuboid and navicular bones. *M. murinus*, the typical form, is pale reddish gray, with white under parts; it is 5 in. in length with a 6 in. tail. *M. coquereli* is characterized by its soft woolly fur which is grayish brown washed with reddish. It is larger, 8 in. or more long, with the tail 13 in. It is said to build a nest of twigs in which it spends the daytime, to emerge at night in search of insects, fruit and leaves. *Phaner furcifer*, the forked-striped mouse lemur, receives its name from the blackish stripe running back from each eye to the occiput and continuing down the back. The rest of the body is grayish.

Subfamily Megalodapinae includes a large extinct lemur of the Madagascar Pleistocene or early Recent, the skull about 12 in. long, which indicates an animal the size of a small hog. The three-cusped molars resemble those of the lemurs and mouse lemurs. The orbits were small and widely separated. The upper incisors were lost and the canines took their place. The skull vaguely resembles that of a hippopotamus.

Subfamily Archaeolemurinae contains two Lower Pleistocene genera, *Archaeolemur* and *Hadropithecus*. The former was about the size of a rhesus macaque and the skull was very monkey-like, with reduced face and large, rounded brain case. The eyes were large and directed forward. The dental formula is $i\frac{2}{2}$, $c\frac{1}{0}$, $p\frac{2}{2}$, $m\frac{3}{3}$, the first premolar functioning as a canine. *Hadropithecus* was much more specialized with massive zygomatic arch and large brain case.

Subfamily Indriinae contains the higher lemurs characterized by large, rounded brain case and small face, long hind legs; short thumb and short index fingers, but large first toes. The other toes are partly united by a web. They progress by leaps. The ears are generally naked, buried in the fur. The indriine lemurs live on vegetation and have a capacious caecum. The indri or endrina (*Indri indri*) has a short tail and large, tufted ears. The face, hands, feet and most of the body of this animal is velvety black; the lower back, tail, the sides of the hind limbs, the forearm and elbow region are white, as are a cheek fringe and the top of the head. The flanks are often pale. In contrast to the common lemurs, the indri is diurnal in habit. The cries of this species are plaintive and mournful. The sifakas (*Propithecus*) differ from the indri by their long tails; their ears are shorter, and they are largely white in colour, marked with yellow. The face is black and nearly naked. *P. diadema*, the crowned sifaka, takes its name from the band of white hairs running across the forehead; this unites with grayish hair on the cheeks to surround the face. In southern Madagascar this species is almost white, while in the north the colour is blackish; the range of the species extends along the entire east coast of the island. Verreaux's sifaka (*P. verreauxi*) is a smaller species (head and body 18 in., tail 22 in.) restricted to the western, southern and northern parts of Madagascar. It has a crest of blackish hairs on the forehead. Some are largely white, with reddish patches on the thigh and arm; in others the head is reddish brown, with the limbs ashy gray. The avahi or woolly lemur (*Avahi laniger*), has a long tail and short muzzle. It is the smallest of this subfamily, the head and body about 12½ in. long, the tail somewhat longer. In colour the avahi is mottled reddish brown and blackish, the sides and limbs are pale, while the under parts are grayish. Individuals may be whitish. Avahis are nocturnal and solitary; they leap considerable distances from branch to branch, but are awkward on the ground, as are their relatives.

Family Daubentoniidae contains only the aye-aye, *Daubentonia madagascariensis* (formerly known as *Chiromys*), one of the most extraordinary of all mammals. It is noted for the rodent-like incisor teeth, a single chisel-like pair in each jaw in which the enamel is restricted to the front and which are ever-growing. Canines are absent and the cheek-teeth, $\frac{4}{3}$, have flat crowns. There are, however, in the young aye-aye milk canines in the upper jaw, and the cheek teeth are more lemuroid. The general anatomy of the aye-aye is strongly lemur-like. The ears are large and naked, the head short and rounded. The tail is bushy, about 20 in. long, while the body is about 16 in. The thumb is clawed but opposable. The fourth finger is longest, while the third is almost as long and remarkably slender. The first toe is opposable with a flat nail, the other toes with pointed claws. In colour it is blackish, with the pale bases of the hair showing through. Arboreal in habit and nocturnal, the aye-aye feeds largely on the larvae of wood-boring beetles which it detects by its keen hearing. The rodent-like teeth are used to gnaw through bark and wood, while the long, slender middle finger is said to be used as a

grapple to insert into the holes of the insect prey and drag out the grub. In addition, it feeds on fruit, leaves and birds' eggs. Fossil jaws with gnawing front teeth suggestive of those of the aye-aye are known from the French Eocene. These are more or less intermediate between the primitive lemurs and the modern aye-aye.

Family Lorisidae includes the lemuroids of southeastern Asia and of Africa, which agree with the true lemurs in the curious comb-like lower front teeth, but differ in many features. The tympanic ring forms part of the auditory bulla, while in the lemurs it is ring-like, inside of the bulla. The internal carotid artery runs entirely external to the bulla instead of sending a branch, the stapedial artery, to run through it. The zygomatic or jugal bone is separated from the lachrymal by the maxillary, while the ethmoid forms part of the orbit.

Subfamily Lorisinae contains four genera. They have woolly fur, pointed face and broad, rounded head, large eyes. The index finger is small or rudimentary, the thumb and first toe are opposable, and the second toe is clawed. The tail is short, usually hidden by fur. *Loris tardigradus*, the slender loris, is confined to the lowland forests of southern India and Ceylon. It is a large-eyed, small-snouted, nocturnal animal, with extremely slender, long limbs and no tail. The limbs are generally strongly bent and the general appearance is that of an emaciated animal. In size this species is about like a squirrel, the head and body about 8 in. long. Its colour is dark gray, with more or less reddish on the back, the underside pale gray; the young are more rusty in colour than adults. The index finger, though small, has three complete joints. The slender loris lives entirely in trees and sleeps during the day, grasping its perch by hands and feet. It is slow in movement, but is more active than its relatives. Succulent leaves, buds, honey, insects and birds' eggs form its diet.

Nycticebus coucang, the slow loris, is larger and much plumper than the slender loris, with smaller eyes and ears. It is about the size of a cat (15 in. long), tailless. The hind limbs are about the same length as the fore limbs. The colour varies considerably in different parts of its range, which extends from Assam, to Cochin China and the islands of Sumatra, Java, Borneo and some of the southern Philippines. This species is generally ashy gray with a buffy or reddish wash, although it may be silvery. Dark-brown markings surround the eyes, and a stripe of the same colour runs down the back, sometimes connecting with the circumocular rings, or there may be a large brown area on the crown. The fur is woolly and dense. The middle upper incisor tooth is much larger than the lateral one, and the upper canines are large. The female, as also in the slender loris, bears a single young one. The slow loris is nocturnal and hardly differs in habit from its slender relative. It lives solitary or in pairs, moving deliberately about the branches, upside down as readily as on top of them.

Perodicticus potto, the potto, closely resembles the slow loris in build. The muzzle is longer and broader; the eyes are farther apart, though large. The tail is about 2 in. in length while the head and body equal some 8 in. The potto is found in West Africa from Sierra Leone to the eastern Congo. Its close, woolly fur is reddish brown. A dorsal stripe of black runs down the back, and there is a dark ring around the eyes. The index finger is smaller than in the Asiatic lorises. Pottos feed on insects and vegetation; in stalking flies they move with extreme deliberation but are usually successful. So slow are their movements that African folk tales say a potto may starve to death travelling between one tree and another.

The awantibo, *Arctocebus calabarensis*, is much more rare than the potto, from which it differs by smaller size and lighter build, slender, pointed muzzle and rudimentary tail. The ears are large and pointed. The index finger is a small tubercle and the third finger is reduced. In the feet the second and third toes are about half the length of the fourth and fifth. In colour the awantibo is yellowish brown, somewhat paler below. A line down the nose is white. In the skull the palate has large perforations behind the incisors. This species is restricted to the Calabar coast of southeastern Nigeria. The African lorisids have strangely paralleled the Asiatic species, the awantibo showing many resemblances to the slender loris, while the potto is much like the slow loris.

Subfamily Galaginae are the long-legged lemuroids of Africa resembling in many ways the Madagascar mouse lemurs. The heel and navicular bones of the ankle are lengthened. The ears are large and naked; they can be folded up so as to lie nearly flat on the head. The galagos have molariform last premolars. *Galago crassicaudatus*, the greater galago, is widely distributed in eastern and southern Africa. It is the size of a small cat, some 13 in. long, with the tail 16 in. or more. The muzzle is longer and heavier than in the other representatives of this group. The feet are broad, with disk-like pads at the tips of fingers and toes. In habits these animals are agile and they leap great distances.

G. senegalensis is smaller, like a squirrel in size, with short face and large eyes. The tail is slender, with longer hair at the tip. In colour this species is pale gray, the tail yellowish or brownish, while the under parts are white. The pygmy galago, *G. demidoffi*, is about 6 in. long, with the tail some $4\frac{1}{2}$ in. It is generally reddish brown above, but the colour may be drab, the end of the tail somewhat darker and the under parts cream colour.

Euoticus elegantulus differs from its close relatives in having first upper premolar resembling the canine in shape and only a little smaller. This species is restricted to the forests of West Africa.

Tarsioidea.—The tarsioids are of equal antiquity with the earliest lemurs, being represented in the Palaeocene and Lower Eocene of France, Wyoming and New Mexico. Even at this date the two groups were quite distinct and had become diversified into distinct genera and subfamilies.

Family Anaptomorphidae includes these ancient tarsioids. *Necrolemur* of France was distinguished by the angle of the mandible which was produced into a large hook-like flange. The canine teeth were not prominent. *Omomys* of Wyoming had a long jaw symphysis, with broad, tricuspate upper molars and unpaired anterior cusp on the lower molars. *Paromomys* of the Middle Palaeocene had enlarged lower incisors. The upper molars were broad, but short anteroposteriorly. Numerous related genera and species were described both from North America and Europe.

Anaptomorphus homunculus also from the Lower Eocene of Wyoming is well known from having been thought at one time to have been ancestral to man. The external upper incisor is small and set close to the canine which was small. The molars were broad, with three cusps. In size this species was about that of *Tarsius*, with eyes large but less extreme than in that species. Another species (*A. aemulus*) did not exceed the size of a squirrel.

Family Tarsiidae contains only the tarsiers (*Tarsius*) found in the forests of Sumatra, Borneo, Celebes, the Sangir Islands and the southern Philippines. The various island populations vary in colour and minor cranial characters, and several species may be recognizable. The tarsier is small, about 6 in. long, with tail 10 in. The hind legs are longer than the body and the hind feet are also long, permitting extraordinary leaps from branch to branch. The lower part of the heel bone and the navicular bone are lengthened and rod-like, somewhat like the foot bones of the frog. The fingers and toes are long and spreading, ending in flattened disk-like pads which aid in holding on to branches of trees in which the tarsier lives. The tail is long, terminating in a tuft. The head is rounded, with short, pointed muzzle, large, naked ears and enormous eyes, set close together, the orbits hardly separated by the nose. The thick, woolly fur is grayish-brown, the under parts are paler. The brain, although large, is remarkably primitive as compared to higher primates. Accordingly the skull, which largely reflects the character of the brain and sense organs, reveals enormous circular orbits, a swollen brain case, expanded auditory bullae and a reduced, greatly constricted nasal chamber. The jaws are slender and the teeth small, the upper molars being transversely widened with low, rounded cusps. *Tarsius* appears to be the rather specialized survivor of a very old primitive stock structurally intermediate between the tree shrews and lemurs below and the monkeys, apes and man above. Most of the known Eocene tarsioids are too specialized

in their teeth to be the ancestors of monkeys (with possible exceptions noted below). The foot structure of at least two of these forms already showed more or less of the characteristic elongation of the heel bone and navicular.

SUBORDER ANTHROPOIDEA

The monkeys, apes and man differ from the lower primates in numerous ways. Cranially the orbits are separated from the temporal fossae by bony walls. The tympanic bulla is not inflated. The brain is highly developed, with numerous convolutions. The uterus is single and rounded; the placenta involves both embryonic and maternal tissue—at birth the lining of the uterus is lost (deciduous)—and it is discoidal or doubly so in shape.

Ceboidea.—The American monkeys are differentiated from those of the old world by widely separated nostrils facing laterally, whence the name "platyrrhine" (flat-nosed). The head is rounded with relatively small jaws and the ears lack the pointed tip common in old world monkeys. The buttocks do not bear callosities and the thumb is never truly opposable to the other digits; it may be vestigial or even absent. The opposable great toe of the hind foot bears a flattened nail, but the nails of the other digits of both hand and foot are frequently compressed laterally and in the marmosets become claws.

The American monkeys are all arboreal. The recent genera inhabit the tropical forests of South America, a few species extending northward into Central America, spider monkeys and howler monkeys even to Mexico. Except from Ecuador northward, the Andes limit the western range of monkeys, though some howlers, spider monkeys and sapajous reach an elevation in Guatemala of 6,000 to 7,000 ft. A fossil cebid *Homunculus,* found in Lower Miocene formations in Patagonia, indicates the great antiquity and former wide range of the family.

Family Cebidae, comprising all the platyrrhine monkeys except the marmosets, is divided into some ten distinct genera. Many monkeys of this group have prehensile tails, capable of curling around a branch and supporting the weight of the body. When the tail is not so efficient a grasping organ it may assist in balancing. The teeth number 36 ($i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{3}{3}$, $m\frac{3}{3}$) and the molars are four-cusped, the inner pair of cusps somewhat crescentic. The brain varies in development, but the cerebral hemispheres are convoluted and cover or almost cover the cerebellum. Many of the smaller species have brains that are large relative to the body's size. The cebids are all forest-living; none of them is very large.

The titis, *Callicebus,* are probably the most primitive of the group. These monkeys range from Panama to the southern border of the forests, although best represented in Brazil and neighbouring countries. The species are usually reddish in colour; they are small; the head and body 12 to 14 in., the tail is about the same length and bushy, partly prehensile. The eyes are medium-sized, the ears smaller than usual in the family. Titis are diurnal in habit. They feed on fruit, insects, birds and birds' eggs.

Closely allied to the titis are the dourocoulis, *Aotus* (often called *Nyctiebus*), the only nocturnal monkeys. The tail is long but not prehensile. The large, closely approximated eyes and short face, surrounded by a ruff of pale fur, and the large, white spot over each eye give these little animals a peculiarly owl-like expression. A central and two lateral black lines border the pale spots. The nostrils are closer together than in other platyrrhines, probably correlated with the closeness of the eyes to each other. The ears are small, almost hidden by the fur. There is considerable variation in colour from iron gray to gray mixed with orange brown, and the fur may be short and soft, or long and lax. There may well be only a single species, although several are recognized by zoologists. The face around the eyes and nose is naked. The dourocoulis feed on fruits and insects which they hunt at night, remaining hidden by day. From the behaviour of *Aotus* and the high development of the olfactory parts of the brain, it is thought that the sense of smell is well developed, more so than in other monkeys. The eyes, unlike those of other Anthropoidea, are adapted for nocturnal vision, and the central area of the retina lacks the fovea or island of pure cones. *Aotus* is found from Panama to Peru and Brazil.

The sakis and their relatives (*Pithecia*) have procumbent lower incisors, somewhat like those of the lemurs, and separated from the large canines by a gap. The tail is bushy and not prehensile; it may be long or short. The nostrils are widely separated. The thumb is comparatively well developed. The hair is generally long, often forming bushy side whiskers. In the white-headed saki (*P. pithecia*), the males are black with white head, while the females are grizzled with a yellowish wash. This species is found in the Guianas and northern Brazil. The race found along the Rio Negro, Brazil, has the head of the male buffy and the hairs are short. The hairy or monk saki (*P. monacha*) has harsh, long fur, a hood of forwardly directed hairs on the head and neck. In colour both sexes resemble the females of the preceding species, but the hands and feet are white. The monk saki occurs on the Upper Amazon from eastern Peru, Ecuador and western Brazil. On the Lower Amazon a rare variety or closely related species (*P. albicans*) occurs; it has pale grayish head, neck and limbs, but is otherwise like *monacha.* These three species are about the size of large cats, nearly a yard in total length, of which the bushy tail is half. The red-backed saki (*P. chiropotes*) of Venezuela, the Guianas and Upper Amazon is smaller, with soft fur and less bushy tail. The long hair on top of the head is parted and suggests a poorly fitting wig, and the beard of the males is also divided. The black saki (*P. satanus*) resembles the preceding form but is blackish, the females and younger animals with brown overlay on the back. It occurs along the Lower Amazon and around Pará (Belem). The white-nosed saki (*P. albinasa*) of western Brazil, is a large black species with red nose and upper lip, a triangular white mark on the nose and naked face. The back may be grizzled. These three species show many cranial characters connecting the sakis with the uakaris. The uakaris (often considered a separate genus called *Cacajao* or, wrongly, *Brachyurus*) differ from all other American monkeys in their short tails (about 6 in. long). *P. melanocephala,* the black-headed uakari, is brown in colour except for black head and face; it occurs along the Rio Negro in northern Brazil. *P. rubicundus,* the red uakari, is brighter in colour than most mammals, rich rufous, the bare face bright vermilion; it is confined to the upper Amazon between this and the Ica river. The bald uakari (*P. calvus*) differs from its close relatives in having the fur sandy white; the face is red as that of the red species. The naked area of the face extends to the ears and the crown of the head, the underside of the body is dark brown. The uakaris are some 20 in. long.

The howling monkeys (*Alouatta,* often wrongly *Mycetes*) are the largest of the new world monkeys, the size of a small dog (some 20 in. long with tail about the same length). The howlers are notorious for their extraordinary vocal powers, their roars being audible for several miles. The powerful prehensile tail is naked at the tip and friction ridges similar to those on our hands and feet have developed. There is a beard in males. The head is high and the skull pyramidal, with greater prognathous development of the face than in other American species. The lower jaw is deep and the hyoid bone of the male is curiously expanded, forming a great bony cup, with the thyreoid cartilage also dilated. The intelligence of howlers is not high, and the brain is small and poorly developed, unlike that of other new world species. The Indians have tamed most monkeys of the Brazilian forest but not the howlers. The red howler (*A. senicula*) is dark reddish chestnut, paler on the back and sides. It occurs from Venezuela and northern Bolivia to the Guianas.

The black howler (*A. belzebul*) is found along the south bank of the Amazon to Rio Tapajoz. East of there a race with a reddish back and hands occurs, although individuals may be almost pure black. The caraya (*A. caraya*) occurs from Goyaz province, Brazil, through the Matto Grosso to northern Argentina. The adult males are black, while the females and young are ashy gray. The brown howler (*A. guariba*) of the mountains of eastern Brazil, is either reddish brown or blackish mixed with buffy. The mantled howler (*A. palliata*) is found from southern Mexico to Ecuador; it is blackish, sometimes grizzled on the back, with a gray or brownish mantle along the sides.

The squirrel monkeys (*Saimiri*, often wrongly *Chrysothrix*) are handsome, diminutive forms, about the size of squirrels. The face is short, almost vertical, with large eyes set close together. The ears are large, the nostrils widely separated. The tail is long, rounded and somewhat club-shaped; it is not prehensile. Their heads are produced backwards, the skull articulating near its middle with the spinal column. The brain is relatively larger than even that of man; the cerebral hemispheres overhang the cerebellum to a greater extent than in any other primate. Although smooth externally, the main grooves or sulci are evident in dissection. *S. sciurea* of Brazil, eastern Peru and northern South America has a gray head, the back gray or washed with gold. *S. oerstedi* of Panama, Costa Rica and Guatemala has a black crown, reddish-gold body, gray tail with black tip, white cheeks and throat.

The sapajous or capuchin monkeys (*Cebus*) are the most familiar of the new world primates, aptly called by H. O. Forbes "the typical genus of the American monkeys." The common names sapajou and capuchin are applied to these familiar monkeys. They are vivacious and relatively hardy; individuals having been known to survive in captivity for 25 years in the North Temperate zone. The thumb is well developed, though not opposable and the hands are used in a great variety of manipulations. The tail is slightly prehensile and usually carried curved toward the underside. With the superior functional adaptation of the hands is correlated a large, highly-developed brain and an intelligence comparable to that of the old world monkeys.

C. capucinus, the white-fronted sapajou, occurs from Honduras to Colombia. The body is black, the face and forehead naked, flesh-coloured, the forehead, cheeks, throat and chest yellowish white. *C. albifrons* is similar, with dull brown instead of black; it is found in Colombia, Ecuador and Peru. The brown capuchin of Ecuador, *C. aequatorialis*, is grizzled brown in colour, the crown, limbs and tail darker. *C. apella*, the smooth-headed capuchin of the Guianas and Venezuela, is fuscous in colour, more grayish on the forelimbs and face, the tail and feet dark. The tufted capuchin *C. fatuellus*, is found from Colombia to the Matto Grosso of Brazil and northern Bolivia. It has a black crown, reddish body, the feet and tail dark dull brown. Considerable variation occurs even in members of the same band. *Cebus* ranges from near sea level to about 7,000 ft. elevation.

A group of closely related monkeys comprises the woolly monkeys, *Lagothrix;* the spider monkeys, *Ateles* (or *Ateleus*); and, intermediate between these, the woolly spider monkey, *Brachyteles*. These are fruit-eating monkeys, all considerably larger than *Cebus*.

Lagothrix has particularly soft, woolly fur, grayish or brownish in colour, and a naked black, peculiarly human face. The generic name means "hare-hair," from the resemblance between fur of the typical forms and that of the hare. The hair of the head is short and stands upright. The common woolly monkey (*L. humboldti*) is heavily bodied, iron gray in colour with darker head and feet. The tail is prehensile and the thumb is moderately developed. This species is found from Colombia to Peru and the Upper Amazon. Throughout this range the colour varies from pale gray to dull reddish brown, and the pelage is long and woolly or short and soft. *L. hendeei* of Peru is very different. The back is rich reddish black, almost dark vinaceous, the head, sides and under parts black. The fur is silky, very long on the underside. A white triangular spot is on the nose; the long hair on the scrotum and the underside of the tail tip are pale golden colour.

The spider monkeys have coarse hair; the thumb is vestigial or absent externally, while the other fingers are elongated to form highly serviceable, hook-like hands for rapid swinging from branch to branch. The limbs and tail are also elongated. Spider monkeys frequently walk erect. The black spider monkey (*Ateles paniscus*) is represented by the typical form in the Guianas and northern Brazil. The face is red and naked, while the hair of the back is long. The variegated spider monkey (*A. belzebuth*) is black with buffy or whitish under parts, the inner sides of the lower legs and forearms similarly buffy. A white or golden triangular or band-like forehead patch is often present. The cheeks are often white or buffy. This species ranges from the Upper Orinoco to eastern Peru and the Lower Amazon on its southern bank. A Colombian race is pale grayish brown sprinkled with black. The brown-headed spider monkey (*A. fusciceps*) is black or blackish brown with head distinctly paler than the back. The hair of the crown is shorter than usual and does not project over the forehead. The black-handed species of Central America, north to Veracruz district, Mexico, (*A. geoffroyi*) may be recognized readily by the black hands, feet and head and reddish-brown or yellowish body fur.

Brachyteles arachnoides, the woolly spider monkey of southeastern Brazil, forms a link between *Lagothrix* and *Ateles*. Its fur is woolly; the thumb is small but still visible externally. The body is yellowish brown, darker on the back of the head. The females are grayer. The hairs on the head are directed backward.

These three genera all have long and powerful prehensile tails, of which the extremity is naked on the underside and provided with friction ridges like a finger. This organ is used not merely in climbing but also for picking up objects. These monkeys are easily tamed, affectionate and intelligent. The brain, especially in *Ateles*, is exceptionally large and complex.

Callimico, a peculiar type previously assigned to the genus *Callithrix*, has most of the external features, including claws, like the Callithricidae, but the skull, though essentially that of a marmoset, has certain likenesses to the Cebidae, the most important being the retention of the third molars. O. Thomas proposed a new subfamily, Callimiconinae, which he was inclined to place in the Cebidae. The callimico is about 8 in. long with a tail little more than a foot in length. Its colour is dark brown, the limbs, under parts and tail black, with white tufts in front of the ears and on either side of the back near the loins. The place of origin is between the Rio Ucayali and the Madeira, western Brazil.

Family Callithricidae contains the marmosets, the smallest of the Anthropoidea. They are handsome little animals, some smaller than squirrels. These were considered by some the most primitive American monkeys, but they probably represent dwarfed descendents of ancient cebids. Marmosets have only 32 teeth ($i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{3}{3}$, $m\frac{2}{2}$); the last molar was lost rather than one of the premolars, as was the case in the old world monkeys. The digits, except the hallux, bear sharp, curved claws in place of nails, forming in such small creatures highly efficient organs for climbing. The hands are used for grasping food, but they are not used much in manipulation as in higher primates, and the intelligence of the marmosets is decidedly inferior to that of the cebids. In the hind foot the great toe is smaller and less opposable than in other primates. The cerebrum, though large, is almost devoid of convolutions. Marmosets live in small bands; they are diurnal and feed on insects and fruit. They commonly breed in captivity, producing two or three young at a birth, instead of one as in monkeys in general.

The common marmoset or ouistiti, *Callithrix jacchus*, is an inhabitant of eastern Brazil, between Pará and Bahía west to the Rio Tapajoz. It is some 9 in. long with a tail of 12 in. The back is barred with black and grayish, as is the tail, while white ear-tufts distinguish this species from its close relative, the black-eared marmoset (*C. penicillata*) of southeastern Brazil which, except for its black head, is otherwise similar. The white-tufted marmoset (*C. aurita*) has the back variegated black and reddish or yellowish, and a ringed tail. A spot on the forehead and the ear-tufts are whitish. This species occurs in São Paulo province, Brazil. The white-headed marmoset (*C. geoffroyi*) of east-central Brazil has black ear-tufts and resembles the black-eared species in body colour, but the head is pure white in front of the ears. It is about 8 in. long, with a tail of the same length.

The yellow-headed marmoset, *C. flaviceps*, also from the east coast of Brazil above Rio de Janeiro, has a whitish face and forehead, the head, neck, shoulders and arms yellowish buff or reddish. The body is variegated black, gray and tawny, the latter colour disappearing on the lower back leaving black and gray bands which extend on the tail. The elegant marmoset (*C. petronius*) of Minas Geraes, Brazil, has long hair, coal black

except for a few yellowish bands on the back. The forehead and upper parts of the ear-tufts are white; the hands and feet, as well as the pale bands of the tail, are pale gray. The golden marmoset (*C. chrysoleuca*) of lower Rio Madeira, Brazil, has silky hair, white on the body with golden under parts, limbs and tail, the latter obscurely barred with white. The silvery marmoset (*C. argentata*) is silky white with the tail black, the limbs are dark fuscous in one race and the body ashy gray. The white-shouldered marmoset (*C. humeralifer*) of Bahía, Brazil, is blackish, mottled with white on the back and with whitish nape, shoulders and ear-tufts. *C. leucippe,* the gilded marmoset of the Rio Tapajoz, is white with legs and tail pale gold. Unlike the similarly coloured golden marmoset, the ears are without tufts. The pygmy marmoset (*C. pygmaea*) is found in the upper Amazon region, eastern Ecuador and Peru and western Brazil. It is about 6 in. long with tail about 7 in. The head and shoulders are ticked black and buffy, the back mottled black and buff and the tail is vaguely banded. The ears are untufted.

The tamarins (*Leontocebus*) have short lower incisors, leaving the canines projecting high above the tooth row. The tail is unbanded and almost always black, and the ears lack the tufts characteristic of *Callithrix.* The white-lipped tamarin (*L. labiatus*) of the Upper Amazon is mostly blackish, the back mixed with gray, the under parts and inner sides of limbs rich orange red. The tail, rusty at the base, becomes purplish black. The red-headed tamarin (*L. pileatus*) is found along the upper tributaries of the Amazon in eastern Peru and western Brazil. It is blackish except for the rufous forehead and crown, while the sides are brownish and the back somewhat mixed with gray. Around the mouth there are long white hairs. The imperial tamarin (*L. imperator*) ranges from eastern Ecuador and the Rio Negro to northern Bolivia; it has a long, upward-curling, white moustache, extending beyond the face. The body is gray, with a red-orange rump and base of the tail, black ear-tufts and end of the tail. The red-handed tamarin (*L. midas*) is relatively large, with large ears; its back is grizzled while the hands and feet are reddish golden. This species comes from the Guianas and was one of the first to become known to science. The negro tamarin (*L. ursulus*) lives along the Lower Amazon, is closely allied to the preceding species, but is distinguished by its black hands and feet; the back and outside of the legs have a reddish mixture. The face is hairy, the hair of the head not elongate, while the ears are large and naked. *L. leucopus,* the white-footed tamarin of northeastern Colombia, is dark gray with white hands, feet and head, the latter parts short-haired; the tail is black with a white tip. The brown-headed tamarin (*L. fuscocollis*) of the Upper Amazon is black variegated with yellowish ochre colour, the head yellowish buffy. The lion or golden tamarin (*L. rosalia*), found around Rio de Janeiro, is characterized by an extensive mane, suggesting that of a lion; its naked face is blackish violet. It is about a foot long, with slightly longer tail. The gold-and-black tamarin (*L. chrysomelas*), which comes from the coastal region of Bahía, Brazil, has body, face, underside and upper arms black, the legs blackish red, the head and forearms golden yellow. The pinché or silky marmoset (*L. oedipus*) of northern Colombia has a plume-like crest on the head, white in colour, as are the under parts and limbs. The back and thigh are brownish. The base of the tail is brown while the distal end is black. Geoffroy's marmoset (*L. spixi*) represents this species in Panama. It is similar in colour, but the hair on top of the head is not elongated, while the crown and nape are reddish brown.

A number of other species are known; the variation in colour and hair pattern is astonishing in this group.

Origin of the New World Monkeys.—The monkeys of South and Central America form an entirely different series from the monkeys of the old world and in spite of their general similarity to the latter, they probably were derived from a different ancestral stock.

In the first place the face in new world monkeys differs widely from that in old world monkeys, especially in the fact that in the new world or platyrrhine series the nostrils are usually widely separated at the base and are directed laterally. Other external differences from the old world monkeys were noted above. The new world monkeys may also be at once distinguished by the fact that there are three bicuspid or premolar teeth on each side, both in the upper and in the lower jaws, whereas in old world monkeys there are two. In the region of the middle ear, on the lower side of the skull, new world monkeys have a large ring-like tympanic bone, whereas in old world monkeys the same element forms a bony gutter, completely covering the drum-membrane on the lower side of the skull. Moreover, the cheek-bone of new world monkeys has a broad contact with the parietal bone, which is never the case in old world monkeys. The placenta in new world monkeys is disk-like, without the secondary placenta seen in old world monkeys.

All known new world monkeys both living and fossil stand on a rather high plane of evolution and there are no "living fossils" to connect the group definitely with any older fossil family. It is also difficult to be sure which is the most primitive living genus, but after repeated analyses of the characters of the skull and teeth it seems probable that the most primitive are certain small monkeys of the family Cebidae, especially the owl monkey (*Aotus*) and *Callicebus.* As noted above, the olfactory region of *Aotus* is less reduced than in most Cebidae and marmosets. These little monkeys have large orbits, short deep lower jaws, short muzzles and unreduced molar teeth. They agree with certain North American Eocene tarsioids in their dental formula $(i\frac{2}{2}, c\frac{1}{1}, p\frac{3}{3}, m\frac{3}{3}) \times 2 = 36$ and in the general form of the skull, but they differ from all known tarsioids in that the tarsal bones are not elongated. On the other hand, it is not impossible that the skeleton of the South American monkeys may have been derived from the type illustrated in the North American Eocene *Notharctus,* but in the present state of knowledge this inference is unsafe in view of the prevailing resemblances of the dentition and skull of *Aotus* to the tarsioids rather than to the notharctids. Finally there is the possibility that the new world monkeys may be derived from early extinct lemuroids resembling *Archaeolemur.*

Typical platyrrhine monkeys (*Homunculus*) in the Lower Miocene of Patagonia were found in association with a peculiar mammalian fauna which for millions of years had its headquarters in South America; but some of the ancestral stocks of this fauna were found in far earlier (Eocene) deposits of North America. In view of other available evidence, an ultimate North American origin for the new world primates seems quite possible. The monkeys now inhabiting Central America are closely related to those of Guiana and Brazil.

The new world monkeys as a whole exhibit a profound adaptation to arboreal life and probably originated in some heavily forested region such as they now occupy.

The old world or Catarrhine primates comprise two superfamily groups.

Cercopithecoidea.—Only family Cercopithecidae, the tailed monkeys, is included here; these monkeys are distinguished from the American species by features mentioned above. Two subfamilies are recognized: Cercopithecinae, including the macaques, baboons, mangabeys and guenons; and Colobinae, comprising the langurs and guerezas or colobus monkeys.

Subfamily Cercopithecinae all have cheek pouches in which food may be temporarily stored. The stomach is simple and these monkeys feed on insects and other animal matter as well as vegetable matter. Of this group the macaques, probably the best known of all monkeys, are widely distributed in India and the East Indies, north to China and Japan, while one species inhabits North Africa and the Rock of Gibraltar.

The macaques are among the most generally adaptable of monkeys and are hardy and long-lived in captivity. Though agile climbers, they are by no means exclusively arboreal and some are entirely terrestrial. They are usually omnivorous, and the crab-eating macaque of India lives chiefly on Crustacea. They have fore and hind limbs of about equal length. The thumbs, though short, are opposable and the animals have considerable manual dexterity. There is a median air sac connected with the larynx. The ischial callosities are well developed. The tail may be long, short, or practically absent as in the Barbary

ape, *Macaca sylvana*. The lion-tailed macaque (*M. silenus*) occurs in India. Its colour is black with an enormous gray beard and ruff, which surrounds the black face with the exception of the middle of the forehead. The tail is tufted at its extremity like that of a lion. The crab-eating macaque (*M. irus*) also has a long tail but lacks a mane. These monkeys feed on crustaceans along the shores and river-banks and swim readily. The colour is grayish or brownish and this species ranges from Siam to Timor in the East Indies, the Nicobars and the Philippines. The bonnet and toque macaques (*M. sinica* and *M. radiata*) have odd wig-like topknots, radiating from a central point; the former lives in southern India, the latter in Ceylon. They have long tails, about the same length as the head and body. The commonest species and the hardiest is the rhesus or Bengal macaque (*M. mulata*) found all over northern India, Burma, Indo-China and southern China. The tail is short, about half the length of the hind leg. The colour is grayish brown, becoming reddish on the rump and tail. The Himalayan macaque (*M. assanensis*) is similar but lacks the reddish on the rear parts and has woolly, thick hair. The Formosan macaque (*H. cyclopsis*) is also closely allied to the rhesus, but is olive gray in colour. The pig-tailed macaque (*M. nemestrina*) is larger, reaching the size of a large dog, and has a long face. The tail is only about 8 in. long. The fur is olive brown. The pig-tailed monkey is found from Burma to Sumatra and Borneo. The stump-tailed macaque (*M. speciosus*) has also a short tail; it is found from Tibet to Malaya, while the short-tailed brown Japanese macaque (*M. fusca*), with its red face, is confined to the Japanese Islands. The Celebes or Moor macaque (*M. maura*) is brownish black, with grayish limbs and a stump of a tail.

The black ape (*Cynopithecus niger*) with baboon-like face, has no tail. The head bears a tuft or crest of hair and the brow ridges are large. This species, a close relative of the macaques, is found in Celebes and Batjan Island.

Mangabeys (*Cercocebus*) are long-tailed monkeys found in the forested parts of tropical Africa. Their upper eyelids are white and their hairs are not banded. *C. torquatus*, the collared mangabey of southeastern Nigeria and the Cameroons, is blackish gray in colour with a bright bay crown and white collar, cheeks and chest. *C. atys*, the sooty mangabey, lives in West Africa from French Guinea to Liberia; it is grayish black above, paler below; the crown patch is speckled with olive. The face is flesh coloured except for the nose, mouth and chin, which are blackish. A race from the Gold Coast (*C. a. lunulatus*) has a white crescentic spot on the crown; the colour is more brownish. *C. agilis*, the gray mangabey of the Congo and eastern Cameroons forests, is dark grayish brown speckled with yellowish buff, especially on the front part of the body and thighs. The side whiskers are outstanding. The underside of the typical race is dirty whitish, but a race south of the Belgian Congo forests (*C. a. chrysogaster*) has under parts which are orange. The crested gray mangabey (*C. galeritus*) is found only along the Tana river, Kenya; it resembles the preceding species except for the long, pointed tuft on the top of the head, and it is smaller. The gray-cheeked mangabey (*C. albigena*) is dull black with horn-like eyebrows and a sooty brown or grayish mantle on the shoulders; the typical race comes from the southern Cameroons and probably also Gabun. The eastern race, from Uganda and the Ituri forest, has a paler mantle and the head is more brownish, while a slightly different form occurs in the northern Cameroons and southeastern Nigeria. *C. aterrimus*, the crested black mangabey, is glossy black, with a vertical peak-shaped sagittal crest of fur and long, grayish cheek whiskers; it lacks the eyebrow tufts and mantle. This species inhabits the forests south of the Congo river.

The gelada or lion baboon (*Theropithecus gelada*) inhabits the mountains of Ethiopia. It is a large, blackish, ground-living monkey, with a long mantle of dark hair, the cheeks and rear parts grayish, while the end of the tail is tufted. The face is long and baboon-like, with nostrils tubular and well back from the end of the muzzle, thus resembling the macaques.

The true baboons (*Papio*) have the nostrils at the end of the muzzle, the tail is shorter than the head and body, and in some forms it is much shorter. These large, ground-living monkeys are a modified branch of the macaque group. In captivity there have been cases of hybrids between macaques and baboons. The sacred baboon (*P. hamadryas*) is the species represented in the ancient sculptures of Egypt. It is found in the Sudan, Ethiopia, Eritrea, Somaliland and southwestern Arabia and is characterized by its speckled gray colouration and the long mantle of the males. Typical baboons are found from the Cape to the Sudan, chiefly where the country is rocky. They are referred to several species, chiefly because of their colouration, which varies from golden and red to dark olive brown. The chacma (*P. comatus*) of South Africa, and the anubis baboon (*P. doguera*) of Kenya and Uganda are dark, while the yellow baboon (*P. cynocephalus*) of Tanganyika, the small yellow species (*P. kindae*) found in Northern Rhodesia and the Katanga and the red baboon (*P. papio*) of the Guinea region, are brightly coloured forms.

The mandrill (*P. sphinx*) might be called the rib-faced baboon, from the ridges on either side of the muzzle in the adult male. The massive head with its swollen blue muzzle, lined with reddish, the yellowish beard and the stump of a tail are distinctive. The general colour is dark olive brown, while the naked skin of the buttocks is bright crimson. The females are much smaller and are difficult to separate from the next species. The mandrill lives in West Africa, from the Sanaga river in the Cameroons to the Gabun and Middle Congo of French Equatorial Africa. The drill (*P. leucophaeus*) of the northern Cameroons is similar in build but the face is black; each side of the muzzle bears a single ridge, the top of which may be flesh coloured; the lip is crimson as are also the bare buttocks, while the face is outlined with white. These two species are frequently considered to form a distinct genus, *Mandrillus*.

The guenons, *Cercopithecus* (or *Lasiopyga*) comprise a number of species found over most of Africa south of the Sahara. The last lower molar tooth has only four cusps rather than the five found in old world monkeys considered thus far. The fur is ticked, the hairs many-banded with dark and light colours, and some species are brightly coloured. Guenons are mostly small monkeys living in trees and subsisting on fruit, leaves and insects. They have well-developed cheek pouches. The Diana monkey (*C. diana*) of West Africa (Liberia and the Ivory Coast) is named from the white crescent on the forehead above the eyes. The face and front of the beard are black, but the cheeks, throat, chest, front of shoulders and a bar on the thigh are white. The body is blackish, finely speckled white, a broad bay streak runs down the back and the back of the thighs. In Nigeria the local race, *C. d. roloway*, has a longer white beard. The dryas guenon (*C. dryas*) lives in the forests south of the Congo river; it is closely allied to the Diana, with a short, full beard, but the general colouration is greenish gray. The De Brazza guenon (*C. neglectus*) is found from the Cameroons to the eastern and southern Belgian Congo. This species has a white beard and muzzle, and white hip-stripe; its orange-buff forehead band is broad, margined above with black; the body is a pale olive gray and the arms, hands, feet and tail are black. It takes readily to water, unlike most of its relatives.

C. aethiops, the common guenon, is found from Senegal to Ethiopia and south to the Cape, but avoids the rain forest areas for the most part. The grivet (*C. a. aethiops*) is olive gray with cheeks and eyebrow marking white; this race lives in Ethiopia and adjacent lands. The vervet of South Africa (*C. a. pygerythrus*) is more greenish with black hands, feet and distal third of the tail; the root of the tail is reddish. In Mozambique this is represented by a more reddish form (*C. a. rufoviridis*); in East Africa there is a yellowish race (*C. a. johnstoni*), while a dull grayish type invaded the eastern Belgian Congo (*C. a. centralis*). In West Africa is found the green monkey (*C. a. sabaeus*) with fur mixed black and yellow; the tail is yellowish, sometimes quite orange and the forehead is blackish although a narrow white band sometimes occurs. Another race, the malbrouck (*C. a. cynosuros*), with flesh-coloured face, well-marked white

forehead band, grayish cheeks, and grayish-green colouration, comes from Angola and southern Belgian Congo.

The moustache monkey (*C. cephus*) is small, with a short face, the upper lip and nose ornamented by a broad bluish-white marking. It has well-developed cheek whiskers of yellow, bordered below by black, whitish under parts and reddish tail. This species is found from the mouth of the Belgian Congo river, north to eastern Nigeria. *C. erythrogaster* of W. Cameroons is closely related but lacks the light markings on the face. The nose is black, there is a large light cheek patch and reddish under parts. The lesser spot-nosed monkey (*C. petaurista*) is reddish in colour with a heart-shaped white spot on the nose and white or yellowish cheek whiskers often divided by black, and the brows are also black. The underside is white. Various local races of this monkey are found in forested regions from Liberia to Katanga and East Africa (North of Lake Victoria Nyanza.)

The hocheur or large spot-nosed monkey (*C. nictitans*) is found on the island of Fernando Po, and from Liberia to the Ubangi river. The tail is long, the colouration of the body and basal half of the tail dark blue gray, the back of the head, forelegs and end of the tail black. The white nose-spot is large and is somewhat rhombic in shape. In the western parts of its range the under parts become white or whitish (*C. n. martini*).

The mona (*C. mona*) comes from West Africa. It is dark reddish olive, becoming blackish on the lower back, and there is a white spot on the rump on either side of the tail. The under parts are white, while the cheek whiskers are straw-coloured. A crescentic band of gray extends across the forehead from ear to ear, bordered below by black. Closely related forms, lacking the white spot beside the base of the tail, and with several minor differences in colour range from Sierra Leone to the eastern Belgian Congo. *C. pogonias*, from Fernando Po, the Cameroons and Gabun, has three black stripes on the head, one medial and one on either temple, while the hands, feet and tail are black. The extensive side whiskers are yellowish and the general colouration of this monkey is yellowish gray.

The diadem monkey (*C. mitis*) is typically bluish gray, with black limbs, under parts and tail. The forehead has usually a whitish bar, and the throat is white. In the Kivu mountains an orange-red race (*C. m. kandti*) occurs, while in East Africa (*C. m. albogularis*) the under parts and throat are white, the back is reddish. The golden Stair's monkey (*C. m. stairsi*) of Mozambique also belongs to this group, yellowish having replaced the whitish bands and the black bands having become pale. The owl guenon, *C. hamlyni*, is a large greenish-gray guenon of the eastern Belgian Congo, with black under parts, limbs and face, except for a white stripe down the nose, and frosted thighs and tail. The white-ruffed guenon (*C. l'hoesti*) has black face, under parts, tail-tip and limbs; the white ruff and throat contrast strongly with this; the head and tail are blackish gray, while the back is dark, rich reddish. The white ruff extends up on the cheeks and the hairs are directed upward. There is strong resemblance in this colour pattern to that seen in the white-throated diadem monkey of East Africa, but the upwardly directed hairs of the ruff and the black limbs distinguish it. This species is found in the eastern Belgian Congo, while a race (*C. l'h. preussi*) with speckled thighs is found in the west (Mt. Cameroon and Fernando Po).

The talapoin or dwarf guenon (*C. talapoin*) is found from the Cameroons to Angola and the eastern Belgian Congo, although in large parts of this range it was not found. It is about 10 in. long with the tail about 16 in.; the general colouration is grayish buff, the nose is black and the cheek whirl whitish as are the under parts. The face is extremely short and the last upper molar tooth has generally three cusps instead of four.

The huzzar or nisnas monkeys (*Erythrocebus patas*) are large and reddish, ground-living animals. The western race (*E. p. patas*) has the nose, a band above the eyes and the outer side of the upper arm black. In East Africa (*E. p. pyrrhonotus*) has a white nose and the upper arms are reddish. The huzzar monkey lives in the savanna country from Senegambia to the Upper Nile; this species is represented on ancient Egyptian monuments and was probably the Cebus of ancient writers.

The blackish green guenon (*Allenopithecus nigroviridis*) is found only along the middle section of the Congo river. It is blackish olive in colour, the face, hands, feet and upper side of the tail black and this colour predominates down the back. The cheeks, throat and under parts are grayish white, the latter mixed with ochraceous and black. The cheek teeth are high-crowned, the cusps drawn together, leaving narrow, longitudinal grooves between them and the limbs are short and stout.

The monkeys of subfamily Colobinae have a sacculated stomach and lack cheek pouches. The teeth are sharp-cusped and the diet is largely leaves, shoots and young twigs of trees, although fruit is also eaten. The African colobus monkeys (*Colobus*) are thumbless. The ursine colobus (*C. polykomos*) of West Africa (Ivory Coast to Sierra Leone) is black, with whitish cheeks, throat and tail. A white-thighed race (*C. p. vellerosus*) represents it in the Gold Coast and Togo. The black colobus (*C. satanus*) is similar to the preceding but lacks white markings; it is found in Fernando Po, the Cameroons and the Gabun. The guereza or mantled colobus (*C. abyssinicus*) occurs from Ethiopia to Tanganyika, the mouth of the Congo and eastern Nigeria. It is black with a long mantle of white along the sides, white cheeks, beard and supraorbital bar, and white-tufted tail. The extent of white varies somewhat and several races are recognizable. The Angola colobus (*C. angolensis*) ranges from the lower Congo to East Africa. The white hairs of the cheeks are long, the shoulder tufts are white and so is the distal part of the tail. The face is pinched, like that of a frail old woman, while the broad muzzle of the guereza suggests an elderly but healthy sailor with white whiskers and beard. The olive colobus (*C. verus*) is the smallest species (the head and body about 21 in., the tail 24 in.). The back is greenish brown, the limbs and tail dark olive, while the under parts are silvery gray. This species is restricted to West Africa, Liberia to the Gold Coast. The bay colobus monkeys (*C. badius*) vary locally and in consequence numerous races are recognized. The typical form comes from West Africa (Sierra Leone to the Ivory Coast); it is black, with bay forearms, legs and under parts. In French Congo a red form (*C. b. tholloni*) occurs, while farther east in Belgian Congo *C. b. powelli* is reddish brown, with dull yellowish-brown limbs. The Zanzibar colobus (*C. kirkii*) is also reddish, its hands, feet and shoulders are black, while a pale yellowish crest on top of the head is parted and falls over the ears and forehead. The red-crowned colobus (*C. rufomitratus*) is brownish gray in colour, with a reddish crown, black supraorbital band and a black transverse crest above the ears. This rare species is known only from the vicinity of Tana river, Kenya.

The langurs or leaf monkeys of Asia are slender-bodied, the limbs are long, as is usually the tail. Unlike their African relatives, the thumb is well developed. The sacred langur or hanuman (*Semnopithecus entellus*) of India and Ceylon is white or pale grayish in colour, the hands, feet and face are black, as are the overhanging eyebrows of stiff hair.

The black langurs of Peninsular India (*Kasi johnii*) are small, about 2 ft. in length with tail nearly 3 ft. The hair is fine and glossy, blackish in colour, while the head is yellowish brown and the rump is grayish. The young are black or grayish. The purple-faced monkey (*Kasi senex*) of Ceylon is closely allied to the preceding, but its face is distinctive, the hairs of the cheeks, chin and throat whitish. The general colour varies from white to black.

The shaggy langurs (*Trachypithecus*) have golden young, the hair of the crown is generally smooth going back to a peak. The nasal profile of the skull is straight. The capped langur (*T. pileatus*) of Assam and Upper Burma is dusky gray with golden, reddish or whitish under parts, a blackish tail. The white-mouthed langur (*T. phayrei*) lacks the cap, the hairs of the crown being like those of the cheek and neck; the areas around the eyes and the mouth are whitish. This species ranges throughout Burma, south to Tenasserim and east to Indo-China. The white-naped langur (*T. obscurus*) is found in the Malay peninsula; like the preceding species, it has a white mouth and white eyelids, but the nape and back of the head are pale, sharply contrasting with the brownish colour of the rest of the upper parts. The silvered leaf monkey (*T. pyrrhus*) occurs from Indo-China and Tenasserim to Borneo and Bali. It is blackish, dark brown or gray, with a frosting of pale gray or buffy on the hair tips. A red phase occurs in the islands.

The lesser leaf monkeys (*Presbytis*) have the young whitish with a blackish cross-like marking on the back and dark hands and feet. One or several whorls of hair on the head give an odd, tousled appearance to these animals. The skull has the nasal profile convex. A great variety of colour and hair patterning occurs in these monkeys and they are difficult to describe. Even in the same species colour

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LEMURS AND MONKEYS OF THE OLD AND NEW WORLDS

1. The ruffed lemur (*Lemur variegatus*) of the Malagasy region. It is coloured either black and white or reddish brown, and feeds on birds, reptiles, eggs, insects and fruit
2. The potto (*Perodicticus potto*) or West African slow lemur, an almost tailless primate somewhat larger than a squirrel
3. Bush baby (*Galago crassicaudatus*) of Africa, a small arboreal lemur with long pointed muzzle and very large eyes and ears
4. Woolly saki (*Pithecia monacha*), a tropical American monkey characterized by a bushy tail and whiskers of long, loose fur
5. The common, or white-eared marmoset (*Callithrix jacchus*), a diminutive American monkey that feeds on insects and fruit
6. An immature woolly monkey (*Lagothrix lagotricha*) of tropical America, distinguished by the naked, singularly human face and the powerful prehensile tail used for picking up objects as well as for climbing
7. Spider monkey (*Ateles geoffroyi*) of tropical America, so designated because of its extremely slender limbs. The tail is very long and prehensile and the hand is thumbless. It is easily tamed
8. White-faced capuchin monkey (*Cebus capucinus*), a vivacious American species that derives its name from the cowl-like form assumed by the hair on the crown of the head. It is common in captivity
9. Guereza (*Colobus abyssinicus*), an arboreal African monkey hunted for its fur which forms a black and white mantle on the sides and back

PRIMATES

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OLD WORLD MONKEYS AND APES

1. Gelada baboon (*Theropithecus gelada*), a large terrestrial monkey of southern Abyssinia. On the old males the hair develops into a mantle-like mane which covers the forequarters, leaving the chest bare
2. Chimpanzee (*Pan troglodytes*), the smaller of the two great man-like apes inhabiting equatorial Africa. It seldom exceeds 4½ feet in height and is almost completely arboreal, sleeping in nests in trees
3. Guenon (*Cercopithecus aethiops*), a small arboreal monkey of the African savannas. It subsists chiefly on fruits and leaves
4. Capped langur (*Trachypithecus pileatus*) female and young of the Malay Peninsula. In common with other langurs it has slender limbs and a very long tail, and feeds on leaves
5. Group of mountain gorillas (*Gorilla beringei*), Belgian Congo, showing two males and two females, the standing male being in characteristic posture of thumping his chest. The male at the left is in the position generally assumed by the gorilla when moving about on the ground
6. Siamang (*Hylobates* [*Symphalangus*] *syndactylus*) Malay Peninsula and Sumatra; largest of the gibbon group with an average height of 3 feet. It is distinguished from other gibbons by a laryngeal air sac
7. Orangutan (*Pongo pygmaeus*), "man of the forest," the least man-like of the three great anthropoid apes. It inhabits Borneo and Sumatra
8. The silvery gibbon (*Hylobates moloch*), one of the small arboreal apes of the Indo-Malay peninsula and East Indies

varieties red, black and white often occur. These monkeys are restricted to the Malay region, reaching the islands of Borneo, Sumatra, Java and Bali, where 25 forms are known.

The snub-nosed monkeys (*Rhinopithecus*) inhabit western China and eastern Tibet. Four species are known: *R. roxallanae*, the golden monkey of western Szechwan, has a bright-blue face, the under parts and lower limbs are golden, while the back is more or less grayish black, overlaid by silver hair-tips. Females are paler. *R. bieti*, from northern Yunnan, is brown with white under parts. *R. brelichi* is the largest Asiatic monkey. It is slate-coloured, with an oval white patch between the shoulders; the head is yellowish and the tail black. *R. avunculus* of Tonkin is blackish with yellowish under parts, creamy cheeks and white-tufted tail.

The doucs or pied langurs (*Pygathrix*) are found in Indo-China. The body in *P. nemaeus* is mottled grizzled gray, the face, hands and feet are yellow. The outsides of the upper limbs black, but the lower legs are chestnut, the forearms are white, as well as the tail and the lower back. *P. nigripes* has the posterior limbs black, the forearms gray, the body also gray.

The proboscis monkey (*Nasalis larvatus*) is restricted to Borneo. It is buffy brown with yellowish-gray rump, tail and limbs. The nose in old males is enormous and inflatable. This monkey lives in trees along river banks. The pig-tailed langur (*Simias concolor*) of the Mentawei Islands, off Sumatra, is the only short-tailed langur. It is smoky brown in colour and has a short, upturned nose. These monkeys are probably related to the golden monkeys and the pied langurs of the mainland.

The old world or catarrhine monkeys are widely distributed, mostly in tropical Asia and Africa, a few outlying forms reaching as far north as Tibet, China and Japan, while the baboons extend southward to South Africa. A single species, the Barbary ape of North Africa inhabits the Rock of Gibraltar in Europe. In the Pliocene, however, fossil monkeys of various species were recorded in England, Germany, France, Italy, Greece, North Africa and India. In the Miocene of Tuscany there was a large form (*Oreopithecus*), in which certain features of the molar teeth suggest remote relationship with the anthropoid apes. In the Lower Oligocene of Egypt was found a small lower jaw fragment, *Apidium*, the lower molars of which may be transitional from the tuberculo-sectorial or primitive mammalian type to the bilophodont form (with two cross-crests) of the old world monkeys. The group seems to have originated somewhere either in Africa or in the European-Asiatic landmass and negative palaeontological evidence indicates their complete absence from America and the Australian region.

No known fossil forms definitely connect the old world stock with the new world series, tarsioids, lemuroids or tree shrews. The new world series, for reasons given above, seems entirely independent; while the known fossil tarsioids appear too peculiarly specialized to be direct ancestors of the old world stock; yet such tarsioids as *Necrolemur* and *Microchoerus* are the only forms so far known that have even the appearance of evolving toward the catarrhine stage. This is broadly characterized as follows.

Nostrils, closely approximated and opening downward, tending to form a V; molars with two cross-crests; dental formula $i\frac{2}{2}, c\frac{1}{1}, p\frac{2}{2}, m\frac{3}{3}$. Tympanic bone forming a gutter leading to the outer ear; stomach simple or (in *Colobinae*) highly complex; habits primarily arboreal, the animals climbing as pronograde quadrupeds, mostly on top of the branches. Hands and feet prehensile. Thumb opposable, more or less flattened nails on all digits. Tail long, short or wanting, never prehensile. Cheek pouches in most genera. Large callous areas on buttocks, with corresponding flattening on lower ends of pelvis. Placenta double, consisting of a primary and secondary discoidal area, except in the baboons, with smooth chorion between them.

Although it has not yet been possible to trace the direct fossil ancestors of the old world group into formations older than at most Lower Oligocene, even the known living and extinct tree shrews, lemuroids and tarsioids preserve the broad stages by which arboreal insectivorus mammals with a relatively low type of brain were transformed into monkeys with a relatively high type of brain, with binocular, stereoscopic vision and an advanced method of intra-uterine nourishment of the young.

Hominoidea.—The anthropoid apes (*q.v.*) and mankind form a group distinct from other old world Primates. The anthropoid apes include the gibbons, the orang, chimpanzee and gorilla (*q.q.v.*); these are recognized as resembling man more closely than monkeys; they are tailless, their teeth and internal anatomy are very like those of man, and the placenta and embryonic stages show the same agreement. The gibbons are frequently considered to form the family Hylobatidae ("tree-walkers"), while the great apes are grouped in the family Pongidae.

Family Hylobatidae's range is now restricted to southeastern Asia, especially the Malay peninsula, Borneo, Sumatra and some other East Indian islands, though in the Miocene gibbons extended into Europe and in the Pliocene as far north as central China. They are slender, long-limbed, monkey-like apes, the most striking feature being the enormously elongate arms, which reach the ground when the animal stands erect. Like other anthropoids, they are tailless. They differ widely from the tailed monkeys in their mode of progression, as they do not run on all fours, either in the trees or on the ground, but hang and swing from branches by their long arms and hook-like fingers, making almost incredibly long leaps in the manner of a trapeze gymnast. This mode of arboreal locomotion was called "brachiation" by Sir Arthur Keith. While travelling thus by the hands, gibbons use the feet for prehension and carrying food. They sit upright and when on the ground run swiftly in an erect position, holding the arms out as balancers. Gibbons differ from most old world monkeys in the absence of cheek pouches and in the pattern of the molars, which is essentially that of the great apes and man. They also in common with these forms have a vermiform appendix and flattened sternum. They nevertheless retain some old world monkey characters; for example, the small ischial callosities are present, and the central bone in the wrist is retained as a separate element. Air sacs, formed as extensions of the laryngeal ventricles, well-developed in the Pongidae, are present only in the siamang. Gibbons have remarkable vocal powers, their high-pitched cries being audible for a mile or more.

Seven species of gibbons (*Hylobates*) may be distinguished. The hoolock (*H. hoolock*) of Burma, Assam and Western Yunnan (China) varies from pale yellowish gray to black; the brow is white and the hands and feet are never pale. The white-handed gibbon (*H. lar*) ranges from Lower Burma and Cambodia, Indo-China to Sumatra; it also occurs in pale and black colour phases. The hands and feet are always paler than the rest of the limbs, and the face is framed in white. The agile gibbon (*H. agilis*) is found from the Malay States to Sumatra; it differs from *H. lar* in having dark hands and feet. The gray gibbon (*H. moloch*) of Java and Borneo is ashy gray, sometimes with a brownish tinge, and the top of the head is usually dark. The under parts are blackish in some races. The black gibbon (*H. concolor*) generally has the hands and feet, and a patch on the head white or pale, but may be entirely black. The white forehead band is lacking. This species occurs in Siam, Indo-China and Hainan.

The large, black siamang, *H.* (*Symphalangus*) *syndactylus*, is found in Malaya and Sumatra. It stands 3 ft. or more in height; the second and middle toes are joined by a web. The chin is better developed than in other anthropoids, but the most conspicuous character is the large, inflatable laryngeal air sac. The dwarf gibbon (*H. klossi*) of the Mentawei and Siberoet Islands, west Sumatra, is intermediate in many characters between the siamang and the other gibbons. It is the smallest of the gibbons and is black in colour.

The three genera of great apes constituting family Pongidae, the orangutan of Borneo and Sumatra, and the chimpanzee and gorilla of the African forests, are by far the closest of all animals to man. Their divergences from man, striking though some of them are, are nearly all differences in degree rather than in kind, and these apes are nearer anatomically and physiologically to man than to any of the tailed monkeys. Their differences from man are largely correlated with habit. Man has become terrestrial, while the apes have retained their primary arboreal habit, and have even developed further arboreal adaptations in varying degrees. In the orang these have become greatly exaggerated, while in the gorilla, which has become partly terrestrial, they are less marked. The chimpanzee is intermediate. The arms have become long and the relatively short legs retain the opposable great toe. This disproportion of limbs results in a peculiar secondary type of quadrupedal progression on the ground, the hands resting on the knuckles and the fore part of the body somewhat elevated. The spinal column has a suggestion of the curves seen in man, but the balance of the head on the neck, the weight of the long arms, form of pelvis and weak gluteal and calf muscles, collectively preclude an habitual erect bipedal gait, though the animals often stand erect. Divergence from the old world monkeys and likeness to man is seen in the absence of ischial callosities and cheek pouches and in the presence of the vermiform appendix. The development of laryngeal air sacs, apparently a point of difference, is in reality a likeness, since man retains homologous vestiges of these in the laryngeal ventricles. In the chimpanzee and gorilla (but not in the orang) the central bone of the wrist becomes fused with the scaphoid during embryonic life, as in man. The menstrual cycle has the same phases as man and in the chimpanzee the interval is the same. In the three apes the period of gestation is nine months and the placenta is essentially of the human type. The secondary placenta, present in old world monkeys, is absent. Even the brain, though roughly only about one-third the size of that of man, is essentially a miniature of the human brain, no part or organ of one being absent in the other, but the differences being differences of proportion of certain parts. The susceptibility of anthropoids to many human diseases to which other animals are relatively immune, indicates the close chemical similarity, and the well-known precipitin tests by G. F. Nuttall showed the blood of these apes to be essentially identical with that of man, while differing from that of old world monkeys.

Of the three great apes, the least man-like is the orangutan (Malay, "man of the forest") which inhabits swampy coastal forests of parts of Borneo and Sumatra. This animal is completely arboreal, rarely descending to the ground, and exhibits exaggerated brachiating adaptations. It is a large ape, over 4 ft. high, with heavy body and short feeble legs but very long arms extending to the ankles when the animal stands erect. The digits of both hands and feet are elongated and hook-like, except the relatively short thumb and great toe. Though the orang is rather deliberate in his motions and does not leap through the trees as does the gibbon, the elongation of the arms permits an extended reach from branch to branch and enables it to progress with considerable rapidity. Among structural characters the following may

be noted: there are but 12 pairs of ribs as in man; the cranium is rounded and lacks the prominent supraorbital crest of the African anthropoids; the carpus retains the central bone as in monkeys and gibbons; the laryngeal air sacs are enormously developed, extending far down under the arms and on the chest in adult animals; the hair is coarse and sparse but very long and bright red in colour; a feature frequently, but not always, present in old males is a pair of prominent ridges of connective tissue on the cheeks. The orang feeds on fruits, especially the durian. There is probably only one species, with several local varieties. It is properly known as *Pongo pygmaeus*, but is often called *Simia satyrus*. A fossil jaw ascribed to Pongo in the Upper Pliocene and a molar tooth (*Palaeosimia*) from the Upper Miocene, indicate the ancient differentiation of the orang line.

The chimpanzee, properly known as *Pan* (= *Antropopithecus*), and the gorilla (*Gorilla*) inhabit the rain forests of central Africa, the chimpanzee having far the wider range. The latter is smaller, more agile and more completely arboreal in habit. The gorilla, probably owing to its great weight (males exceed 400 lb.), is largely terrestrial, though it climbs readily and in the west coast species the females and young are said to sleep in nests built in trees. Though the arms are somewhat longer than those of the chimpanzee, the hands have shorter fingers and are less adapted for brachiation; the feet show distinct secondary adaptation to walking on the ground. The foot of the mountain gorilla (*G. beringei*) of the eastern Belgian Congo presents the closest approach to the human foot found among primates. In both chimpanzee and gorilla the ribs number 13 pairs, one more than in man, but the total number of presacral vertebrae is the same, and a 13th rib in man is not uncommon. In both apes the hair is mainly black. In the chimpanzee the skin is usually light coloured in early life, tending to become dusky later; in the gorilla the face is intensely black. In both animals a heavy brow ridge overhangs the eyes and in the gorilla the cranial form in adult males becomes greatly altered by the development of huge crests for muscle attachment. The gorilla has well-marked alae of the nose, separated from the cheeks by distinct grooves. *See* CHIMPANZEE, GORILLA.

Origin and Evolution.—Of the fossil gibbons the best known is *Pliopithecus antiquus* from the Miocene of middle Europe. This differs from the recent gibbons in the lesser specialization of the canines and front lower premolar. A fossil humerus and femur of *Pliohylobates eppelsheimensis* from Eppelsheim, Germany, are close to those of the recent gibbons.

The earliest known forerunner of the gibbons and possibly also of the great apes and man is the fossil lower jaw named *Propliopithecus haeckeli*, from the Lower Oligocene of Fayûm, Egypt. This little jaw, while no bigger than that of a small monkey, already shows the relatively great depth characteristic of all anthropoids and of early man; its molar teeth also have the five main cusps arranged substantially as in the higher forms. Many nominal species of fossil anthropoid apes of the genera *Dryopithecus*, *Sivapithecus* and others are known.

MAN

The origin and evolution of man is fully discussed in other articles (ANTHROPOLOGY; BRAIN; MAN, EVOLUTION OF, etc.).

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(W. K. G.; J. H. McG.; J. E. HL.)

PRIME MINISTER, BRITISH. Though a Wolsey or a Cecil might achieve for a time a predominant position among the counsellors of the English crown, the persistence of the doctrine that ministers were all equally royal servants, severally responsible to the sovereign for their respective departments, was for centuries fatal to the recognition of any such predominance in theory. Thus G. Burnet describes Clarendon as "chief, or the only, minister," but the latter knew only too well that the style "first minister" was "a title so newly translated out of French into English that it was not enough understood to be liked, and every man would detest it for the burden it was attended with." Even in the 18th century it is more usual to find partnerships of two or three individuals, such as Marlborough and Godolphin, Harley and St. John, Stanhope and Sunderland, Townshend and Walpole, Newcastle, Henry Pelham and Hardwicke, sharing the principal burden of government. But the place vacated by the sovereign when, from 1717 onward, he ceased to attend cabinet meetings, had necessarily to be filled by a single individual, and this presiding officer developed almost inevitably into a prime minister. Sir Robert Walpole, though he "unequivocally denied" the title, is usually reckoned the first of the line, and certainly during his last spell of office (1721–42) he developed many of the attributes of premiership. He was master of his cabinet; he insisted on a general subscription by his colleagues to the Whig principles; he dismissed his opponents; he dispensed the royal patronage; and, with reservations, he may be described as commanding a majority in the house of commons. How novel, how unpopular, such a position still was may be gathered from the proceedings of both houses in 1741. "According to our Constitution," said Sandys, "we can have no sole and prime minister . . . every . . . officer has his own proper department; and no officer ought to meddle in the affairs belonging to the department of another." And the minority in the house of lords was, if possible, even more downright. "We are persuaded," they protested, "that a sole, or even a first minister, is an officer unknown to the law of Britain, inconsistent with the Constitution of the country and destructive of liberty in any Government whatsoever."

On the fall of Walpole the further development of the office was checked, first, by the group system and consequent group coalition governments of the latter half of George II's reign, and later, by the interference of George III, who aspired to be himself "the only element of coherence in a ministry." Thus Grenville (1763–65) thought that "Prime Minister is an odious title," and North (1770–82) would not countenance it even from his own family. It was the younger William Pitt who, on the fall of personal government, consolidated the work of his predecessors and by his long tenure of power (1783–1801) accustomed the nation to the office, if not to the name. The extent of his achievement can be measured by the terms of his famous interview with Lord Melville in 1803. He "stated not less pointedly and decidedly his sentiments with regard to the absolute necessity there is in the conduct of the affairs of this country, that there should be an avowed and real minister, possessing the chief weight in the council, and the principal place in the confidence of the king. In that respect there can be no rivalry or division of power. That power must rest in the person generally called the first minister, and that minister ought, he thinks, to be the person at the head of the finances. . . ." Nevertheless, old prejudices die hard. In 1806 it could still be said in parliament that "the Constitution abhors the idea of a prime minister," and in 1829 that "nothing could be more mischievous or unconstitutional than to recognize by act of parliament the existence of such an office." Such recognition was not granted until 1905, when the prime minister became known to the law merely as one who had precedence next after the archbishop of York.

The prime minister is appointed by the sovereign. "I offered," said Sir Robert Peel (1834–35, 1841–46) on his resignation of office, "no opinion as to the choice of a successor. That is almost the only act which is the personal act of the sovereign; it is for the sovereign to determine in whom her confidence shall be placed." And, as late as 1894, Queen Victoria could call Lord Rosebery (1894–95) without consulting the retiring prime minister, Gladstone (1868–74, 1880–85, 1886, 1892–94), or the wishes of the parliamentary majority. Nevertheless, the Crown's freedom of choice is narrowly circumscribed. The "economic" reforms of Rockingham's administration (1782), by reducing the royal patronage, made it less easy for the sovereign to put ready-made majorities at the disposal of whatever minister he might fancy, and the Reform bills of the 19th century made the ministry dependent on parliament and the electorate rather than on the royal favour. The prime minister is normally the acknowledged head of the party commanding a majority in the house of commons, and it is only, therefore, on occasions when no party commands an absolute majority of the house, or when the majority party has no acknowledged head, that there is room for the exercise of the royal discretion.

The prime minister has no salary as such. He merely draws the emoluments of whatever office he may happen to hold. At the close of the 17th century the lord treasurer was already regarded as the most important government official, and since the treasury came to be put into commission, the leading minister has normally held the office of first commissioner, or first lord, and it is by virtue of that office that he draws his salary of £10,000 a year. But Chatham (1766–68) was lord privy seal; Salisbury (1885–86, 1886–92, 1895–1902), successively secretary of state and lord privy seal; and Ramsay MacDonald (1924, 1929–35), simultaneously first lord of the treasury and secretary of state. In addition, the prime minister is usually the leader of the house, though David Lloyd George, Clement Attlee and Winston Churchill each at times found this burden excessive and transferred it to other shoulders. In the 18th century, when cabinets were almost exclusively composed of peers, the leading minister, curiously enough, was recruited most of the time from the commons; in the 19th century, when commoners came to form the bulk of the cabinet, the prime minister was, more often than not, a peer. But with the expansion of the franchise and the reduction in the powers of the lords (notably by the Parliament act of 1911) it became increasingly difficult for a peer to exercise the premiership effectively. No peer was prime minister after Lord Salisbury, and when Lord Curzon was passed over for the premiership in favour of Stanley Baldwin in 1922 this was generally regarded as a decisive demonstration of the need for a prime minister to be in the commons.

"As the cabinet stands between the sovereign and parliament," wrote Gladstone, "so the prime minister stands between the sovereign and the cabinet." He it is who, with the king's consent, appoints his fellow ministers to their respective posts. Originally, of course, the sovereign exercised an unfettered choice. Even so old and faithful a servant as Cecil never knew whom the queen would appoint to her council. In Anne's reign it required the united and persistent pressure of a ministry to get a Harley out or a Sunderland in. Pitt, at the close of the 18th century, had to put up with Thurlow, "the king's chancellor," and, at the dawn of the 19th century, to do without Fox, the king's *bête noire*.

So even today, when the prime minister's choice is theoretically as free as was originally the crown's, the pressure of party, the claims of talent and the prescriptive rights of previous officeholders render that freedom largely nugatory. Finally, it is the prime minister individually and not his cabinet collectively who advises the king to dissolve parliament. In the event of a cabinet dispute this places him in a very strong position, especially since with it is coupled the right of dismissal. However the responsibility of the cabinet to the prime minister and the remaining functions of the latter belong properly to the history of the cabinet (*q.v.*).

The history of the second quarter of the 20th century, with its recurring crises, showed that the position held by the prime minister was still subject to development and still dependent upon personal factors. In the financial crisis of 1931 the king exercised his prerogative of choosing a prime minister other than the leader of the largest parliamentary party. He chose, as leader of a "national" coalition, James Ramsay MacDonald, the leader of a minor section in a defeated and divided Labour party, not Stanley Baldwin, who was leader of the largest party. For a time the office of prime minister was inevitably weakened. The abdication crisis (1936), on the other hand, temporarily gave to the prime minister (Baldwin) the sovereign's prerogative of acting as liaison between the prime ministers of the dominions. The much greater crisis of 1940 produced further drastic changes. When Winston Churchill was appointed he was not the acknowledged leader of any party. The stresses of war and the personal ascendancy of Churchill increased the importance and prestige of the prime minister as such. He assumed a responsibility for the armed forces and for their direction almost equivalent to the responsibility held by the president of the United States. He became more of an ambassador-at-large than any predecessor and spoke for his country even before the U.S. congress. Radio broadcasting put him into an intimate relationship with the whole country, quite without precedent and far transcending his indirect relationship with the electorate through parliament.

The prime minister's position was, on the whole, strengthened vis-à-vis his cabinet colleagues, vis-à-vis parliament and perhaps vis-à-vis the electorate. He commands a significantly increased volume of patronage: almost 80 ministerial posts alone are his exclusive appointment. In the 19th century Gladstone was thought to be abnormal in having a policy of his own, and most prime ministers before 1914 were, at best, no more than strong chairmen in their cabinets. Later prime ministers were in this respect far more Gladstonian than Gladstone. This met with criticism, but, by concentrating its attacks upon the central figure, the opposition unwittingly did much to consolidate the prime minister's dominance. More than once, too, a prime minister has seemed to say to his parliamentary critics what Benjamin Disraeli accused Gladstone of saying in 1873: "Unless you are prepared to put someone in my place, your duty is to do whatever I bid you." Although in 1945 the electorate appeared to be offered a choice between a party program (Labour's) and a party leader (Churchill) and appeared to prefer the program to the personality, yet in general 20th-century elections were increasingly a choice between rival candidates for the premiership. (For lists of the prime ministers and other principal government officials, *see* MINISTRY.)

BIBLIOGRAPHY.—Such books as *The Prime Ministers of Britain, 1721–1921*, 4th ed. (1924), by Clive Bigham, give certain dates and facts, but the history and functions of the office can be authoritatively studied only in the memoirs and biographies of the statesmen themselves and in the party, ministerial and cabinet histories.

(F. L. B.; G. C. Ms.; H. G. N.)

PRIMER (percussion or friction), flame-producing device actuated by impact or friction and intended to ignite either the powder charge in a gun or the detonator of a high explosive charge. Electrically ignited primers are also in use. (*See* DETONATORS; EXPLOSIVES; LEAD AZIDE; MERCURIC FULMINATE.)

PRIMITIVE METHODISTS, a community of nonconformists, formed in consequence of the belief that Methodism as founded by the Wesleys tended, after the first generation, to depart from the enthusiasm that had marked its inception and to settle down to the task of self-organization. There were some ardent spirits who continued to work along the old lines and whose watchword was revivalism; and from their efforts came the Bible Christian, the Independent Methodist and the Primitive Methodist denominations. One of the zealous evangelists to whom Primitive Methodism owes its existence was Hugh Bourne (1772–1852), a millwright of Stoke-upon-Trent, Eng. He joined a Methodist society at Burslem, but, business taking him at the close of 1800 to the colliery district of Harrisehead and Kidsgrove, he was so impressed by the prevailing ignorance and debasement that he began a religious revival of the district. His open-air preaching was accompanied by prayer and singing. One of the afterfruits of this revival was the conversion (Jan. 1805) of the joint founder

of Primitive Methodism, William Clowes (1780–1851) of Burslem, who threw his house open for love feasts and prayer meetings and did a great deal of itinerant evangelization among the cottages of the countryside. Lorenzo Dow, U.S. revivalist, introduced the idea of the "camp meeting." The first camp meeting was held on Mow Cop, since regarded as the Mecca of Primitive Methodism. It lasted from 6 A.M. to 8 P.M., and Bourne and his friends determined to continue the experiment as a counterblast to the parish wakes of the time, which were little better than local saturnalia; but serious difficulties were presented by the antagonism of the Wesleyan Methodist circuit authorities. But Bourne and his friends persisted against both conference and the local superintendent, who issued bills declaring that no camp meeting would be held at Norton in Aug. 1807. The meeting was held, and ten months later Bourne was expelled by the Burslem quarterly meeting. Camp meetings went steadily on, and in 1810 the methods of the meetings organized by Bourne and Clowes were found to be incompatible with those of Wesleyan Methodism. A chapel was built at Tunstall, which became the nucleus of a circuit. In May 1811 the Camp-Meeting Methodists and the Clowesites united to form the connection which took the name "Primitive Methodists" in 1812. Clowes and James Crawfoot, a former Wesleyan local preacher, were set apart as preachers to "live by the Gospel."

The period 1811–43 was a time of rapid expansion for the new sect. Enthusiasts pressed forward through the "Adam Bede" country to Derby (which became the second circuit in 1816); Nottingham, where a great camp meeting on Whit Sunday 1816 was attended by 12,000 people; Leicestershire, where Loughborough became the third circuit, with extensions into Rutland, Lincolnshire and Norfolk; and ultimately to Hull, which became the fourth circuit and where a meeting which deserves to be called the first conference was held in June 1819. The Hull circuit during the next five years, through its Yorkshire, western, northwestern and northern missions, carried on a vigorous campaign with great success, especially among the colliers of Durham and Northumberland. Simultaneously Tunstall circuit, having thrown off its lethargy, was carrying on an aggressive evangelism. Work in the Black Country was extended to Liverpool and Manchester on the one side and south Shropshire on the other; and thence to Herefordshire, Glamorganshire and Wiltshire. Thenceforward, while the Oxford movement was awakening one section of the people of England the Primitive Methodists were making themselves felt among other classes of the population. The early Primitive Methodists had to meet mob violence that often amounted to sheer ruffianism, especially in Wessex and the home counties. On the other hand, there was legal persecution all over the country, and the preachers suffered many things from the hands of rural clergy and county magistrates. There are a score of cases of serious imprisonment, and a countless number of arrests and temporary detention. Local preachers received notice to quit their holdings, labourers were discharged, those who opened their cottages for meetings were evicted and to show any hospitality to a travelling preacher was to risk the loss of home and employment.

The years 1842–53 mark a transition period in the history of Primitive Methodism. From being a loosely jointed home missionary organization, the movement developed on the lines of a real connectionalism. One of the first steps was to move the Book Room and the meeting place of the executive committee to London. Soon after came the gradual process by which the circuits handed over their mission work to a central connectional committee. The move to London was proof that the leaders were alive to the necessity of grappling with the rapid growth of towns and cities, and that the connection, at first mainly a rural movement, had also urban work to accomplish. The period 1853–85 finds Primitive Methodism as a connection of ten federated districts, a unity which may be described as mechanical rather than organic. Conference—the supreme assembly—was a very jealously guarded preserve, being attainable only to preachers who had travelled 18 and superintended 12 years and to laymen who had been members 12 and officials 10 years. This exclusiveness naturally strengthened the popularity and power of the districts, where energy and talent found a scope elsewhere denied. Thus, Hull district inaugurated a bold policy of chapel buildings; Norwich that of a foreign mission; Sunderland and Manchester the ideal of a better-educated ministry; Nottingham district founded a middle-class school; Leeds promoted a union of Sunday schools, and the placing of chapel property on a better financial footing. The period as a whole had some anxious moments; emigration to the gold fields and the strife which afflicted Wesleyan Methodism brought loss and confusion between 1853 and 1860. Yet when conference met at Tunstall in the latter year to celebrate its jubilee it could report 675 ministers and 11,384 local preachers, 132,114 members, 2,267 chapels, 167,533 scholars and 36,988 teachers.

Work in Australia and New Zealand prospered, and the former country finally contributed more than 11,000 members to the formation of the United Methodist Church of Australia, New Zealand with its 2,600 members preferring to remain connected with the home country. In the United States there had been a quiet but steady growth since the first agents went there in 1829. There are three conferences—the eastern, Pennsylvania and western, with about 70 ministers, 100 churches and 7,000 members. The Canadian churches had a good record, consummated in 1884 when they contributed 8,000 members and 100 ministers to the United Methodist Church of the dominion. In Jan. 1870 the first piece of real foreign missionary work was begun at Fernando Po, followed in December of the same year by a mission on the Orange river in South Africa. This station is the centre of a polyglot circuit or district and carries on an efficient institution for training teachers, evangelists and artisans. In 1899 another South African mission was started, and a few years later work was begun in southern Nigeria.

Following 1885 Primitive Methodism developed from a connection into a church, the designation employed since 1902. In England a union for social service was formed in 1906, the natural outcome of Thomas Jackson's efforts for the hungry and distressed in Clapton and Whitechapel, and of similar work at St. George's hall, Southwark. Other significant episodes have been the unification of the funds, the equalization of districts and the reconstruction of conference on a broader basis, the Ministers' Sustentation fund and the Church Extension fund, and the enlargement and reorganization of the college at Manchester. This undertaking owed much to the liberality of Sir William P. Hartley, whose name the college, which is affiliated to the Victoria University of Manchester, now bears. The Christian Endeavour movement in Great Britain derives, perhaps, its greatest force from its Primitive Methodist members; and the appointment of central missions, connectional evangelists and mission vans, which tour the more sparsely populated rural districts, witness to a continuance of the original spirit of the denomination, while the more cultural side is fostered by the Hartley lecture. In 1932 the Primitive Methodists contributed 222,021 members to the Methodist Church in England through merger. In the United States in the early 1950s there were approximately 12,000 members. (*See* also METHODISM.)

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PRIMO DE RIVERA, MIGUEL (1870–1930), Spanish soldier and statesman, known as the marquis de Estella, was born at Jerez de la Frontera Jan. 8, 1870, and studied at the Madrid Military academy. After four years in Toledo, he went to Morocco in 1893 as lieutenant of the infantry regiment of Extremadura, and in Oct. 1893 became a captain. In 1895 he was adjutant to Gen. Arsénio Martínez de Campos in Cuba, and rose to be major commanding the infantry battalion of Zamora.

He served in the Philippines in 1897, and negotiated the treaty of Biagnabato (Biacabato) on Dec. 12, 1897. He then held commands at Barcelona, on the general staff and at Algeciras. In 1915 he was appointed governor of Cadiz, but he was relieved from the office after advocating the exchange of Gibraltar for Ceuta or other North African territory and criticizing the government's policy in Morocco. However, he was soon afterward promoted to general and chief of the 1st infantry division in Madrid. In 1921 Estella was elected senator for Cadiz, but after urging the nation to relieve itself of the Moroccan burden he once again lost his post. He then became captain general of Catalonia with a view to ending the reign of terror there, and he soon reaped a measure of success. He saw the chaos in Catalonia as an indirect consequence of the parliamentary breakdown, and issued the manifesto dated Sept. 12, 1923, suspending the constitution and proclaiming in its place a directorate consisting of military and naval officers. (*See* SPAIN: *History: Dictatorship of Primo de Rivera* (1923–30). Primo dissolved the directorate on Dec. 3, 1925, and substituted a government of civil as well as military ministers. The dictator became premier. He resigned on Jan. 28, 1930, and died in Paris on March 16, 1930.

PRIMOGENITURE, a term used to signify the preference in inheritance which is given by law, custom or usage to the eldest son and his issue, or in exceptional cases to the line of the eldest daughter.

The history of primogeniture is given in the article LAW OF SUCCESSION. *See* also INHERITANCE; INTESTACY.

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PRIMROSE. The genus *Primula* contains about 300 species distributed throughout the cooler parts of Europe and Asia, and found also on the mountains of Abyssinia and Java; a few are American. They are herbaceous perennials, with a permanent stock from which are emitted tufts of leaves and flower-stems which die down in winter; the new growths formed in autumn remain in a bud-like condition ready to develop in spring. They form the typical genus of Primulaceae (*q.v.*), the floral conformation of which is very interesting on several accounts independently of the beauty of the flowers.

The variation in the length of the stamens and of the style in the flowers of *Primula* has attracted much greater attention since Charles Darwin investigated them. Some of the flowers have short stamens and a long style, while others have long stamens, or stamens inserted so high up that the anthers protrude beyond the corolla tube, and a short style. Gardeners and florists had for centuries been familiar with these variations, calling the flowers from which the anthers protruded "thrum-eyed" and those in which the stigma appeared in the mouth of the tube "pin-eyed."

Darwin showed by experiment that the most perfect degree of fertility, as shown by the greatest number of seeds and the healthiest seedlings, was attained when the pollen from a short-stamened flower was transferred to the stigma of a short-styled flower, or when the pollen from the long stamens was applied to the long style. As in any given flower the stamens are short (or low down in the flower-tube) and the style long, or conversely, it follows that to ensure a high degree of fertility cross fertilization must occur, and this is effected by the transfer of the pollen from one flower to another by insects. Incomplete fertility arises when the stigma is impregnated by the pollen from the same flower. The size of the pollen-grains and the texture of the stigma are different in the two forms of flower.

Among species found in Britain may be mentioned the common primrose (*P. vulgaris*); the cowslip (*P. veris*); and the oxlip (*P. elatior*), a rare plant found only in the eastern counties. In addition to these, two other species occur in Britain, namely, the Eurasian *P. farinosa*, bird's eye primrose, found in Wales, the north of England and southern Scotland, and *P. scotica*, which occurs in Orkney and Caithness. These two species are found also in high arctic latitudes, and *P. farinosa*, or a very closely allied form, exists in Fuegia. About 15 species occur in North America, chiefly in the western and northwestern parts of the continent.

The auricula (*q.v.*) of the gardens is derived from *P. auricula*, a yellow-flowered species, a native of the Swiss mountains. The Himalayas are rich in species of primrose, often very difficult of determination or limitation, certain forms being peculiar to particular valleys. Of these *P. denticulata, stuarti, sikkimmensis, nivalis, floribunda*, may be mentioned as frequently cultivated, as well as the lovely rose-coloured species *P. rosea*. The royal cowslip (*P. imperialis*) resembles *P. japonica* but has leaves measuring 18 in. long by 5 in. wide. It grows at an elevation of 9,000 ft. in Java and has deep yellow or orange flowers.

The primrose is to be had in cultivation in a considerable variety of shades of colour, ranging from the palest yellow to deep crimson and blue. Since the varieties do not reproduce quite true from seed, it is necessary to increase special kinds by division. The primrose is at its best in heavy soils in slight shade, and with plenty of moisture during the summer. One of the most popular of winter and early spring decorative plants is the Chinese primrose, *Primula sinensis*, of which some superb strains have been obtained. *P. japonica*, a bold-growing and very beautiful Japanese plant, is hardy in sheltered positions in England but must be grown in the cool greenhouse over most of the U.S. *P. cortusoides* of Siberia and *P. sieboldi* of Japan, of which there are many lovely forms, is suitable for outdoor culture and under glass. There are several small-growing hardy species which should be accommodated on the best positions on rockeries, where they are secure from excessive dampness during winter; excess of moisture at that season is the worst enemy of the choice Alpine varieties. They are propagated by seed and by division of the crowns after flowering. *P. forresti* is an orange-yellow flowered species from China, as is also *P. bulleyana*. They are hardy in favoured spots in the rock garden.

Evening primrose belongs to the genus *Oenothera* (*q.v.*) (family Onagraceae).

The Cape primrose comprises hybrid forms of *Streptocarpus*, a South African genus belonging to the family Gesneriaceae. The Arabian primrose is *Arnebia cornuta* of the family Boraginaceae, a garden annual.

PRIMULACEAE, a family of gamopetalous dicotyledons belonging to the order Primulales and containing 22 genera with about 600 species. It is cosmopolitan in distribution, but the majority of the species are confined to the temperate and colder parts of the northern hemisphere and many are arctic or alpine. Nine genera are represented in the British flora.

The plants are herbs, sometimes annual as in pimpernel (*Anagallis arvensis*), but generally perennial as in *Primula*, where the plant persists by means of a sympodial rhizome, or in *Cyclamen* by means of a tuber formed from the swollen hypocotyl. The leaves form a radical rosette as in *Primula* (primrose, cowslip, etc.), or there is a well-developed aerial stem which is erect, as in species of *Lysimachia*, or creeping, as in *Lysimachia nummularia* (creeping jenny or moneywort). *Hottonia* (water violet) is a floating water plant with submerged leaves cut into fine linear segments. The leaves are generally simple, often with a toothed margin; their arrangement is alternate, opposite or whorled. The flowers are solitary in the leaf-axils as in pimpernel, moneywort, etc., or umbelled as in primrose, where the umbel is sessile, and cowslip, where it is stalked, or in racemes or spikes as in species of *Lysimachia*. Each flower is subtended by a bract, but there are no bracteoles, and corresponding with the absence of the latter the two first developed sepals stand right and left. The flowers are hermaphrodite and regular with parts in fives (pentamerous) throughout, though exceptions from the pentamerous arrangement occur. The sepals are leafy and persistent; the corolla is generally divided into a longer or shorter tube and a limb which is spreading, as in primrose, or reflexed, as in *Cyclamen;* in *Soldanella* it is bell-shaped; in *Lysimachia* the tube is often very short, the petals appearing almost free; in *Glaux* the petals are absent. The five stamens spring from the corolla-tube and are opposite to its lobes; this anomalous position is generally explained by assuming that an outer whorl of stamens opposite the sepals has disappeared, though sometimes represented by scales as in *Samolus* and *Soldanella*. The superior ovary—half-inferior in *Samolus*—bears a simple style ending in a capitate entire stigma, and contains a free-central placenta bearing generally a large number of ovules, which are exceptional in the group Sympetalae in having two integuments. The fruit is a capsule dehiscing by five, sometimes ten, teeth or valves, or sometimes transversely (a pyxidium) as in *Anagallis*.

Cross pollination is often favoured by dimorphism of the flower, as shown in species of *Primula*. The two forms have long and short styles respectively, the stamens occupying corresponding positions half-way down or at the mouth of the corolla-tube; the long-styled flowers have smaller pollen-grains, which correspond with smaller stigmatic papillae on the short styles (*see* PRIMROSE).

The family is divided into five tribes by characters based on the presence or absence of tubers, the regularity of the flower, the aestivation of the corolla, etc. The ovules are generally semi-anatropous so that the seed is peltate with the hilum in the centre on one side (or ventral), but sometimes, as in *Hottonia* and *Samolus*, anatropous with the hilum basal—together with the method of dehiscence of the capsule and the relative position of the ovary.

The chief British genera are *Primula;* and the *Lysimachia*, loosestrife, including *L. Nummularia*, moneywort; *Anagallis*, pimpernel; and *Hottonia*, water violet. The most familiar American genera are *Primula* (primrose), *Samolus* (water pimpernels and brookweeds), *Lysimachia* (loosestrife), and *Dodecatheon* (shoot-

ing stars or American cowslips).

See F. Pax and R. Knuth, "Primulaceae," *Pflanzenreich* 22 (iv, 237): 1–386, fig. 1–75 (1905).

PRINA, GIUSEPPE (1768–1814), Italian statesman. He was an adherent of Napoleon Bonaparte, and when Eugène Beauharnais became viceroy of Italy, was appointed minister of finance. His skill in devising fresh taxes to meet the enormous demands of Napoleon's government made him the best-hated man in Lombardy. After the emperor's forced abdication in 1814 Prina's party moved in the senate that delegates should go to Vienna to request that Eugène Beauharnais be raised to the throne of a free Italian kingdom. This provoked the formidable riot in which Prina was dragged about the town for four hours, until almost torn to pieces, he received his death-blow.

PRINCE, MORTON (1854–1929), U.S. psychologist, was born in Boston, Mass., Dec. 21, 1854, and was educated at Harvard university (B.A., 1875; M.D., 1879). His particular interest lay in the study of abnormal psychology, a field in which he taught for many years. He was founder (1906) and editor (1906–29) of the *Journal of Abnormal Psychology*. His books include *The Nature of Mind and Human Automatism* (1885); *Dissociation of a Personality* (1906); *The Unconscious* (1913); *The Psychology of the Kaiser* (1915); and *Clinical and Experimental Studies in Personality* (1929). He died Aug. 31, 1929.

PRINCE, a title implying either political power or social rank. The Latin word *princeps* originally signified merely "the first." As an honorary title it was applied in the Roman republic to the *princeps senatus, i.e.,* the senator who stood first on the censor's list, and the *princeps juventutis, i.e.,* the first on the roll of the equestrian order. The assumption of the style of *princeps senatus* by Augustus (*q.v.*) first associated the word with the idea of sovereignty and dominion, but throughout the period of the empire it is still used as a title of certain civil or military officials; while in the middle ages it is applied vaguely in charters to the magnates of the State or the high officials of the palace, *principes* being treated as the equivalent of *proceres, optimates* or *seniores.* In the Visigothic and Lombard codes *princeps* is the equivalent of *rex* or *imperator.*

From Italy the use of the title spread—first, with the crusaders, to the Holy Land, where Bohemund, son of Tancred, took the style of prince of Antioch; next, with the Latin conquerors, into the East Roman empire, where in 1205 William de Champlette, a cadet of the House of Champagne, founded the principality of Achaea and the Morea. This example was followed by lesser magnates, who styled themselves loosely, or were so styled by the chroniclers, "princes." From the East the fashion was carried back to France; but there the erection of certain fiefs into "principalities," which became common in the 15th and 16th centuries, certainly implied no independent sovereignty, and the title of "prince" ranked below that of "duke," being sometimes borne by cadet branches of ducal houses. On the other hand, the title of "prince" was borne from the time of Charles VII. or Louis XI. by the sons of the royal house, so-called "princes of the blood," who took precedence in due order after the king. To these were added, from the time of Louis XIV., the *princes légitimés,* recognized bastards of the sovereign.

In Germany, Austria and other countries formerly embraced in the Holy Roman empire the title of "prince" had a somewhat different history. During the first period of the empire, the "princes" were the whole body of the *optimates* who took rank next to the emperor. In the 11th century, with the growth of feudalism, all feudatories holding in fief of the Crown ranked as "princes." Towards the end of the 12th century, however, the order of princes (*Fürstenstand*) was narrowed to the more important spiritual and temporal feudatories who had a right to a seat in the diet of the empire in the "college of princes" (*Fürstenbank*). Finally, in the 13th century, seven of the most powerful of these separated themselves into a college which obtained the sole right of electing the emperor. These were called "prince electors" (*Kurfürsten*), and formed the highest rank of the German princes (*see* Electors). The formal designation of "prince" (*Fürst*) was, however, extremely rare in Germany in the middle ages; but in the 17th and 18th centuries the number of principalities was increased.

Thus, in Germany, with the decay of the empire the title "prince" received a sovereign connotation, though it ranked, as in France, below that of "duke." There were, however, in the countries formerly embraced in the Holy Roman empire other classes of "princes." Some of these inherited titles, sovereign under the old empire, but "mediatized" during the years of its collapse at the beginning of the 19th century; others received the title of "prince" at the end of the empire as "compensation" for ceded territories. There were also in Austria and Germany "princes," created by the various German sovereigns, and some dating from the period of the old empire, who took a lower rank, as not being "princes of the Holy Roman empire" nor entitled to any royal privileges. Some of these titles were bestowed to give rank to the morganatic wives and children of royal princes; others as a reward for distinguished service, *e.g.,* Hardenberg, Blücher, Bismarck. In this latter case the rule of primogeniture was usual, the younger sons taking the title of "count" (*Graf*). All these princes were styled *Fürst,* having the predicate "Serene Highness" (*Durchlaucht*). The word *Prinz,* actually synonymous with *Fürst,* was reserved as the title of the non-reigning members of sovereign houses and, with certain exceptions (*e.g.,* Bavaria), for the cadets of mediatized ducal and princely families. The heir to a throne was "crown prince" (*Kronprinz*), "hereditary grand duke" (*Erbgrossherzog*) or "hereditary prince" (*Erbprinz*). The heir to the crown of Prussia, when not the son of the monarch, had the title of "prince of Prussia" (*Prinz von Preussen*).

In Italy the title "prince" (*principe*) is also of very unequal value. The heads of great families sometimes bear the title of "prince," sometimes that of "duke." The title of "prince of Naples" is attached to the eldest son of the king of Italy.

"Prince" is also the translation of the Russian title *knyaz.* In general, though the title "prince" implies descent from one or other of the ruling dynasties of Russia, it is in itself of little account owing to its being borne by every member of the family.

The title of "prince" is also borne by the descendants of those Greek Phanariot families (*see* Phanariotes), who formerly supplied hospodars to the Turkish principalities on the Danube. The only instance in Europe of "prince" as a completely sovereign title is that of the prince of Monaco, the formal style having been adopted by the Grimaldi lords in 1641.

Great Britain.—In Great Britain "prince" and "princess" as titles are confined to members of the royal family, though non-royal dukes are so described in their formal style (*see* Duke). Nor is this use of great antiquity; the custom of giving the courtesy title of "prince" to all male descendants of the sovereign to the third and fourth generation being foreign to English traditions. It was not till the reign of Henry VII. that the king's sons began to be styled "princes"; and as late as the time of Charles II., the daughters of the duke of York, both of whom became queens regnant, were called simply the Lady Mary and the Lady Anne. The title of "princess royal," bestowed on the eldest daughter of the sovereign was borrowed by King George II. from Prussia. Until recent years the title "prince" was never conferred on anybody except the heir-apparent to the Crown, and his principality is a peerage. Since the reign of Edward III. the eldest sons of the kings and queens of England have always been dukes of Cornwall by birth, and, with a few exceptions, princes of Wales by creation. Before that Edward I. had conferred the principality on his eldest son, afterwards Edward II., who was summoned to and sat in parliament as prince of Wales. But Edward the Black Prince was the original grantee of the principality as well as of the dukedom, under the special limitations which have continued in force to the present day. The entail of the former was "to him and his heirs the kings of England" and of the latter "to him and his heirs the first-begotten sons of the kings of England." Hence when a prince of Wales and duke of Cornwall succeeds to the throne the principality in all cases merges at once in the Crown, and can have no separate existence again except under a fresh creation, while the dukedom, if he has a son, descends immediately to him, or remains in abeyance until he has a son born. If, how-

ever, a prince of Wales and duke of Cornwall should die in the lifetime of the sovereign, leaving a son and heir, both dignities are extinguished, because his son, although he is his heir, is neither a king of England nor the first-begotten son of a king of England. But, if instead of a son he should leave a brother his heir, then —as was decided in the reign of James I on the death of Henry, prince of Wales, whose heir was his brother Charles, duke of York—the dukedom of Cornwall would pass to him as the first-begotten son of the king of England then alive, the principality of Wales alone becoming merged in the crown.

But even now the children of the sovereign other than his eldest son, though by courtesy "princes" and "princesses," need a royal warrant to raise them *de jure* above the common herd; and even then they remain "commoners" till raised to the peerage. In 1905 King Edward VII established what appeared to be a new precedent, by conferring the titles of "princess" and "highness" upon the daughters of the princess Louise, duchess of Fife, created "princess royal."

PRINCE EDWARD ISLAND, the smallest province of Canada, lies between approximately 45° 58′ and 47° 4′ N. and 61° 59′ and 64° 27′ W. The island is in a great semicircular bay of the Gulf of St. Lawrence, which extends from Point Miscou in New Brunswick to Cape North in Cape Breton. From the mainland it is separated by Northumberland strait, which varies from 9 to 30 mi. in width. Structurally, however, it is a continuation of the northern plain of Nova Scotia and on the island the red rocks again appear (Permian of 150,000,000 years ago). In the main the rocks consist of soft red micaceous sandstone and shales, with interstratified but irregular beds of brownish-red conglomerates containing pebbles of white quartz and other rocks. There are also beds of hard dark-red sandstone with the shales. Bands of moderately hard reddish-brown conglomerate, the pebbles being of red shale and containing white calcite, are seen at many points; and then greenish-gray irregular patches occur in the red beds, as a result of the bleaching out of the red colours by the action of the organic matter of plants. The soft red rocks have allowed rapid denudation, especially by the sea, and consequently the island is extremely irregular in shape; deep inlets and tidal streams almost divide it into three approximately equal parts; from the head of Hillsborough river on the south to Savage harbour on the north is only 1½ mi., while at high tide the distance between the heads of the streams which fall into Bedeque and Richmond bays is even less. North of Summerside the land nowhere rises more than 175 ft. above sea level; but between Summerside and Charlottetown, especially near New Wiltshire, is a ridge of hills, running from north to south and rising to a height of nearly 500 ft. The north shore, facing the gulf, is a long series of beaches of fine sand. In 1936 the federal government established Prince Edward Island National park, embracing an area of 7½ sq.mi., which extends along the north shore for 25 mi. On the south, low cliffs of crumbling red sandstone face the strait. The oceanic influences make the climate of the province milder than that of the neighbouring mainland. The mean January temperature is 15° and the mean for July a little over 65°. The winter and summer rainfall is about the same, between 3 in. and 5 in. in January and July respectively. Fogs are less common than in New Brunswick or Nova Scotia.

History.—Jacques Cartier sighted Prince Edward Island in June 1534. It was first called Ile St. Jean until renamed after Prince Edward, duke of Kent, in 1798. Under the French little attention was paid to the island prior to the peace of Utrecht, when they began to make efforts to colonize it; and the creation of a feudal proprietorship gave to the French settlers a precarious existence. In 1758 the island, with its capital at Port La Joie (Charlottetown), was occupied by a British force under Lord Rollo, and a partial expulsion of the French inhabitants took place, comparable with that of the Acadians from the mainland of Nova Scotia. Ceded finally to Great Britain in 1763, it remained under the government of Nova Scotia until 1769, when it became a separate colony. Unfortunately, the island was divided into 67 townships of 20,000 ac. each which, in 1767, went to a few large proprietors, often nonresident, and a century of struggle between landlords and tenants (many of them American loyalists and Scottish immigrants) ensued.

In 1864 a conference met at Charlottetown to consider a possible union of the maritime provinces, and the visit of a delegation from Canada widened this into the general conference on confederation which brought into existence the dominion of Canada. The strong local patriotism and prosperous self-sufficing condition of the island defeated the attempt to include it in the greater union; but the prospect of improved communication with the mainland induced it to come in on July 1, 1873. The islanders entered confederation gladly, "under the impression," wrote Lord Dufferin, governor general of Canada, "that it is the Dominion that has been annexed to Prince Edward Island." Two years later the long-standing question of land tenure was settled; the federal government advanced to the provincial administration funds with which to purchase the estates of the proprietors, and the land was then resold to the tenants.

Area and Population.—The greatest length of the island is 140 mi., its greatest breadth 40 mi., its total area 2,184 sq.mi. The population reached 109,078 in 1891 but fell to 88,038 in 1931; an increase then began, and in 1951 there were 98,429 inhabitants. It is the most densely populated province in Canada, having nearly 45 persons per square mile. As in all the maritime provinces, there is a steady migration to the Canadian west and to the U.S. The population is mainly of British descent, but also comprises descendants of French Acadians and American loyalists. A few Indians of the Micmac tribe remain. Charlottetown, the capital, had a population in 1951 of 15,887.

Administration.—Four members of the house of commons and four senators are sent to the federal legislature. The local government consists of a lieutenant governor and of a legislature of 15 councillors and 15 assemblymen elected for five years. Women can be elected to the assembly, which conducts not only the general affairs of the province, but most of those of the towns and villages.

Education.—Primary education in the province has been given free since 1852. It is under the control of a minister of education, who has a seat in the provincial cabinet. In 1947–48 there were 479 schools, the enrolment in ordinary and technical day schools being 18,051. Higher education is obtainable in Charlottetown at the Prince of Wales college and normal school, head of the provincial school system, and St. Dunstan's college, under Roman Catholic control. During 1933–36 the Carnegie corporation financed establishment of a free circulating library system, and this was then taken over by the provincial government, which provides an adequate library service to every rural school.

Agriculture.—The soil, an open sandy loam, deep red in colour, is generally fertilized with mussel mud dredged from the bays and tidal streams. Dairying is successfully carried on; the first cheese factory was opened in 1892, and the first creamery in 1894. The total area under field crops in 1949 was 489,000 ac. All the staple crops are grown and fruit is raised, apples of good quality being exported. The hog population of the province during World War II was higher than at any other time in its history. The production of certified seed potato is an important industry. The breeding of silver foxes in captivity for their pelts was commenced in 1887. In 1910, 25 silver fox pelts sold for more than $1,000 each, and in 1938 the island produced about 70,000 pelts, more than any other Canadian province. By 1940 there were 913 fox and mink fur farms in the province. Thereafter marketing problems developed, and the number of fur farms declined to 246 by 1948.

Fisheries.—Though smaller in value than those of any other seaboard province, the fisheries of Prince Edward Island are, in proportion to the total population, extremely productive. Lobsters are an important catch, together with smelts, herring, cod and mackerel. The federal government operates an experimental oyster farm and biological station in a tributary of Malpeque bay, near Ellerslie, and the oyster industry, after a long period of sterility, has become of major economic importance.

Other Industries.—Much of the land is covered with natural forest of birch, beech, maple, spruce, cedar and other woods, the

1949 estimated total stand of merchantable softwood timber alone being 6,100,000,000 cu.ft. Besides the production of butter and cheese and the processing of fish, the principal industries are sawmilling, the making of castings and forgings, and printing and publishing. In 1947 there were 36 vegetable products, 95 animal products, 118 wood and paper products, 6 iron products and 5 textile and chemical products establishments, having 1,906 employees and producing $12,653,451 of goods, about half of which was from the animal (farm and sea) products group.

Communications.—The railways of Prince Edward Island (286 mi. in length in 1951) are operated as part of the system of Canadian National railways, connection with the mainland being maintained by rail-ferry steamer via the town of Borden (named in honour of Sir Robert Borden) and Cape Tormentine, across Northumberland strait. At the eastern end of the island a ferry for motorcars operates (except during the winter) between Woods Islands and Caribou, near Pictou, N.S. The roads of the province total 3,610 mi. in length (1949), 222 mi. being pavement and 897 mi. gravel surfaced.

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PRINCE RUPERT, port, British Columbia, Can., at the mouth of the Skeena river, 500 mi. N.W. of Vancouver. Pop. (1951) 8,435. The city is built on an island, connected by a steel bridge with the mainland, and is a western terminus of the Canadian National railways. There is a fine natural harbour, sheltered by Digby Island and a promontory of the Tsimpsean peninsula, with a government dry dock, a private shipbuilding yard and a terminal grain elevator. Steamers run regularly to Vancouver, Anyox, Stewart, Seattle, etc. Fish, largely salmon, halibut and cod, form the chief article of trade, and in most years Prince Rupert has a larger annual tonnage of fish than any other Pacific port. There are refrigerating plants and fish-fertilizer works, major canneries and lumber and shingle mills. Mining and lumbering are carried on in the neighbourhood.

PRINCES' ISLANDS, a cluster of nine islands in the Sea of Marmora, forming a caza of the prefecture of Constantinople. They figure in Byzantine history chiefly as places of banishment. A convent in Prinkipo (now a mass of ruins at the spot called Kamares) was a place of exile for the empresses Irene, Euphrosyne, Zoë and Anna Dalassena. Antigone was the prison of the patriarch Methodius, and its chapel is said to have been built by the empress Theodora. In Khalki the monastery of the Theotokos (originally of St. John), after 1831 a Greek commercial school, was probably founded by John VI or VII. Palaeologus was rebuilt about 1680, and again in the 18th century by Alexander Ypsilanti, hospodar of Moldavia. Close beside it is the tomb of Edward Barton, second English ambassador to the Porte. Hagia Trias (a school of theology since 1844) was rebuilt by the patriarch Metrophanes. On Prote were the monasteries to which Bardanes (Philippicus), Michael I Rhangabes, Romanus I (Lecapenus) and Romanus IV (Diogenes) were banished.

See G. Schlumberger, *Les Îles des Princes* (Paris, 1884); A. Grisebach, *Rumelien und Brussa* (Göttingen, 1839).

PRINCETON, a city of Illinois, U.S., 105 mi. W.S.W. of Chicago; the county seat of Bureau county. It is on federal highways 32 and 6, and is served by the Burlington route as well as by many truck and bus lines. Pop. 5,765 in 1950; in 1940 it was 5,224. It is the trading centre of a very productive corn farming region and hybrid seed-corn processing plants and other smaller manufacturing industries.

PRINCETON, a city of Indiana, U.S., on federal highway 41, 27 mi. N. of Evansville; county seat of Gibson county. It is served by the Chicago and Eastern Illinois and the Southern railways. Pop. (1950) 7,673. It is the trade centre for an agricultural region, and there are coal mines and gas and oil wells. Manufacturing includes electric relays and timing devices, and paintbrushes. The city was founded in 1814 and chartered in 1884.

PRINCETON, a borough of Mercer county, N.J., U.S., on federal highway 206, about equally distant (50 mi.) from New York city and Philadelphia, Pa.; served by the Pennsylvania railroad. The population was 12,230 in 1950, 7,719 in 1940 and 6,992 in 1930 by the federal census. During the school year the population is increased by several thousand students and teachers.

Princeton is located on high land (210 ft. above sea level), surrounded on three sides by Stony brook. Carnegie lake (3.5 mi. long and 800 ft. wide), the gift of Andrew Carnegie, was constructed in 1905–06. The borough is a beautiful academic and residential community, with no factories. It is the seat of Princeton university (*q.v.*), Princeton Theological seminary, St. Joseph's college (Roman Catholic, 1914), Westminster Choir school (founded 1926 in Dayton, O.; moved to Princeton 1932), Institute for Advanced Study (1930) and several preparatory schools for boys and for girls. The Lawrenceville school for boys (1810) is 5 mi. W. Princeton Theological seminary, established by the general assembly of the Presbyterian Church in 1812, has had many theologians among its professors and presidents. At times there have been as many as 30 denominations represented in the student body. It is well endowed and has a fine campus near the university.

On the eastern shore of Carnegie lake, in the township of West Windsor, are the laboratories of the department of animal pathology of the Rockefeller institute. There are many beautiful modern estates, and a number of colonial buildings still stand. The Quaker meetinghouse adjoining the battlefield and replacing one built in 1726 dates from 1760. "Morven," the homestead of the Stocktons, built between 1701 and 1709, has entertained many presidents and other prominent persons. "Rockingham," at Rocky Hill, a village 3 mi. N., was occupied by Washington for three months in the autumn of 1783, and it was there that he wrote his farewell orders to the army. It is now maintained as a historical museum.

Settlement there began in 1696 and the name was adopted in 1724. Princeton was incorporated as a town in 1813 and as a borough in 1873. Among the early settlers was Richard Stockton, grandfather of the signer of the Declaration of Independence who bore the same name, and John Olden, great-grandfather of New Jersey's Civil War governor. The College of New Jersey (now Princeton university) moved there from Newark in 1756. On Aug. 27, 1776, the first legislature of New Jersey met in Princeton. On Jan. 3, 1777, near Stony brook about 1 mi. W. of Princeton, Washington won an important victory over part of Cornwallis' troops, both sides losing many brilliant officers. A battle monument by F. W. MacMonnies, which has as the central figure an equestrian statue of Washington, was dedicated in 1922. In old Nassau hall, the largest building in the colonies when it was erected in 1754–56, the Continental Congress sat from June 30 to Nov. 4, 1783, receiving there on Oct. 31 the news that peace had been signed.

PRINCETON, a city in the mountains of southern West Virginia, U.S., the county seat of Mercer county; on the Virginian railway and federal highways 19, 21, 219 and 460, 10 mi. N.E. of Bluefield. The population was 8,279 in 1950 and 7,426 in 1940 by the federal census. Coal mining and railroad shops are the principal industries, and there are several textile and garment factories. The city was founded in 1826 and incorporated in 1862.

PRINCETON UNIVERSITY, a privately endowed nonsectarian institution of higher learning for men, at Princeton, N.J., until 1896 called officially the College of New Jersey. Its buildings are grouped in the central portion of a campus of about 2,100 ac., one of the most beautiful in the country. Nassau hall, the oldest and historically the most interesting building on the campus, was at the time of its completion in 1756 the largest academic building in the American colonies. It was designed by Robert Smith, architect of Independence hall in Philadelphia, and named in honour of William of Nassau, William III of England. There in 1783 George Washington received the formal thanks of the U.S. congress for his conduct of the Revolutionary War.

Characteristic of life at Princeton, in addition to the university's rural location and consequently its active outdoor interests, are the residential dormitory system, the system of elective upperclass eating clubs and the form of student self-government illustrated particularly by the honor system, under which undergradu-

ates participate in the administration of university discipline.

At mid-20th century the university offered undergraduate courses in the liberal arts and sciences leading to the degrees of bachelor of arts and bachelor of science in engineering. In addition to the arts and sciences, graduate work leading to the master's and doctor's degrees was also offered in architecture, engineering and public and international affairs. The department of military science offered basic and advanced courses leading upon graduation to a commission as second lieutenant of field artillery in the U.S. army officers' reserve corps, and the department of air science offered a course of study leading to a commission as second lieutenant in the air force reserve.

In all admissions, regard is given to character, personality and promise as well as to scholarly attainment. Enrolment is limited in both the undergraduate department and the graduate school.

In Sept. 1947 Princeton established a four-stage program leading to the A.B. degree: (1) fulfilment of entrance requirements and completion of qualifications for college study; (2) exploration of the major fields of learning; (3) concentration in one of the divisions (social sciences, natural sciences or humanities); and (4) departmental specialization, the students' achievement being tested by a senior comprehensive examination.

A feature of instruction is the preceptorial method, introduced in 1905, by which large classes are broken into small groups or informal conferences with preceptors on prescribed reading. Princeton has no professional schools for utilitarian ends, except the school of engineering and possibly the school of architecture, although both of these are strongly humanistic in their curricula and methods. The school of architecture developed directly out of the department of art and archaeology, and on successful conclusion of the course confers the degree of master of fine arts.

In assuming the university title in 1896, it was definitely concluded that Princeton's future did not lie in developing professional schools but in upholding pure learning and in devoting itself "to the liberal aspects of those studies which underlie and broaden professional and technical education." The university, therefore, became not a congeries of professional schools overshadowing an undergraduate department but rather a large, homogeneous and well-organized body of undergraduate students, with a small and carefully selected graduate school, devoted to the liberal arts and sciences.

There are a large number of scholarships and fellowships, both graduate and undergraduate, and a particularly well developed system whereby undergraduates of limited means are enabled to earn part or all of their expenses.

History.—The university owes its origin to a movement set on foot by the Synod of Philadelphia in 1739 to establish in the middle colonies a college to rank with Harvard and Yale in New England and William and Mary in Virginia. As a result of dissension in the church, no progress was made until 1746, when the plan was again broached by the Synod of New York, formed by the secession of the presbytery of New York and the presbytery of New Brunswick, radical (New School) presbyteries of the Synod of Philadelphia. Most of the leaders of the presbytery of New Brunswick had been educated at Log college, a school with restricted curriculum at Neshaminy, Pa., about 20 mi. from Philadelphia, founded in 1726. The opportunity was taken by the Synod of New York to found a larger institution of higher learning, broader in scope and training, and to transfer to the new project the Log college interests. On Oct. 22, 1746, John Hamilton, acting governor of New Jersey, granted a charter for erecting a college in New Jersey, which was opened in May 1747, at Elizabeth, N.J. A second charter was granted by Gov. Jonathan Belcher who on his arrival in the province in 1747 had at once taken the college under his patronage. The college was removed to Newark where the first graduation exercises were held in 1748; but the situation was unsuitable, and in 1752 the trustees voted to remove the college to Princeton. While additional funds were being collected in Great Britain, work was begun in Princeton in 1754 on the first college building, Nassau hall.

John Witherspoon, president during the Revolutionary period, influenced the college strongly by his personality and political prominence, and graduates of his training became leaders in public affairs. The history of the college during the first half of the 19th century was uneventful: Because of its large southern clientele, it suffered in the Civil War a blow from which it recovered only under the energetic administration of Pres. James McCosh (1868–88). The undergraduate enrolment was nearly trebled, gifts amounting to more than $2,000,000 were contributed, only half of which sum was for endowment, 14 new buildings were erected, and important changes in the curriculum were put into effect. Fellowships were established in 1869, the elective system was introduced in 1870, the John C. Green school of science was erected in 1873, the graduate department was systematized in 1877 and the faculty grew from 17 to 40 and the number of volumes in the library from 25,000 to 65,000.

Under Pres. Francis L. Patton (1888–1902) a school of electrical engineering was established, the honor system was instituted and the plan of electing alumni trustees adopted, 17 buildings were erected, the student body was doubled and the faculty increased to 100, while the endowment reached $2,500,000. In 1902 Woodrow Wilson, of the class of 1879, was elected president. In his administration the undergraduate curriculum was again revised, the departmental system was organized, and an extensive building program was completed. To obtain the necessary funds, a committee of 50 alumni was formed, later changed into a Graduate council. Through their agency in the eight years of President Wilson's administration the university received more than $4,500,000, the faculty was greatly strengthened and the library increased to 271,000 volumes. A plan for grouping the university into small self-contained units was prematurely proposed by the president in 1907 and was withdrawn by the trustees. The Princeton plan of a residential building for graduate students had been successfully tested on a small scale, and a bequest in 1908, although inadequate for the full project which included professorships and fellowships, gave the plan its first semblance of permanent realization. Additional funds being conditionally offered in 1909, controversy developed as to the site for the building and finally as to the plan itself, the president no longer favouring it. A further bequest of about $2,000,000 for the project brought matters to a head and the president recommended acceptance of the legacy. In Sept. 1910, having received the democratic nomination for governor of New Jersey, he resigned the presidency.

John Grier Hibben, of the class of 1882, professor of philosophy in the university, was the 14th president of Princeton, January 1912 to June 1932. His administration was marked by extended administrative reorganization, by very large additions to the endowment and by extensive expansion along material and scholastic lines. Faculty autonomy was made complete: a joint committee of trustees and faculty was organized to consider all matters of educational policy and administration; the faculty was given voice in forming its committees and initiating appointments, promotions and increases of salary; the rights of the individual in cases of dismissal were safeguarded; faculty retiring allowances and insurance were arranged. In World War I more than 5,000 Princeton men saw service, 150 of them losing their lives; university laboratories were occupied by government bureaus of research.

Edward Dickinson Duffield of the class of 1892 and a trustee of the university served as acting president until the election of Harold Willis Dodds, professor of politics, as 15th president in June 1933.

In 1913 the erection of the residential graduate college rendered permanent what had been an experimental feature of the Princeton graduate school. The school of architecture was opened in 1920. The school of engineering was reorganized in 1921, and the school of public affairs, designed to give its students a broad background for an understanding of and active participation in local, state, national and international affairs, was founded in 1930.

During World War II almost 20,000 students in the various programs of the armed forces were trained at Princeton. The university commemorated the academic year 1946–47 as its bicentennial anniversary and in 1949 established ten bicentennial preceptorships to encourage scholarship and teaching.

In 1951 Princeton established the James Forrestal Research centre in the former plant of the Rockefeller Institute for Medical Research, comprised of 15 buildings and laboratories. The centre's immediate aim in the early 1950s was to carry on research in aeronautical engineering, chemical kinetics, applied mathematical analysis and related sciences. Technical and administrative headquarters of a program of fundamental research in jet propulsion undertaken in co-operation with other universities were established there.

Buildings include the John C. Green Engineering building (1927), with the engineering laboratory added in 1951; the Palmer Memorial stadium (1914), with a capacity of more than 50,000; and the New observatory (1934), with a dome 45 ft. in diameter and a 23-in. telescope. Buildings erected after World War II include the Herbert Lowell Dillon gymnasium (1947), with a main floor 100 by 240 ft. and locker facilities for 1,700; the Harvey S. Firestone Memorial library (1948), with 1,800 reading places and a capacity for 2,000,000 volumes; and the Architectural laboratory (1949).

In the academic year 1951–52 there were 461 faculty members and 3,537 students. The endowment was $51,723,000 and the library contained 1,500,000 volumes.

PRINCIPAL AND AGENT. In law an agent is a person authorized to do some act or acts on behalf of another, who is called his principal. The law regulating the relations of principal and agent is almost alike throughout the whole British empire, and differs only slightly from the law of the rest of Europe.

In a general view of the law of agency it is necessary to have regard to the rights and duties of the principal, the agent, and third persons with whom the agent deals. The agent should not do what he has no authority for; yet as between the principal and those with whom the agent deals, the test of the principal's responsibility for what is done by the agent on his behalf, but in excess of his actual authority, is his ostensible authority.

Agents are of different kinds, according to the extent of their implied powers. The main restraint in the powers of an agent is in the old maxim, *delegatus non potest delegare*, designed to check the complexity that might be created by enquiries into repeatedly-deputed responsibility. As a general rule an agent cannot delegate his authority or put another in his place; but this rule is sometimes modified, for it may arise from the nature of his employment or the necessity of the case that he has to employ other persons for the accomplishment of certain objects.

In the general case agency is constituted by the acceptance of the mandate or authority to act for the principal, and the evidence of this may be either verbal or in writing. But an agent who has to execute a deed in the absence of the principal must be appointed by deed for that purpose. As a corporation aggregate can in general act only by deed its agent must be so appointed, except in the case of trading corporations and joint stock companies, to which this rule has no application. Agency is often constituted, at the same time that its extent is defined, by mere appointment to some known and recognized function—as where one is appointed agent for a banking establishment, factor for a merchant, broker, or traveller. In these cases usage defines the powers granted to the agent; and the employer will not readily be subjected to obligations going beyond the usual functions of the office; nor will third persons dealing with the agent be bound by private instructions inconsistent with its usual character. While, however, third persons, ignorant of such secret limitations, are not bound to respect them, the agent himself is liable for the consequences of transgressing them. Agency may also be either created or enlarged by implication. What the agent has done with his principal's consent the person with whom he has dealt is justified in believing him to be authorized to continue doing.

In questions of this kind the distinction between a general and a special agent is important. A general agent is one employed to transact all his principal's business of a particular kind; as a factor to buy and sell; a broker to negotiate contracts of a particular kind; a solicitor to transact his legal business; a shipmaster to do all things relating to the employment of a ship. Such an agent's power to do everything usual in the line of business in which he is employed is not limited by any private restriction or order unknown to the party with whom he is dealing. On the other hand, it is incumbent on the party dealing with a particular agent, *i.e.*, one specially employed in a single transaction, to ascertain the extent of his authority. As to a mercantile agent, *see* FACTOR.

The obligations of the principal to the agent are: to pay the agent's remuneration, or, as it is often called, commission, the amount of which may be fixed by contract or usage; to repay all advances made by the agent in the regular course of his employment; to honour the obligations lawfully undertaken for him; and to indemnify the agent against all liabilities incurred by him in the proper execution of his mandate. The agent is bound to exercise proper skill and use the proper means for carrying out the functions which he undertakes. He must devote to the interests of his principal such care and attention as a man of ordinary prudence does on his own. He must observe the strictest good faith; and must not enter into transactions in which his interests are in conflict with the interests of his principal. Thus, when he is employed to buy, he must not be the seller; when he is employed to sell, he must not be the buyer. A mercantile agent who guarantees the performance by persons with whom he deals of the obligations contracted by them is said to hold a *del credere* commission.

In the United States courts have often been somewhat more liberal in interpreting an agent's powers than in England, a fact probably attributable to the absence on the part of third parties dealing with agents, of the degree of caution characteristic of an older business community. On the other hand, statutes in some American states forbid certain types of agents, notably real estate brokers, from recovering their commissions at law unless their contract of employment was written and signed. It should be noted further that modern American merchandizing practice works out into many situations deemed by business men "agencies," which may however be dealt with by the law as "sales"; a situation which makes reliance on any general statements of law quite unsafe. Finally, especially in the United States, much of the law as to a master's responsibility for the acts of his servant (*see* MASTER AND SERVANT) has been carried over to make a principal responsible for wrongs committed by his agent in the course of his employment.

See also AUCTIONS AND AUCTIONEERS; BROKER; FACTOR; GUARANTEE, etc.; also Smith's *Mercantile Law* (12th ed., 1924); Bowstead, *On Agency* (7th ed., 1924). Tiffany, *Agency* (2nd ed. by Powell); Mechem, *Principles of Agency;* Klaus, 28 Columbia L. Rev. 312, 441.

PRINCIPE ISLAND, a Portuguese island in the Gulf of Guinea, of volcanic origin, 90 m. N.E. of St. Thomas with an area of 42 sq.m. The highest point is Pico-Papagaio, nearly 3,000 feet. Pop. (1940) 3,108 (56 white). The tsetse fly (which is not found in St. Thomas) infests the wooded part of the island, and through it sleeping sickness has been spread. The chief settlement is S. Antonio. Cocoa is cultivated.

PRINCIPLE, in philosophy, means something ultimate (Latin *principium,* a beginning). The early Greek philosophers applied the term (or rather its Greek original ἀρχή) to whatever they regarded as the primal stuff of which things are made, the source of all things. The term was used in this sense even in the 17th century or later. The followers of Paracelsus and others described salt, sulphur and mercury as "principles," in the sense of ultimate elements; and Robert Boyle used "principles" and "elements" indifferently as synonymous terms. The term "principle" was naturally applied not only to the original stuff of reality but also to its fundamental laws. And now only the fundamental laws or assumptions of science and philosophy are usually called principles, the terms elements, energy, etc. being used instead of "principle" in the other application it once had. Popularly the term is often employed for any kind of general truth or guiding norm. Hence the pleonasm "first principles" to distinguish them from derivative truths or secondary norms, etc.

PRINGLE, SIR JOHN (1707–1782), British physician, was born on April 10, 1707, at Stitchel, Roxburghshire, and educated at St. Andrews, at Edinburgh, and at Leyden. He settled in

Edinburgh as a physician, but after 1734 also acted as professor of moral philosophy in the university. In 1742 he became physician to the earl of Stair, then commanding the British army in Flanders, and in 1744 was appointed physician-general to the forces in the Low Countries. In 1749, having settled in London, he was made physician in ordinary to the duke of Cumberland, and subsequently received other court appointments as physician, being made a baronet in 1766. In Nov. 1772 he was elected president of the Royal Society, but resigned his presidency in 1778. He died on Jan. 18, 1782. Pringle was the founder of modern military medicine. He remedied camp sanitation and the ventilation of hospitals, and laid down the principles for preventing dysentery and hospital fever, at the same time showing that the different forms of dysentery were varieties of one disease and that gaol fever was the same as hospital fever.

His chief works are: *Observations on the Nature and Cure of Hospital and Jayl Fevers* (1750); "Experiments on Septic and Antiseptic Substances" in the *Philosophical Transactions* of the Royal Society (1750), and especially the *Observations on the Diseases of the Army* (1752). His *Six Discourses* (1783), contains a biography by A. Kippis.

PRINGSHEIM, NATHANAEL (1823–1894), German botanist, was born at Wziesko in Silesia, on Nov. 30, 1823. He studied at the universities of Breslau, Leipzig, and Berlin, graduated in 1848 as doctor of philosophy with the thesis *De forma et incremento stratorum crassiorum in plantarum cellula,* and rapidly became a leader in the great botanical renaissance of the 19th century. His contributions to scientific algology were of striking interest. Pringsheim was among the very first to demonstrate the occurrence of a sexual process in this class of plants, and he drew from his observations weighty conclusions as to the nature of sexuality. Together with the French investigators G. Thuret and E. Bornet, Pringsheim ranks as the founder of our scientific knowledge of the algae. The conjugation of zoospores, regarded by Pringsheim, as the primitive form of sexual reproduction, was a discovery of fundamental importance. A work on the course of morphological differentiation in the Sphacelariaceae (1873), a family of marine algae, is of great interest, inasmuch as it treats of evolutionary questions; the author's point of view is that of Naegeli rather than Darwin. Closely connected with Pringsheim's algological work was his investigation of the Saprolegniaceae, a family of algoid fungi, some of which cause disease in fish. His career as a morphologist culminated in 1876 with the publication of a memoir on the alternation of generations in thallophytes and mosses.

From 1874 to the close of his life Pringsheim's activity was chiefly directed to plant physiology. He founded the *Jahrbuch für wissenschaftliche Botanik,* and the German Botanical Society. His work was for the most part carried on in his private laboratory in Berlin; he only held a teaching post of importance for four years, 1864–68, when he was professor at Jena. He died in Berlin on Oct. 6, 1894.

His works include memoirs on *Vaucheria* (1855); the Oedogoniaceae (1855–58); the Coleochaeteae (1860) *Hydrodictyon* (1861); and *Pandorina* (1869) The last mentioned bore the title *Beobachtungen uber die Paarung der Zoosporen.*

A fuller account of Pringsheim's career will be found in *Nature,* (1895) vol. li; in the *Berichte der deutschen botanischen Gesellschaft* (1895), vol. xiii and in *Hedwigia* (1895) vol. xxxiv.

PRINSEP, VALENTINE CAMERON (1838–1904), English artist, was born on Feb. 14, 1838. His father, Henry Thoby Prinsep, who was for sixteen years a member of the Council of India, had settled at Little Holland House, which became a centre of artistic society. Val Prinsep first studied under G. F. Watts, and later in Paris in the *atelier* Gleyre. "Taffy," in his friend Du Maurier's novel *Trilby,* is said to have been sketched from him. He was an intimate friend of Millais and of Burne-Jones, with whom he travelled in Italy and he had a share with Rossetti and others in the decoration of the hall of the Oxford Union. He first exhibited at the Royal Academy in 1862 but the first picture to attract notice was a portrait (1866) of General Gordon in Chinese costume. He was elected A.R.A. in 1879 and R.A. in 1894. In 1877 he went to India where he painted a huge picture of the Delhi durbar, exhibited in 1880 and afterwards hung at Buckingham Palace. Prinsep wrote two plays, *Cousin Dick* and *Monsieur le Duc,* produced at the Court and the St. James's theatres respectively; two novels; and *Imperial India: an Artist's Journal* (1879). He was one of the founders of the Artists' Corps.

PRINTING. Letterpress printing is the art of producing impressions by means of pressing an inked relief surface on to paper or other material. The term "printing" can be applied to any process by which a print is obtained, but it usually refers to typography, or, as it is now generally termed, "letterpress printing," which includes not only printing from type, but the obtaining of impressions from wood cuts, line and half-tone blocks in monochrome and colour. It has been claimed that the craft of letterpress printing is the medium which turned the darkness of the middle ages into light; which secured to posterity the intellectual achievements of the past; and which furnished to civilization a means of recording all future progress.

The Chinese were the first printers. The oldest known printed book, printed from blocks, was discovered in the Chinese province of Kansu in 1900. It bears the statement, "Printed on May 11, 868, by Wang Chieh, for free general distribution, in order in deep reverence to perpetuate the memory of his parents." Printing from movable type was first done by Pi Shêng in China in the years 1041 to 1049. Both events are well authenticated. Because of the large number of characters in what in Chinese corresponds to an alphabet, the new method was not generally adopted.

History.—There is no certainty as to the actual date of the European invention of printing from movable type, which was independent of the discovery of the principle by the Chinese, but it is assumed that it took place about 1440. At an early date books were printed from engraved wood blocks, thus the term "block books" indicates that all the words on the page of a book have been cut by hand on to a solid block of wood. It is by no means certain, however, if these preceded the invention of movable types, for it is known that block books were produced after the invention of printing. In fact, no extant block book bears a date earlier than 1470. That prints were obtained from wood blocks previous to 1440 there is ample evidence, but these were of a pictorial character. In the John Rylands library, Manchester, England, there is a wood block print depicting St. Christopher, dated 1423. It is known that block prints were produced in Japan as early as A.D. 770.

Just as there is no actual certainty as to the date of the European invention of printing from movable types, so it is also doubted who the inventor really was and where the invention took place. Claims are made for Germany, Holland, France and Italy. One authority, however, sums up the position by stating:—

> Holland has books but no documents;
> France has documents but no books;
> Italy has neither books nor documents;
> Germany has both books and documents.

It is generally agreed that certain letters of indulgence are the first documents bearing a printed date, and these were printed from type cast in a mould and issued in 1454 and 1455 from a press at Mainz, and ascribed to Johann Gutenberg.

From the press at Mainz a Vulgate bible was published in 1456. This was attributed to Gutenberg, the strongest claimant to the honour of the invention of printing. This book became known as the Mazarin bible, because a copy was found in the famous library of Cardinal Mazarin, or, as it is sometimes called, the 42-line bible, owing to the fact that the large majority of its pages are 42 lines to the column, of which there are two on a page. In 1457 the Mainz psalter was produced; it was the first book to bear the name of the printer and the place and date of its production. It was also the first attempt at colour printing. The printers were Johann Fust and Peter Schoeffer, the latter one of Gutenberg's workmen.

From Mainz the art of printing spread throughout the continent. In 1464 Sweynheym and Pannartz, two Germans, carried it into Italy, beginning at Subiaco near Rome. In 1469 Johann and Wendelin, of Speier, began in Venice. They were followed

there by Nicolas Jenson, a Frenchman, who printed from 1470 to 1480. Jenson added lower case to the capital letters he found on the Roman monuments, and the type design thus created has since remained standard. Another famous printer in Venice was Aldus Manutius, who printed from 1495 to 1515. He was the originator of italic lower case letters, to which were later added italic capitals. Aldus, as he was generally known, contributed to the spread of learning by printing the classics in small inexpensive volumes. In 1470 printing was introduced into France by three men of German nationality, Krantz, Ulrich Gering and Michael Friburger, who in that year set up a printing establishment within the precincts of the Sorbonne in Paris.

Berthold Ruppel is usually credited with the introduction of printing into Switzerland, the date being possibly 1468. The most famous and learned printer in Swiss history was Joannes Froben (*q.v.*). With him was associated, as press corrector, the great Dutch scholar, Desiderius Erasmus. In the Low Countries (Holland and Belgium) printing was done at Utrecht as early as 1471, but the name of the printer is unknown. N. Ketelaer and G. de Leempt were the first Dutch printers to place their names in a printed book of their own production, the date being 1473.

Spain's first known printer was Lambert Palmart who began at Valencia in 1474. The best-known name in the history of Spanish printing is that of Kromberger, Jacob and John (father and son), the elder having begun at Seville soon after the opening of the 16th century, the exact date being unknown.

William Caxton was England's first printer. He was a native of Kent. After serving an apprenticeship to a London mercer, he resided for a period of about 30 years in the Low Countries, where he eventually became governor of a company of English merchants known as the English Nation. He learned the art at Cologne and, with Colard Mansion, started business at Bruges, moving in 1476 to Westminster where he set up a press at The Red Pale in the Almonry. His first production in England was a papal indulgence, issued on Dec. 13, 1476. He continued there during an active period of 15 years, producing about 100 volumes. He died in 1491 and his press passed to his assistant, Wynkyn de Worde.

The introduction of printing into England was characterized by a number of innovations. In all other countries the pioneers were wandering German printers who began to print in Latin. England's first printer was an Englishman who used only his own language. Caxton wrote or translated much of the material he converted into books, and he printed with type faces of a design that was neither Gothic nor roman.

The quality of printing began to deteriorate in the 16th century, due somewhat to the fact that the ruling powers in church and state became alarmed because the new art seemed to be creating too much freedom of thought. Measures of repression were adopted and printing ceased to be an art and became merely a vehicle for the conveyance of information. Some great printing and publishing families, such as the Estiennes in France and Plantin and the Elzevirs in the Low Countries, carried on the traditions, but the general level of quality was low. A change came in England early in the 18th century. In 1720 William Caslon began to produce a roman type face that was little more than a refinement of that designed by Nicolas Jenson, but it was accepted as a practically new design and has ever since borne Caslon's name. It exercised a profound influence upon 18th century typography. A generation later John Baskerville, after seven years of experimenting with type, ink and papermaking, began to print in Birmingham. Because of the high quality of his productions he, too, exercised a decided influence upon the printing of the time. Just before Baskerville's death in 1775, another printer of similar eminence was coming into notice in Italy. He was Giambattista Bodoni, who began at Parma in 1768 and continued until his death in 1813.

Printing began in the western hemisphere in Mexico City, probably in 1539, when a printer named Giovanni Paoli reached there with an equipment sent, at the request of the reigning archbishop, by John Kromberger, of Seville, Sp. In what is now the United States, the first press began at Cambridge, Mass., in 1638. Jesse Glover had left England with it, but had died on the way over. It was set up by Stephen Day and his son Matthew, a lad of 18 years, who had some knowledge of printing. Their first work was called the "Freeman's Oath." The first book from the press, known as the Bay Psalm Book, was produced in 1640.

The deterioration in the quality of printing, which began to manifest itself in the 16th century, continued with exceptions noted through the 17th, 18th and 19th centuries. A revival came in the last decade of the 19th century, led by William Morris at the Kelmscott Press in England. Morris' books were issued in limited editions and are prized by book collectors. They cannot be said to be highly successful, however, as books; it was pictorial effect rather than legibility for which Morris strove. He had many imitators, but few successful followers.

The standard of bookmaking in the 20th century remained high. In England, apart from the few excellent private presses, good work was produced by the presses of the universities and many other commercial printing houses. Bruce Rogers (1870–) in New York, and Daniel Berkeley Updike (1860–1941) at the Merrymount Press, in Boston, produced volumes that from all the points that go to make up good bookmaking were scarcely surpassed. Frederic W. Goudy (1865–1947) produced type designs that will give his name a permanent place in printing history.

The Printing Press.—The development of the printing press provides a remarkable history of achievement. Hand presses were for more than 100 years constructed of wood and operated on the screw principle. Willem Janszon Blaeu (1571–1638), of Holland, made the first improvements, but no radical change came until the end of the 18th century. Adam Ramage, of Philadelphia, Pa., and Charles, Earl of Stanhope, of London, working at about the same time, made further improvements, Stanhope's press, appearing in 1800, being the first to be constructed entirely of iron. George Clymer, beginning in Philadelphia and continuing in London from 1817 to 1834, was the first to abandon the screw entirely, his substitute being a series of compound levers. The handlever press, known as the Washington hand press, operated on the toggle-jointed bar principle, appeared about the same time and eventually superseded all others. John J. Wells, Peter Smith and Samuel Rust, of New York, all had a hand in its development.

In 1790, William Nicholson, an Englishman, took out a patent for a cylinder press, but this did not get beyond the drawing of plans. It was left for Frederick Koenig—a Saxon—to construct the first power-driven machine in 1811. This, however, proved but little more than the adaptation of power to the hand press, and it is assumed that only one of these machines was made and used for book printing. Soon after this, Koenig and a fellow countryman, Andrew Bauer, constructed a flat-bed machine with a continually revolving cylinder. Two of these machines, called cylinder presses, were erected in the *Times* (London) and the issue dated Nov. 29, 1814, states that it "was printed by steam power." The machine produced 1,100 impressions per hour, thus quadrupling the output of a hand press. Later, a machine was constructed to print upon both sides of the sheet before delivery, and these machines were in operation until 1827.

Augustus Applegath and Edward Cowper, engineers of the *Times*, built a machine in 1827 for printing on one side of the sheet, and capable of giving 4,000 impressions an hour. This was in use until 1848, when Applegath invented a new type of machine with cylinders in a vertical position and on which the type was secured by means of wedge-shaped column rules. Around the type cylinder were grouped eight impression cylinders, the sheets being delivered in a vertical position and taken off by hand. The output of this machine was 8,000 impressions per hour. There was only one of these machines made and it was ultimately replaced by the Hoe type revolving machine, which made way for the Walter rotary perfecting press in 1868.

In 1846, Robert Hoe, founder of the world-renowned American printing machinery manufacturing firm, built a new style of press. This was known as the Hoe type revolving machine. The type cylinder was placed in a horizontal position and the type secured in cast-iron beds by special locking up apparatus. Each bed repre-

sented one page of a newspaper. Grouped around the type cylinder were four, six or ten impression cylinders, each of which had feeders laying on sheets of paper. As the main cylinder rotated, the type was inked by a roller, the sheets as they were fed in being taken by grippers to receive the inked impression of the type. In this instance, the sheets were delivered by means of "mechanical flyers." This machine was capable of turning out 2,000 sheets per feeder per hour, *i.e.*, with a four-cylinder machine 8,000 impressions were obtained. The first machine was erected in London in 1856; it had six cylinders and was installed to print *Lloyd's Weekly Newspaper*.

An impetus was given to the production of newspapers by the invention of the papermaking machine by the brothers Fourdrinier, in 1803, while the knowledge of how to cast curved stereo plates also helped forward the development of newspaper production. In 1865, the first printing press to print from a continuous reel of paper was made by an American named William Bullock. The machine consisted of four cylinders—two impression cylinders and two plate cylinders—but as the paper passed from the reel it had to be cut before printing. This led to many difficulties and the machine was soon discarded owing to its unreliability.

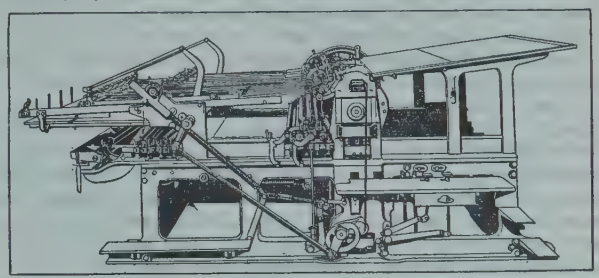
The proprietors of *The Times* were continually endeavouring to construct a rotary perfecting machine and in 1868 the famous Walter rotary perfecting press was built to print *The Times*. A reel of paper was used, both sides being printed from curved stereo plates and the sheets delivered flat. These were used until 1895, and were undoubtedly the models from which present-day newspaper rotaries have developed. One drawback to the speedy production of newspapers in the early days of the rotary machine was that they were delivered flat and had to be folded by hand. In 1870, the first folder attachment was invented by two English engineers, G. Duncan and W. A. Wilson, and since then the development of the rotary press has been rapid: the reason undoubtedly being the overcoming of the folding difficulty which in turn has enabled proprietors to produce newspapers in large numbers and at the nominal price at which they are now sold. Present-day newspaper presses are capable of printing simultaneously from as many as 15 reels and to produce over 300,000 copies per hour. Credit must be given to Sir Rowland Hill for the inception of the idea of printing on both sides of the paper from a reel, the suggestion having emanated from him in 1835.

In 1822, Daniel Treadwell of Boston applied power to a machine built on the "bed and platen" principle. The original machine of this type was improved upon by Adams, of Boston, and for many years this class of machine was used for printing fine books and woodcuts.

The next notable development of a printing machine was one worked by treadle and adaptable for the printing of small jobbing work such as cards, handbills, etc. The first machine of this character was made by S. P. Ruggles, of Boston, Mass., in 1830, and was known as the Ruggles card press. Just over a quarter of a century later (1856) George P. Gordon, an American, built a press which proved to be the forerunner of what are now known as light platen machines. This was constructed with the type bed in a vertical position, was named "the Franklin," and rapidly became in general use throughout the world.

Improvements on platen machines became necessary by the introduction of half-tone and colour printing. In 1869 Merritt Gally, of Rochester, N.Y., invented a new type of platen machine known as the Universal press which proved the pattern for heavy platen machines for colour printing. About 1850 a London printer named Main introduced a new type of flat-bed printing machine. Instead of a continuous rotary motion, as in the Koenig machine, the cylinder "rocked," making about three quarters of a revolution and then reversing, at the same time rising to allow the return of the bed. This machine was generally known as a "tumbler" and was the forerunner of what is now known in Great Britain as the Wharfedale stop-cylinder machine which was invented about 1860 by William Dawson and David Payne of Otley.

The modern type of flat-bed printing machine is known as the two-revolution press. It is so called because the cylinder, the rotary movement of which is continuous, makes two revolutions for every sheet printed. The second revolution occurs as the cylinder rises to permit the return of the bed carrying the forme. (This movement was a feature of the Napier machine built about 1830.) The most widely used form of this type of machine, and the one which has made it so popular, was invented in 1883 by Robert Miehle, a practical pressman, and the first



BY COURTESY OF LINOTYPE AND MACHINERY CO.

TWO-REVOLUTION PRINTING MACHINE

machine was installed in America in 1888. "The Miehle," as it is generally termed, has revolutionized the manufacture of printing machinery. It is to be found in most printing offices, producing not only commercial but the finest coloured work; machines of this type are made for every class of work, and are known as single-colour, two-colour and perfecting machines, respectively.

Mechanical Typesetting.—The first type composing machine was patented in England in 1822 by Dr. William Church of Boston. This machine set ordinary founder's type from channels previously filled by hand. Upon the depression of the respective keys, the type was released into a raceway, it being delivered in one continuous line and subsequently justified by hand. This was followed by numerous attempts, all more or less successful, to set and justify founder's type mechanically. All these efforts, however, still left the problem of distribution unmastered, the most successful attempt to achieve this being that of Joseph Thorne who, in 1880, brought out a combined typesetting and distributing machine.

In 1878 Ottmar Mergenthaler (1854–99), a German immigrant to America in 1872, constructed a "type impression" machine and in 1885 took out patents for a slug casting machine, the forerunner of the Linotype. In the following year, 1886, this machine was actually used in the United States, but was not introduced into Great Britain until 1890. The typograph, another slug casting machine, was the invention of John Raphael Rogers, who was a consulting engineer with the Mergenthaler Linotype Company. The first machine was built in Cleveland, but, as the U. S. courts found that Rogers infringed certain patents owned by the Mergenthaler Company, the use of the machine was prevented in the United States. Ultimately, the Mergenthaler Company purchased the U.S. rights of the typograph company. In 1890 this machine was being built in Canada and, on the expiration of the linotype agreement, its manufacture was commenced in Detroit, Mich. In 1893 the manufacture of the typograph was undertaken in Germany, the first typograph built in that country being put on the market in 1896. Germany is now the headquarters for the manufacture of this type of machine where it has achieved a remarkable success.

It was about the same time as Mergenthaler placed his invention for a slug casting machine on a successful basis that Tolbert Lanston, a clerk in the Pensions Office at Washington, developed and perfected a method of casting type by means of a perforated sheet on the Jacquard principle. He applied for his patent in 1885, this being granted two years later, the year in which the first machine was produced.

The Practice of Printing.—As in all processes of printing, there are two main operations in letterpress printing: (1) The setting up of the type, reading, making up the type and blocks into pages, imposition and locking up. This embraces the work of a compositor and is done in the composing room. (2) Print-

ing, which includes the fixing of the forme on the machine, making ready (a process whereby irregularities of pressure are removed), getting position on the sheet, inking and the printing of the sheets. This work is done by the machine minder or the pressman, the latter being the American term.

Type.—The typefounder supplies type to the printer in founts which are of varying weights but made up in recognised proportions of characters, *i.e.*, letters (based upon the number of "A's" in the fount), signs and spaces, etc. Type is cast from an alloy of lead, tin and antimony and is made to a standard height (·918 in.) so that the faces may present a uniformly level surface.

Type characters or faces may be classified under three headings: (1) Gothic (Encyclopædia Britannica), (2) Roman (Encyclopædia Britannica), (3) Italic (*Encyclopædia Britannica*). Type is known by its size and character. Within the last quarter of a century, the designation of sizes has undergone a change. In some instances it is still known as nonpareil, brevier, pica, etc., but it is customary to give the sizes in "points." In this the vertical thickness of the body determines the size, and what is known as the "point system" is now accepted as a standard measurement. A point is equal to .013837 in., and there are approximately 72 points in 1 in. Type sizes are graduated by points up to 12-point; those above 18-point are multiples of 6-point. There are types from 3- to 5-point but these are not in general use, being too small for ordinary purposes. The $5\frac{1}{2}$-point is used considerably in American newspaper "want" advertisements.

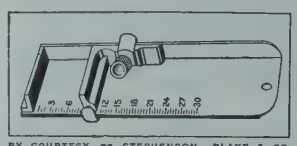
The following are a few of the approximate sizes of type in general use for printing books:—

Points	Old terms	Number of words to a square inch
6	Nonpareil	47
7	Minion	38
8	Brevier	32
9	Bourgeois	28
10	Long Primer	21
11	Small Pica	17
12	Pica	14
14	English	11
18	Great Primer	7

The above table is set in 8 point: the body of this book is set in 9 point. In addition to these sizes there is a wide variety of display types, *i.e.*, types used for advertisement purposes which can be cast up to 144-point:—12 times the size of 12-point, or, to use an old term, 12-line pica. However, it is deemed inadvisable to cast in metal much above 72-point or 6-line pica. There is no accepted standard for naming type faces. Similar characters of design bear the distinctive names which the different type founding firms give it.

Composing.—The first work of a compositor when the type is received from the founder is to "lay" it in cases. A case may be described as a wooden tray about $32\frac{1}{2}$ in. long, $14\frac{1}{2}$ in. broad and about $1\frac{1}{3}$ in. deep. The case is divided by cross partitions into "boxes," each of which holds a different character. Generally, there are two kinds of cases, namely, the upper case (capitals) and the lower case (small letters). It is usual for the upper case to have 98 boxes, the capitals on one side and small capitals on the other, and the lower case 53. The divisions in the upper case are all of the same size while those in the lower case are of varying sizes according to the number of a particular letter contained in the fount. For instance, the box for the lower case "e" is about five times the size of that for the capital "E" in the upper case. The letters in the lower case are not placed in alphabetical order but in accordance with the frequency with which a particular letter is used in the English language, those most frequently used being nearest the hand of the compositor.

When the compositor is given "copy" to set up, he places it in front of him on the upper case, and memorizing as many words as he can he proceeds to pick up from the various boxes in the case the particular letters required. These letters he places in a "composing stick" which in reality is a narrow metal tray (usually about 10 in. long and 2 in. wide) with flanges on the back and the right hand side, and on the left an adjustable slide which can be fixed to the particular "measure" or length of line required for the work in hand. On each type there is a "nick" (or "nicks"), *i.e.*, a slight groove on the front of the "body" of the type, which is a guide to the correct placing of the type in the composing stick. At the completion of each word "a space" (a short piece of metal) is inserted, it being by this means that the words are separated. When the line is completed it is "justified" or made tight to the "measure" of the composing stick with spaces of varying widths, to make the lines of uniform length.



BY COURTESY OF STEPHENSON, BLAKE & CO.

COMPOSING "STICK"

The compositor proceeds to set up the matter line by line until the stick is full. He then carefully removes the type from the stick and places it upon a shallow tray with raised edges on three sides called a "galley." When a galley is full, proofs are taken and read in conjunction with the manuscript, the reader carefully marking in by recognized symbols the corrections necessary. This is returned to the compositor who makes the necessary alterations by lifting, where necessary, the line out of the galley and replacing it in the stick, the reason for this being to ensure that justification of the lines is uniform throughout during the process of correction. When the work is completed finished proofs are pulled, usually in galley form, and sent to the author for correction.

The next operation in the production of a book is to make the type up into pages, the depth and width of which are determined by the size of paper on which it is to be printed. It is usual to send the author another set of proofs for a final "revise." When the work is finally passed for press, the pages are placed in such a position that when the sheet is printed and folded they fall in correct sequence. This is called "imposition," and includes placing the pages within an iron frame called a "chase," which, when there are a number of pages to be printed together, has crossbars—one across the length of the chase, the other across the width. The determined space between the pages is filled up with what is called "furniture," which is made of either wood or metal, and about $\frac{1}{4}$ in. lower than type, so that it does not get inked during the process of printing. The whole is then locked up within the chase by means of a system of wedges, called "quoins," thus making the type and furniture portable. When this is accomplished it is known as a forme and is ready to be printed.

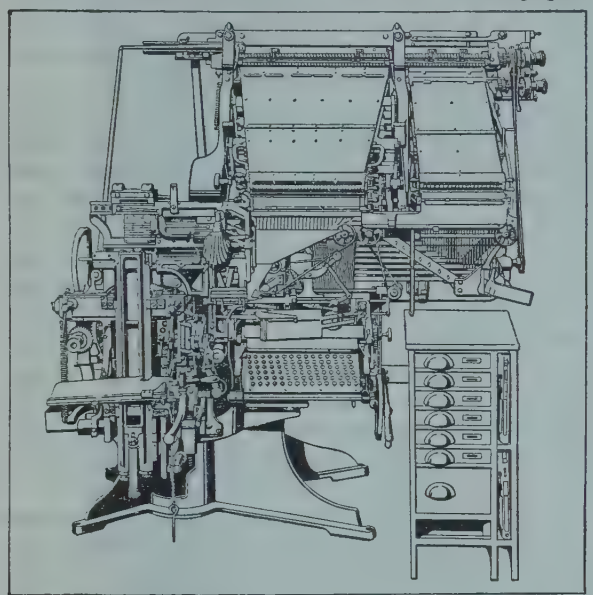
Composing Machines.—The setting of the type for newspapers, magazines and books is now almost entirely a question of mechanical composition and the machines used for this purpose can be divided into two classes:

(1) That which casts a "slug" (or line of type), such as the Linotype, Intertype, Typograph and Ludlow.

(2) That which produces justified lines of single types, and known as the Monotype.

Slug-Casting Machines.—Such machines as the Linotype and Intertype consist of a keyboard, magazines (containing matrices), casting apparatus and a distributing system. The compositor on these machines is called an "operator," and when he presses a key representing a particular character on the keyboard, it operates certain levers which allow a matrix, with the letter cut into its edge, to be released from the magazine. The matrix, dropping on to a revolving belt, is carried automatically to an assembly box. By touching another key, a double wedge spaceband is placed between the words. When the line is full a lever is depressed and causes the matrices and spacebands to be carried to a position in front of the mould, behind which is situated a pot of molten metal. While in this position, the line is justified by the pushing up of the spacebands from below, the line thus spreading out to the full measure. A plunger in the metal pot then descends and forces the molten metal into the mould and against the face of the matrices. The resultant metal bar or "slug" with the letters in relief is then automatically trimmed for height and thickness prior to its being ejected on to a receiving galley. The matrices from which the slug has been cast have meanwhile

been lifted by an arm to the top of the machine, and are caused to travel along a serrated distributor bar until the matrix finds its way into its correct channel in the magazine. Each matrix has on its top edge a double series of seven teeth, the arrangement of same varying with each matrix. The individual matrix travelling along the corresponding rail on the distributor bar eventually arrives at a break in the rail on which it has been hanging and



BY COURTESY OF LINOTYPE AND MACHINERY CO.

MODERN LINOTYPE

has no alternative but to drop into its respective magazine channel.

All the operations are automatic and continuous, it being possible for three lines of matrices to be in circulation at the same time, one in course of assembly, another in the process of casting and a third in the stage of distribution.

The Typograph is a further and somewhat different expression of slug-casting machine. In this machine the matrices hang on a series of wires which converge fan-shape towards the point of assembly. As the operator touches the respective keys on the keyboard, the matrices slide by gravity down the wires to the point of assembly. The line is justified by means of circular space discs which expand as they are caused to revolve just prior to the casting. The slug cast by this machine does not require trimming to give either the height or the body width. The operation of distribution is performed automatically, the top frame of the machine tilting backwards and so reversing the angle of the wires when the matrices automatically slide back to their original postion.

The Ludlow Typograph is a class of slug-casting machine designed for the production of display lines. It does not, however, set up matrices, its function being to produce cast slugs from lines of matrices set up by hand in a special composing stick. As each line is set by the compositor the stick containing it is clamped into the machine which produces a solid line of type with the characters in slug form. This particular form of slug-casting machine is employed in the main for producing headlines for use in newspaper and periodical work, advertisements and various similar purposes.

Monotype.—The Monotype is a system of mechanical composition that produces justified lines of single types. It comprises two distinct machines—a keyboard and a caster. The keyboard has the appearance of an elaborate typewriter. As the operator depresses each key, holes are punched into a strip of paper which automatically travels with each tap of the keys from one spool-holder to another, each letter being represented by its particular combination of perforations. At the end of each line a pointer indicates what special keys should be touched in order to ensure the justification of such line when eventually cast in metal.

When the spool is completed it is placed in position on the casting machine which contains a metal pot, a mould and a matrix holder called the "die case." The latter usually contains 225 matrices arranged in 15 rows of 15 in the compass of a 3-in. square. The perforated strip of paper controls the action of the mechanism which brings the respective matrices into position over the mould in the order desired. When the matrix has been momentarily clamped into position, a jet of metal is forced into the mould and the type cast. The characters as cast are pushed along until, when the line is completed, they are automatically transferred on to a galley. The last line of the spool is the first to be cast, but when each galley is completed the lines will run in correct sequence as in the copy. There is an adaptation of the Monotype machine by which rules, ornaments, and a wide range of display type faces may be cast, and afterwards put into cases to be used by the hand compositor.

Machining.—When the forme is sent to press from the composing room the printer's work commences. The printer is called a machine-minder in Great Britain, and a pressman in America, and it mainly depends upon him as to whether the work bears the hall mark of "quality" (or otherwise), the printing of the sheets demanding the greatest of care in every stage.

The first operation is to prepare the impression surface (the platen or cylinder) by covering it with a number of sheets of a suitable paper. This is followed by locking the forme securely in the bed of the machine in a position necessary to the requirements of the particular work in hand. The quoins securing the work in the chase are loosened, and the type "planed down" with a planer, *i.e.*, a smooth flat piece of wood is placed on the type and carefully struck with a mallet to ensure that the "feet" of the type rest solidly on the bed; the quoins are then again tightened and an impression "pulled" on a sheet of paper. Invariably this first pull shows irregularities in the weight of pressure, some parts being so weak that they are unreadable and others so heavy as nearly to cut through the sheet of paper. It is in the rectification of these inequalities that the skill and experience of the machine-minder are exhibited, for unless this work is done with understanding, the printed sheets will appear "patchy" and difficult to read. When the printed sheet has been made "readable" the pages are "registered," *i.e.*, placed to print in the proper position on the sheet, and in printing book work, made to "back up" correctly. A well printed book, if the pages are of uniform size, should have the lines on both sides of the leaf printing exactly on the back of each other.

When a forme of type is registered, a sheet is sent to the reader for revision (in case of any letters having been broken off or a word "pied"). While this is taking place, the operation called "make-ready" is commenced, and it is not unusual for a large forme to take two or even three days to make ready. The desired results are obtained by cutting out on a sheet of thin paper the heavy parts with a sharp knife and "patching up" with paste on the sheet, varying thicknesses of paper on those parts that are weak. When the sheet is completed it is "stuck up" on the impression surface in a position corresponding exactly with that part of the forme which requires the particular treatment. Another impression is then pulled, and the work of cutting out and patching up is continued until the impressions seen on the back of the sheet present an even and regular appearance. The supply of ink has then to be adjusted so that the requisite amount will be transferred to the type in a uniform manner throughout the "run."

When printing half-tone work, "interlaying" is often done to ease the pressure on the high lights and to give greater resistance to the solids contained in the plate while printing. "Overlaying" is invariably used when printing illustrations either in monochrome or colour. It is a means of supplying the graduated pressure necessary to ensure that a clean sharp impression of the inked blocks will be made upon the sheet of paper.

There are various methods of making overlays, the usual being to pull three impressions from the block on thin, hard paper. On the first sheet, which is the foundation sheet, all the high lights are cut out; on the next sheet all the solids are carefully cut out

and pasted accurately in a corresponding position on to the first sheet. The third sheet has the high lights and intermediate tones cut out, leaving the three-quarter tones and solids; this is then pasted on to the foundation sheet on which the solids have already been fixed. When the overlay is completed and held up to the light "a picture" of the illustration in its various tones will be seen. The overlay is then pasted on to the impression surface in a position to correspond exactly with the block on the bed of the machine; thus the varying tones in the plate will receive graduated degrees of pressure, and by this means a true representation of the tones in the block is obtained when inked and impressed on to a sheet of paper.

There are mechanical means of making overlays. The most popular form is known as the "chalk" overlay. An inked impression of the illustration is taken on both sides of a piece of paper, which is treated with a chalk preparation. The ink, according to its density, acts as a resist when the prepared paper is immersed in a solution of chloride of lime, the result being that a graduated surface in hardened chalk is obtained in exact relation to the tones contained in the plate, the solids being highest and the other tones correspondingly lower. When the etching is completed the paper is allowed to dry and then pasted on to the impression surface. Another method (a photo-mechanical one) is that of a thin piece of zinc etched in relief, with the tones in correct relation to each other.

When printing newspapers there is no time for making ready and when blocks are printed they are prepared mechanically by putting the printing surface on different planes. This is generally called "bumping" and is done by making a metal "interlay" which is forced into the back of the plate, with the result that the tones in the plate are slightly raised in accordance with the pressure required to give a correct impression, the solids being highest and the high lights lowest. This method of obtaining regulated pressure is likewise frequently resorted to in magazine printing and in a particular method of colour printing.

Duplicate Plates.—To secure economical and expeditious production of large editions it is necessary to print at the same time a number of duplicate plates identical with the original page of type or blocks. This is done by two processes, known as stereotyping and electrotyping.

Stereotyping.—Stereotyping is a process whereby duplicate plates of pages of type and relief printing blocks are obtained. This is done by taking a mould of the forme in plaster of paris or papier mâché, placing it in a "casting box" and pouring molten metal into the box and over the face of the mould.

Like others of the crafts included in the printing industry, there is some obscurity about the date of the invention of this process, but it can be safely dated as about the beginning of the 18th century (1700–25). It is attributed to William Ged, an Edinburgh goldsmith. It is believed that he made a mould by pouring gypsum (plaster of paris) over a page of type, and allowing it to set. In 1730 it is known that he went to Cambridge and made plates for a bible for the university, but it is said that these plates were spoiled by the printers and the process abandoned. Ged returned to Edinburgh in 1733, where he died in 1749. About 1779, Tilloch and Foulis seemed to have "reinvented" the process of stereotyping, since they took out patents in April 1784 for a method of making plates for printing. Earl Stanhope is likewise credited with having reintroduced Ged's process early in the 19th century. In America, stereotyping was introduced by David Bruce (1813) who served his apprenticeship in Edinburgh. The first book stereotyped in the United States was the Westminster Catechism, printed by John Watts in 1813.

The Plaster Process.—This method of making stereotype moulds is not now in general use, but certain firms in England employ it for duplicating half-tone plates, the usual method being to spread on a sheet of stout paper a coating of about $\frac{1}{8}$ in. of fine plaster of paris which, when about to set, is placed in contact with a forme (the imposed type matter or blocks), and subjected to pressure. When the plaster is set, the mould is dried by heat.

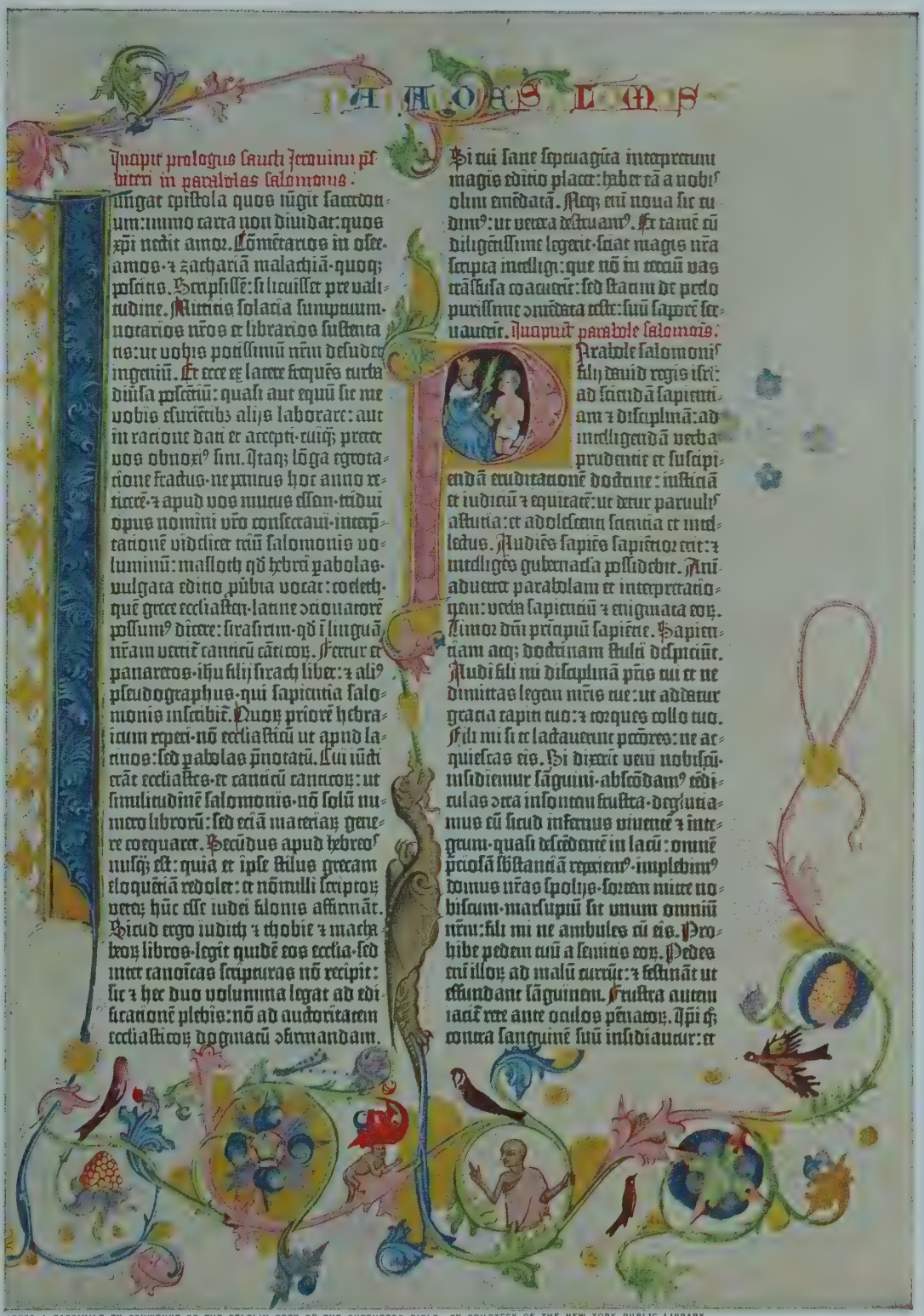
The Paper Process.—A plate by the papier mâché method is obtained by making a "flong" composed of blotting and tissue papers pasted together. The particular method of making a flong is largely an individual opinion of the stereotyper, but generally it is made up of a sheet of strong, coarse blotting called a backing sheet. On this a fine sheet of blotting is pasted, followed by three sheets of tissue one on top of the other. It being necessary to keep the flongs damp, they are placed between damp blankets. The type from which stereotypes are to be made is placed within bevelled type-high bearers and locked up in a strong chase, the bearers serving the purpose of protecting the edges of the type and facilitating the moulding.

Moulding.—The face of the forme is then carefully brushed over with oil, the open spaces between the lines being packed with card or pieces of thin metal to prevent the cracking of the flong when moulding. A piece of the damp flong about an inch larger all round than the surrounding bearers is placed face-downwards (tissue side) on to the forme and, by means of a stiff brush with a long handle, is beaten by hand evenly into the type until a uniform depth is obtained. The "blanks" (depressions) on the back of the flong are then filled in with felt or card and covered with a strong sheet (usually brown paper). Both the forme and the flong are then placed into a drying press, being kept under pressure until the flong is baked dry. The flong is then carefully removed from the forme and becomes known as a matrix, or, as the stereotyper calls it, a "mat." This is then trimmed, and a long piece of brown paper, called a "tail," is pasted on to one end. The latter acts as a guide to lead the molten metal on to the face of the matrix when the plate is being cast.

Casting.—The matrix is then placed in a casting box which consists of two flat surfaces, the top part being hinged so that it may be thrown back in a perpendicular position. When the matrix is placed in the box it is held in position by two steel gauges which not only determine the thickness of the plate but prevent the molten metal running out at the bottom and sides of the casting box. When the matrices and gauges are correctly positioned the top is lowered and clamped to the lower surface. It is then tightly secured by means of a screw, the whole of the box being tilted into a perpendicular position. The mouth of the box is bevelled to allow the molten metal to be easily poured in. This is done by means of a ladle. A few moments are allowed for the metal to set. When the box is opened the gauges are removed and the matrix relieved from the newly cast plate, the casting operations being repeated from the same mould according to the number of stereo plates required. The plate has then to go through a series of finishing operations to put it in a proper condition for printing. The plates are mounted on a block of wood to bring the printing surface to type height.

Newspaper and Periodical Printing.—It is in newspaper and magazine production that stereotyping has made the greatest progress. Speed is essential in these particular branches of printing, and instead of a wet flong a special manufacture of dry flong is used, the matrix being moulded either by cylindrical pressure, usually known as a "mangle," or by means of a special press on the platen principle. The matrix is then dried and when thoroughly free from moisture is placed in a casting box which is half cylindrical in form and conforms to the diameter of the cylinder of the printing machine on which the plate is to be printed. Metal is then pumped direct from the metal pot into the casting box. When the plate is cool it is removed from the box in a semi-circular shape.

Automatic Casting.—The ever-increasing demand for speed and accuracy in the production of newspapers has brought into general use an ingenious machine called "the Autoplate." This is an American invention, capable of producing two plates in a minute in place of the one plate in three minutes, which was the usual time taken to cast a plate when the work was done by hand. On the Autoplate the matrix is fixed into clips and carried to the casting box, which, when closed, is flooded with molten metal pumped from a large metal pot. After a short "dwell," the casting box is opened and the plate removed from the matrix, the former being cooled by a system of water circulation. The


PARABOLAS SALOMONIS
Quapit prologus sancti Jeronimi pbi
tri in parabolas salomonis.
Frigat epistola quos rigit sacerdo
um: nimio carta non diuidat: quos
xpi nectit amor. Cometarios in ose
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luminū: masloth qđ hebrē pabolas
vulgata edino pūbia vocat: coeleth
quē grece ecclesiasten latine cōionatore
possum⁹ dicere: siraforim: qđ i lingua
rām uerē canticiū cāticoz. Ferunt et
panareos: ihu filij sirach libet: z ali⁹
pseudographus: qui sapientia salo
monis inscribit. Quoz priorē hebra
icum reperi: nō ecclesiasticū ut apud la
tinos: sed gabolas pnotatū. Cui iūcti
cāt ecclesiastes: et cantīcū cantīcoz: ut
similitudinē salomonis: nō solū nu
mero librorū: sed ecīā materiaz gene
re coequarer. Secūdus apud hebreos
nullus est: quia et ipse stilus grecam
eloquēiā redolet: et nōnulli scriptoz
uetuz hūc esse iudei filonis affirmāt.
Sicut ergo iudith z thobie z macha
beoz libros legit quidē eos eccliā: sed
inter canonicas scripturas nō recipit:
sic z hec duo uolumina legat ad edi
ficationē plebis: nō ad auctoritatem
ecclesiasticoz dogmatū confirmandam.
Si cui sane septuagīta interpretum
magis edino placet: habet eā a nobis
olim emēdatā. Sexta enī noua sic ru
dinis: ut uetera destruam⁹. Et tamē cū
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Parabole salomonis
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ad sciendā sapientiā
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intelligendā uerba
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quiescas eis. Si dixerit ueni nobiscū:
insidiemur sāguini: absconda⁹ tendi
culas oni insontem frustra: deglutia
mus eū sicut infernus uiuentē z integrē
cum: quasi descendentē in lacū: omnē
preciā substantiā repiem⁹: implebim⁹
domus nras spoliis: sortem mitte no
biscum: marsupiū sit unum omniū
nrm: fili mi ne ambules cū eis. Pro
hibe pedem tuū a semitis eoz. Pedes
enī illoz ad malū currūt: z festināt ut
effundant sāguinem. Frustra autem
iacit rete ante oculos pennatoz. Ipsi et
contra sanguinē suū insidiantur: et

AFTER A FACSIMILE BY SCHWENKE OF THE PELPLIN COPY OF THE GUTENBERG BIBLE, BY COURTESY OF THE NEW YORK PUBLIC LIBRARY

ILLUMINATED PAGE FROM THE GUTENBERG BIBLE

The Gutenberg Bible, traditionally accepted as the first book printed from movable type, was issued at Mainz, Germany, about 1454. The illustration shows page one of the Proverbs of Solomon. The pages are illuminated to give the effect of a hand-copied manuscript, as desired by the printers, who did not wish their invention discovered. The book was probably printed in 10 sections on 6 presses working simultaneously. Of nearly 300 copies, only 45 are known to be in existence to-day

PRINTING

BY COURTESY OF R. R. DONNELLEY & SONS COMPANY

TYPESETTING AND MAKE-UP

Top left: Linotype operator whose touch on the keyboard casts a full line of type in one piece of type metal (a slug)

Top right: The monotype machine does not set type. On a paper roll (a monotype ribbon) it creates a perforation for each character, later cast individually by the monotype caster

Centre right: The perforated ribbon is fed into the monotype caster where individual characters are cast and composed into justified lines of type (words spaced to fit the intended line length). In monotype composition, changes and corrections can be made by hand

Bottom left: In hand typesetting, the compositor works from cases of particular type faces. He selects them one at a time and assembles them in a "stick" which is preset to the desired line length

Bottom right: Type being arranged in galley trays before preliminary proofs are pulled. Often hand-set and machine-set type are brought together at this point. The next step is make-up, in which hand compositors (make-up men) assemble and arrange type into pages

BY COURTESY OF R. R. DONNELLEY & SONS COMPANY

PROOFREADING, MAKE-READY AND FLAT-BED PRINTING

Top left: Proofreading against original copy

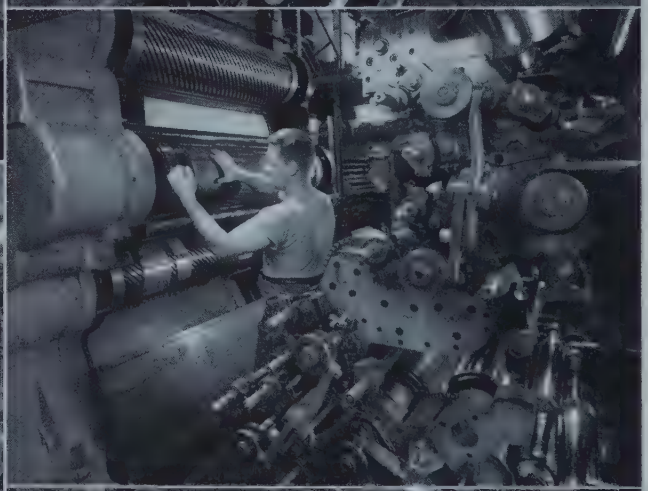
Top right: Imposition and lockup, the arranging of pages into "forms" which will print on large press sheets on which pages appear in sequence for folding into signatures. The stoneman is locking page forms of type and engravings after checking positions with a transparent layout sheet. This form will print on a flat-bed press

Bottom left: Make-ready, the process of insuring an even printing surface so that no part of the printed matter is lighter or darker than others. After inspecting a trial proof, the pressman indicates dark and light areas, prepares a pattern as shown, cuts out areas where the impression was too dark, leaving paper to raise areas that were too light. The slight thickness of the paper is enough to insure evenness of "colour"

Centre right: A flat-bed cylinder press. Paper starts from the stack at right, travels over and around the cylinder as the flat type form passes under it horizontally. Ink rollers (left of cylinder) apply ink to the form on each cycle

Bottom right: When numerous copies are to be printed, the printing is not done directly from the type form. Instead, electrotype or stereotype plates are moulded from the original type form, shown being locked in special heavy chases for moulding

PRINTING



BY COURTESY OF R. R. DONNELLEY & SONS COMPANY

ROTARY PRINTING

Top left: For a cylinder (or rotary) press, the flat printing plates must be adapted by curving them to the exact radius of the cylinder on which they must fit

Top right: In placing curved plates on the cylinders, they must be adjusted to align properly with other plates

Centre right: A multi-colour rotary press. When printing in more than one colour, separate sets of plates are required for each colour ink. Plates on each cylinder must be placed accurately to make each colour impression register exactly over the last colour impression on the printed sheet

Bottom right: When numerous copies are to be printed, paper is fed into the press from large rolls. This is characteristic of newspaper and magazine printing, large circulation catalogues and directories

Bottom left: Large continuous presses take roll paper stock in at one end and deliver completely printed and folded signatures, or sections, at the other end

plate is then mechanically bored, routed and finished, ready for the printing press, every operation being automatically controlled.

A later development in the automatic casting of stereotype plates is the invention of a Swiss engineer and is known as "the Winkler." In this instance, a "perfect plate" is produced without resorting to the usual finishing operations. The metal pot is directly connected with the casting box and the weight of the metal in the pot provides the necessary pressure to cast a large-sized plate without leaving surplus metal to be trimmed off. This machine produces two finished plates per minute.

(J. R. R.; J. C. Os.)

Electrotyping.—Electrotyping is a method of producing duplicate printing plates by electroforming. A mould of the original plate or form is made in wax, prepared sheet lead, sheet plastic or one of several proprietary media and the face of the duplicate is deposited upon this mould by electroplating. The metal plated on the mould is generally nickel, copper or iron or a combination of these metals.

When A. Volta invented the galvanic battery in 1799, the foundation of the process was laid. About 1839 two Englishmen (Thomas Spencer of Liverpool and C. J. Jordan of London) and M. H. Jacobi of St. Petersburg were experimenting with the making of plates by electrometallurgy. About the same time, J. A. Adams, a wood engraver in New York, is credited with having made an electrotype, which was used for printing in 1841; this process he also used for duplicating illustrations for Harper's family Bible, which was issued between 1842 and 1844. To obtain a mould he used a soft metal. About 1840 Smee's battery was introduced, making the deposition of copper a commercial proposition. About this date graphite was first used to make the surface of a mould made in wax conductive. A French cabinet-maker, Victor Morel, took a prominent part in improving the process for printing purposes. He was ultimately engaged to install a foundry in the establishment of Cassell (London). Electrotyping owes a debt to this publishing and printing house for the experiments they made at great cost, with a view to perfecting the electrotyping process. Beeswax as a moulding medium was first used by them.

Moulding.—The mould upon which the metal shell is deposited is made in a hydraulic press. Four different kinds of moulds are commonly used: (1) lead mould, (2) wax mould, (3) wax mould on prepared sheet and (4) plastic sheet mould.

Lead moulds are made in pure lead sheets and are used where the most exacting duplication of original engravings is required, both as to detail and size. Before being plated, lead moulds must be washed with a solution of potassium bichromate to facilitate separation of the mould and the deposited shell.

Wax moulds are the original means of reproduction and are made in "cases" which consist of metal plates coated with wax and shaved to a uniform thickness. This wax is made up of varying proportions of ozocerite, gum, turpentine, Burgundy pitch and beeswax. It is melted and poured over the cases after which they are shaved to thickness and flashed with a gas flame for smoothness.

The preformed wax moulding sheets are a late development largely to replace the old wax case. They consist of a thin metal foil sheet and one or more layers of waxes and gums. This material is supplied in rolls or sheets and is cut to size by the moulder.

Both kinds of wax moulds are prepared for plating by a "builder" who cuts down the spots where the wax has flowed into low areas of the original and builds up wax at points where more relief is desired.

Originally all wax moulds were made conductive by polishing with graphite, or washing with an emulsion of graphite and water, or both. A hot iron passed around the outside of the mould prevented deposition of metal where not needed. The use of graphite has largely been discontinued and moulds are made conductive by the silver spray process.

Plastic moulds are the latest type and by mid-20th century were to a great extent replacing all other types. They are made in sheets of various thermoplastics and combine the advantages of very accurate reproduction and ability to be used many times. Unlike lead moulds the plastic moulds lend themselves admirably to the moulding of foundry type, monotype or linotype either alone or in combination with engravings. They may be stored for future use, eliminating the need to keep type standing. Such moulds are made by preheating the original or form and the plastic sheet to a temperature at which the plastic sheet is soft and ductile and moulding in a chilled hydraulic press. The mould is chilled under pressure against the original and maintains a faithful reproduction of it. Plastic moulds are prepared for the plating battery by a silver spray process.

The silver spray processes are an adaptation of mirror silvering. Solutions of ammoniacal silver nitrate and a reducing agent (similar to photographic developer) are sprayed simultaneously on the mould, depositing a thin layer of metallic silver which is an excellent electrical conductor. The surfaces to be coated must be sensitized by wetting with stannous chloride solution which is thoroughly rinsed off before spraying. Plastic moulds are thoroughly scrubbed before sensitizing. Wax moulds are sprayed with a cleaning solution because they cannot safely be scrubbed.

All types of moulds except wax cases are fastened to glass or plastic cases for plating and an electrical connection must be made from them to the hook which suspends them in the plating bath and connects them to the negative pole of the plating power source.

Generally a small copper plate is embedded in the upper margin of the mould and is contacted by a clamp on the hook by which the case is suspended. This copper plate is embedded in the mould or wax case before the silver spraying (or the old graphiting) operation.

Deposition.—The mould is now ready for the depositing bath, although a wax mould is sometimes previously prepared by covering it with a solution of copper sulphate into which fine iron filings are sprinkled and the whole stirred with a soft camel's-hair brush, thus precipitating a fine film of copper on the mould. Extreme care must be taken to see that all connections are clean.

The depositing equipment consists of a bath or tank which has an acid-resistant lining. This is filled to within about six inches of the top with water into which is placed copper sulphate and a percentage of sulphuric acid. When working, the solution is agitated by compressed air to keep the concentration uniform. A regular temperature must be maintained. The electric current necessary for depositing is obtained from a D.C. generator or rectifier situated in close proximity to the bath. The current is carried from the source to the bath by two heavy copper rods extending the length of the tank, one being connected to the positive pole and one to the negative pole of the generator. Placed on the long copper rods are shorter copper rods running across the bath. On the short rod connected with the positive pole and suspended by means of hooks into the solution is a copper anode. The prepared mould or cathode is suspended in a similar manner on the other short rod connected with the negative pole with its face toward the anode. The copper sulphate when dissolved in the water and sulphuric acid breaks up into two portions: (1) a copper portion which is electrically positive, (2) a sulphate portion which is electrically negative. The positive copper portion is attracted to the negative pole (*i.e.*, the mould or case) and is there deposited while the negative sulphate portion travels to the anode (which is positive) and there combines with the copper to yield more copper sulphate so that the concentration of the bath is kept more or less constant. In this way the shell is grown until a sufficient thickness is obtained.

Nickel is deposited in a similar manner, but the bath is composed of a solution of nickel sulphate and ammonium chloride. Electrotypes are sometimes faced with a deposit of nickel to increase their durability and also to prevent certain chemical actions which may occur when printing with coloured inks from a copper surface. The deposition of chromium at mid-20th century was receiving much attention, it being one of the hardest metals and of great durability.

When the deposition is complete the mould is taken from the bath and the shell removed by pouring hot water over it until the wax melts, the wax removed being used again. Where sheet lead is used as the moulding medium the lead is separated from the shell by peeling or stripping. Extra care is necessary to hold the shell perfectly flat during this operation. Where plastic moulds have been used as a base for depositing the shell, the stripping operation is much simpler; the plastic sheet is readily lifted from the shell after trimming the rough edges. The plastic mould after being cleaned may be used for the deposition of additional shells. This is one of its great advantages as a moulding medium.

Backing.—The next operation is the backing up of the shell. When it is released from the mould it is trimmed around the edges and prepared for receiving the molten alloy metal backing. Since the metal (which is composed of lead, tin and antimony) will not adhere to copper the back of the shell must be tinned. This is accomplished by electroplating the tin on the back of the shell or by the fusing of tin foil or powdered solder using a suitable flux. The shell is then placed face downward on a pan or tray usually with flanges and the molten metal poured over the back and allowed to solidify.

With the growing use of rotary printing presses which require curved plates, many different methods of curving by both hot and cold processes have been devised and great accuracy in making these plates absolutely uniform in thickness as well as curvature is necessary. A method of centrifugal casting or backing was developed that showed great promise of supplanting the older methods of making curved plates. By this process shells deposited in a curved form are inserted in a cylinder. While the cylinder is revolving in horizontal position the backing metal is poured into it and the centrifugal force holds the metal against the shell. After cooling the backed-up shell is easily removed from the cylinder.

Finishing.—When the backing of a flat plate is completed it is removed from the pan and the face cleaned, its rough edges trimmed and then passed through a series of finishing operations such as

roughing and shaving the back to the proper thickness, routing the nonprinting parts of the surface, bevelling the plate for use on a metal base or mounting it on wood or metal. The greatest care must be exercised in each detail of these operations to prevent damage to the printing surface.

By the process of electrotyping the duplication of engravings, etchings and type matter is accomplished and the reproduction of the finest half tones and colour plates in accurate register and with fidelity to the original is made possible. (W. A. Sh.)

PRINTING MACHINES

The different styles of printing machines are too numerous to detail. In America they are called "presses" and in Great Britain (with the exception of proving presses) they are called "machines." They may, however, be classified as platens, automatics, cylinders and rotaries. Many firms adopt standard makes of machines to suit their requirements. The larger number of machines in general use print on one side of the sheet at a time, but in offices where magazines and books are produced "perfecting" machines are employed. These machines have two type beds and two impression cylinders, thus when one side of the sheet is printed, it is mechanically reversed and the other side receives an impression from another set of plates or type. In colour printing there are machines for printing a number of colours before delivery of the sheets. The usual method in multi-colour printing, is to print two colours before the sheet is delivered. There are two impression cylinders and two beds each with its respective forme of type or blocks. When the sheet receives its first impression it is transferred to another cylinder and the second colour is superimposed on the first. Thus, in reproducing pictures in four colours the sheets go through the machine twice before the work is completed.

Colour printing has been attempted by placing machines "tandem wise," *i.e.*, end on to each other, the sheets being carried from one machine to another by means of a travelling conveyor and automatically placing the sheets into the lays on the respective machines. Four colours have been printed by this method. The most effective multi-colour printing method, however, is that done on rotary presses, where a sheet is taken by means of grippers round a large impression cylinder and receives an impression from four sets of plates, each inked with a different colour.

The Hand Press.—The hand press is of the platen type, *i.e.*, an impression is taken from the whole forme at the same moment by means of a flat surface. The hand press is mainly used for proof-pulling. Photo-engravers usually pull the proofs of their plates on such a press, and it is invariably used by amateurs and those running private presses for printing small editions.

On the hand press the type bed runs on two rails and is propelled under the platen by means of a rounce consisting of a handle and a pulley to which belts are attached; the ends of the belts are secured to the ends of the bed, and by turning the handle the bed is moved to and fro as the belts wind and unwind round the pulley; while to obtain the necessary pressure the platen is depressed by means of a lever, which when pulled forward acts upon a toggle joint (inclined pieces of metal) bringing it into a perpendicular position. This forces the platen down and presses the sheet on to the inked forme. On the bar being released the platen is lifted to its normal position by springs. Attached to the end of the type bed a hinged frame is fixed and covered with parchment or fine linen; this is called the "tympan," and it is on this that the making ready is fixed and the sheet of paper secured by means of "lays" (pins being usually used). The paper is kept from being soiled by a "frisket" (another hinged frame fixed on to the top of the tympan and covered with paper with parts cut out corresponding to the area of the type which has to be printed). The portions of paper remaining on the frisket keep the sheet from being marked by the furniture or chase which is liable to become inked when rolling a forme by hand. Two hundred and fifty impressions an hour are considered a good production on this type of press.

Platens.—The platen machines now used are generally known as "light" and "heavy" types. The terms explain the class of work for which they are intended.

Light platens are fast-running machines suitable for general job work, and are invariably actuated by what is known as the "clam shell" movement, which brings the platen on which the packing and "making-ready" are fastened, and on which the sheet to be printed is placed to guides, into a position where the sheet can be pressed against the forme, which is held in a perpendicular position. The forme is automatically inked by two or three rollers passing over the surface, the ink being fed by a roller from a "duct" on to a rotating "disc," which assists in the distribution of the ink before the inking rollers take up a supply from the disc. The platen and the bed are brought together by means of rods working on eccentrics. By moving a lever acting upon the eccentric the platen is thrown back, thus preventing the forme from printing by keeping the platen from reaching the forme. This style of machine can be worked by treadle, although motive power is now usually employed. The feeder stands in front of the machine, lifts a sheet of paper with his right hand, places it on to lays on the platen which rises and prints the sheet. On the return motion of the platen the feeder removes the printed sheet with his left hand and places it on a table, at the same time placing another sheet on to the platen ready for printing. The average size of a sheet printed on these machines is 10 in. by 15 in. and the speed is approximately 1,500 impressions per hour.

Heavy platens are of exceptional strength built to meet the exacting demands of high grade printing. The frame is cast in one solid piece and the platen is placed on finished rails. The movement of the platen is known as the "rocking-sliding" action due to the platen having on its underside semi-circular rails which work on the rails on the frame and is controlled by a cam known as a "swan's neck." The platen is connected with the back of the frame by two arms, the ends on the platen side working in eccentrics. As the machine works the platen is brought into action with a rocking motion until it reaches a perpendicular position and is then pulled into contact with the forme by a "slide up" or parallel movement.

A cylindrical inking system is a feature of this class of machine. The ink from the duct is fed on to a series of rollers, and oscillating metal drum. This ensures a better distribution and also enables a graduated supply of ink to be conveyed to the forme by four inking rollers. It is on this style of machine that the best half-tone and colour work is printed. The machines are built for large sheets (the usual size being about 22 by 14), and are fed and operated in the same way as light platens. The average production from a heavy platen is approximately about 1,000 impressions per hour.

Cylinders.—The term "cylinder" is given to those machines where the impression is obtained by means of a cylinder pressing a sheet of paper on to the face of a forme which is secured on a flat horizontal bed. The cylinder runs in bearings held by brackets and rotates as the bed moves to and fro beneath it. There are three different styles, (*a*) the drum cylinder, (*b*) the stop cylinder, (*c*) the two-revolution cylinder.

The drum cylinder, the successor to Koenig's machine (1811), is now but little used. The cylinder, continually revolving, makes one revolution for each impression. One half of the cylinder is lower to allow for the return of the type bed which has a short travel. When the cylinder completes its travel the gripper automatically opens and the printed sheet is transferred to a delivery apparatus known as the "flyers." The sheets as they are delivered are placed one on top of the other on a board at the rear of the machine. The inking equipment is what is usually known as the "pyramidical system," the ink duct being placed in front of the cylinder and the ink transferred to the forme by a system of rollers. The sheets are fed in from the top or crown of the cylinder. These machines are made in various sizes, and a production of between 2,000 and 3,000 is a fair average.

The stop cylinder is essentially an English machine, and commonly known as a "Wharfedale." In this class there is a small cylinder, about three quarters of the circumference being used for impression. On both ends of the cylinder pinions are geared into corresponding racks on each side of the type bed. One of the gears on the cylinder "runs loose" and the other is fixed with the teeth on the under portion cut away. This allows for the return of the bed after the sheet has been printed. The carriage is supported by "bowls" running on rails and receives its reciprocating motion by

means of racks fixed on the underside of the carriage geared into large wheels running on bearers and in gears. These are connected by a rod to another set of gear wheels which obtain their motion from small pinions keyed on to the driving shaft.

The cylinder is rotated by means of racks fixed on the side of the bed. As the carriage is propelled to and fro the gears on the cylinder turn the cylinder and in this way the sheet is printed and is usually fed by hand to lays at the base of the cylinder. When printed it is automatically removed to the delivery board by means of "flyers."

The inking system includes an ink trough, or "duct," situated at the back of the machine. From the duct a supply of ink is fed by means of rollers and placed on to a "slab" fixed to the end of the carriage. As the carriage moves to and fro, the ink on the slab is distributed by a group of rollers. The inking rollers (held in brackets behind the cylinder) get their supply of ink from the slab as it passes under them and by this means inking the printing surface. This type of machine is made in a large number of sizes and can run at anything from 1,000 to 2,000 impressions an hour.

The Vertical Job Press.—This press is an adaptation of the stop-cylinder principle to a small printing machine with automatic feeding device. The movement of the bed is on a vertical plane with the cylinder rotating over the forme but in an opposite direction to the bed.

This machine has been likened to a cylinder machine placed on its end but with the cylinder on which the sheet is placed travelling over the inked forme. The cylinder stops to enable the grippers to take a sheet from the feedboard. The sheets are automatically fed into lays and, after printing, are delivered at the back of the machine. It is a high speed machine capable of printing a sheet 19 in. by 13½ in. and producing about 3,000 copies per hour.

There are on the market two or three well known machines that are adaptations of the stop-cylinder principle to a small press with automatic feeding device.

The two-revolution machine is now generally accepted as the standard type of cylinder printing machine for general work. It derives its name from the fact that the cylinder makes two revolutions for each sheet printed. During one revolution the sheet is printed, after which the cylinder rises clear of the forme to allow the return of the carriage to deliver the sheet on to the flyers. In this type of machine the cylinder is not actuated by the bed. Both cylinder and bed are driven independently but in unison with each other.

The inking mechanism is on the slab principle and the sheets are fed from the crown of the cylinder, a feature being the method of delivery of the printed sheet which is done in such a way that the newly printed work does not come into contact with anything that would be likely to smear the wet ink. This style of machine is capable of producing an average of about 2,000 copies per hour. One well-known machine is an adaptation of the two-revolution principle to a small press with automatic feeding attachment. The two-revolution make of machine is made with two cylinders, either for "perfecting," *i.e.*, printing both sides of the sheet, or for printing two colours before the sheet is delivered. These machines have two type beds, each with separate inking equipment. The demands for fine work, coupled with the need for speed have brought this style of machine to an extremely high degree of efficiency and accuracy.

A large number of small cylinder machines are built with the object of giving a large output, but quality and speed do not usually go together. Hand feeding of printing machines is rapidly being superseded by automatic feeding. There are two distinct types of machines for this purpose. One is known as a "pile feeder" where a large stack of paper is placed in a contrivance which automatically rises as the sheets are removed from the top by means of suction, placed on the feed board, and carried to the lays on to the printing machine. In the event of the sheet not reaching the lays, the machine stops. The other type is known as the "continuous feeder." In this case the sheets are "put up" a few at a time and while the printing machine is running they are "combed out" and mechanically controlled until they reach the lays, and should they not do so, the machine automatically stops.

Rotaries.—In this class of machine the impression is obtained by means of two cylinders, one of which carries the plate and the other the necessary packing, the paper passing between the two. The plates have to be curved to suit the cylinders and are secured by means of clamps. Where only one size of plate is printed on the machine, as in newspapers, two clamps are fixtures and the other two are movable in order to provide for the secure locking up of the plates. Where plates of various sizes are printed the plate cylinder is spirally grooved, into which movable clamps are fitted to suit the size of the plates to be printed.

There are two types of rotary machine: one of which prints single sheets (on one side), and the other where the paper is fed from a reel, printed on both sides and folded before delivery.

The inking mechanism on a rotary consists of an ink duct, a distributing drum, and a series of rollers to carry the ink from the drum to the rollers which ink the plates. The speed of a sheet-fed rotary being beyond the capacity of hand-feeding, makes automatic feeding an essential. On the reel-fed, or, as it is sometimes called, the web-fed perfecting rotary press, the travel of the paper through the machine and the folding of the pages are entirely automatic. Both sheet-fed and reel-fed rotaries are used for fine colour printing from half-tone plates.

The most effective multi-colour printing machines are those which consist of a large impression cylinder with four separate plate cylinders each with its own mechanism for inking. The plate cylinders are half the circumference of the impression cylinders and two sheets may be printed (on one side) at each revolution of the cylinder. The sheet is taken from the feed board by means of grippers attached to the cylinder, is carried under the first plate cylinder (where a yellow impression is printed on the sheet), then under the second set of plates (where a red impression is made on the top of the yellow impression), the sheet passing on to the two remaining plate cylinders (where blue and black impressions respectively are superimposed on the top of the previous colours), and the sheet is delivered with the picture completed in its full range of colours and tints. Electrotype plates are used for printing, these having to be curved to suit the circumference of the plate cylinders, it being impossible to use "overlays" on the impression cylinder. The impressions from the four sets of plates take place on the same section of the cylinder. As each set of plates requires a different "make ready," the plates are "bumped" (the surface graded in height according to the tones in the plate).

In America this is accomplished by the McKee process, in which the plate is "made ready" and the make-ready impressed into its back through hydraulic pressure. The back of the plate is then shaved to proper thickness and the plate curved to fit the rotary cylinder.

The rapid printing of the McKee four-colour machines made it necessary to devise a method for quickly drying the sheets to prevent offset or smudge. This was at first accomplished by interleaving the freshly printed sheets with specially prepared manilla paper. The device known as travelling offset prevents offsetting upon the impression cylinders of wet perfecting rotaries. It winds and unwinds (working backward and forward) around a reel which engages the second impression cylinder. This has given way to other methods, such as the spraying of a coat of powdered paraffin over the printed surface, so thin as to be imperceptible, but sufficient to prevent offsetting of the sheets.

Special inks are required for printing wet colours on the top of each other. The results cannot be said to equal those obtained when sufficient time is allowed for each colour to "set" before printing the following colour.

In newspaper production the reel-fed rotary has been brought to a high degree of efficiency. Although a newspaper machine is of great size and seems highly complicated, really it is simple. It comprises a number of units, each of which "perfects" a number of pages. If the pages exceed the number of plates which can be printed on a single unit, another unit or units can be linked up together, and the printed "webs" come to a point in proper sequence where they are folded and cut before delivery.

There is usually a blank space left on one or more pages of

a newspaper for the purpose of publishing news which has arrived after the paper has gone to press. This late news is printed into the blank spaces by a contrivance called a "fudge box" which is circular in form and into which are secured linotype slugs. The "fudge" is fastened on to an auxiliary cylinder equipped with inking mechanism. This works in unison with one of the main impression cylinders and as the paper is printed an impression of the lines in the fudge box is made in the space left for the purpose. The "edition seals" and lines printed in colour in newspapers are produced by the same means.

There is in practice a very wide limit in the planning of a newspaper machine. Units can be arranged in a straight line or placed one on top of the other. The capacity is determined by the number of folders which it is possible to fit on the machine. Each of these can turn out 45,000 folded copies per hour. Not infrequently the paper is run through the machine at an approximate rate of 54 m. per hour and it is possible to join up new reels and change the fudge box without stopping the machine. (*See* BOOK; PRINTING TYPE; COLOUR PRINTING; PHOTO-ENGRAVING; also LITHOGRAPHY.)

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PRINTING TYPE. At the time of the invention of printing, European scripts were changing. The ideas of the artistic and literary movement of the 15th century, known as the Renaissance, were drawn from the classics of old Rome, and as many of the texts were preserved in the beautiful caroline hand, scribes learnt to copy the letters as well as the text of the original. The resulting "neo-caroline" hand was probably first seen at Florence, where Niccolò Niccoli, a celebrated humanist, directed a school of copyists about 1425 and trained scribes to write a very neat, round letter, which was in fact a revised and, in certain respects, more beautiful version of the old 9th century hand. The new letter won a great success in literary circles, and by the middle of the 15th century a company of scholars, artists and nobles, passionately interested in the culture of pre-Christian civilization, enthusiastically practised it. They thought the old heavy black-letter most objectionable, and invented for it the nickname "gothic" (*i.e.,* barbarous) by which it has been known ever since. Thus the neo-caroline letter, or "littera antiqua" as it was then called, became accepted for secular manuscripts. Moreover, just as there had been for centuries a formal and an informal "gothic," the modern-antique writing was upright for formal text and sloping for informal current use. These are the originals of our so-called "roman" and "italic" types.

By the time of Gutenberg, therefore, the scripts in use in Europe consisted of the old so-called "gothic," and the new so-called "humanistic." The former showed national peculiarities according as it was handled by German, French or English scribes, but the "humanistic" was for some time confined to Italy. This, then, was the calligraphic situation when in the north men were straining their ingenuity to invent some form of multiplying texts by means of impressions from movable types.

Leaving it for specialists to determine the priority of invention as between the Dutch "Costeriana" and productions of Johann Gutenberg of Mainz, we may note that printing type began with that pointed black-letter design to which the scribes, secular and monastic, had long accustomed the librarians and readers of Europe. There can be no doubt that Gutenberg's pointed text is a magnificent type, not perhaps as fine as others of later date, but well cut, harmonious and very pleasantly conscious of its discipline and integrity. His informal Italianate bookish type (of the Indulgence) is also successful.

The Churches and the Printer.—The current demand for ecclesiastical works produced a number of exceedingly handsome founts of formal pointed text. Inevitably the Church's permanent need of books made her the early printer's best customer, and the finest types were cut for use in mass-books, psalters, breviaries, rituals, etc.

The uncompromising joints of typical German black-letter are rounded in early Italian printing, and angles give place to curves. Rounded scripts were characteristic of Italian book-making in the two centuries preceding the introduction of printing into Italy by Conrad Sweynheim and Arnold Pannartz at the Benedictine monastery of Subiaco near Rome in 1464. These two Germans used a type based upon the common round bookhand neither "gothic" nor "humanistic." Other Germans migrated south, coming through what is now the Austrian Tyrol, followed the road to Venice, and printed in "gothic" letters of the rounded kind. Four years after the printing at Subiaco of Sweynheim and Pannartz' *Lactantius* in *fere humanistica* type there was cut in Venice a letter which may positively be described as a pure humanistic letter—or, in printers' language, a pure *roman.* The design was first used in Italian printing in 1469 by two Germans who had come to Venice from Speier in the Rhineland, and is so well made that it presents a modern appearance to our eyes. In fact, with Johann and Wendelin da Spira we come into contact with the modern book, although the title-page and other preliminaries have yet to develop. It must be noted, however, that a good roman was still earlier used in Germany by Adolph Rusch of Strassburg, in a *Durandus* issued not later than 1464. Had this example been followed, Germany might have followed up the "gothic" triumphs of Gutenberg, Sensenschmidt and Stuchs with no less notable roman founts. But Rusch's isolated and barren achievement lay outside that main line of development which, beginning with the da Spira fount, held within it the promise of a brilliant future which was to place Venice above any other printing centre. The da Spira letter was surpassed the next year by the design of the Frenchman, Nicholas Jenson. This is an even more distinguished type, so elegant and readable that the authorities in typography have pronounced it to be the most perfect type ever cut. Jenson also used more than one gothic letter whose technique rivalled that of his famous roman, and which found great contemporary favour. His roman was much copied in Italy and 25 years passed before the appearance of any rival which might be regarded as having the slightest right to dispute its primacy.

The Aldine Press, 1495.—But in 1495 there was founded in Venice a press whose reputation for scholarship was destined to become unique. Aldus Manutius Romanus was both a scholar and a business man, but it does not appear that he took great interest in the technical problems of printing. His passion was for pure scholarship, and he devoted himself to the printing of inedited Greek and Latin texts. Some diversity of opinion exists with regard to Aldus's merit as a typographer. The late Robert Proctor says roundly that his founts "whether Greek, Roman or Italic are in each case lamentably devoid of any beauty of form other than that conferred on them by good cutting." Proctor was upset by Aldus's patronage of cursive Greek hands as type-models, so full of unnecessary flourishes and ligatures; and the unfortunate effect of Aldus's prestige was to perpetuate a sloped Greek calligraphic lower-case. But it is more than doubtful whether the romans of Aldus can reasonably be lumped in with the Greek and Italic as equally bad in design. The contention that such beauty

as they have is that conferred upon them by good cutting is also a little wide of the mark, in view of the fact that none of the Aldine types possesses anything like the technical excellence of Jenson's. It may also be suggested that the design of one of the Aldine romans equals Jenson's in point of design, but a liberally linked page of Jenson's shows that the capitals are unnecessarily assortive.

The press began with an *Erotemata* which Constantinus Lascaris brought out in March, 1495, the capitals of which fount reappear later in the year in conjunction with a lower-case which is of prime historical importance. The complete fount first appears as a short tract, *De Aetna,* by one of the leading Italian humanists, Pietro Bembo, afterwards Cardinal. The *Erotemata* capitals, though well designed, are too roughly cut to combine agreeably with the very beautiful lower-case letters. The type of the *De Aetna* represents, as it were, only a "first state." Aldus retained it for the *Diario* of Alexander Benedictus in 1496. In June of the next year he issued the work of a local physician, Nicholaus Leonicenus, entitled *De Epidemia,* which was set in a letter of similar design but on a smaller body. In the famous *Hypnerotomachia Poliphili* the same face appears in a lighter, more graceful and more harmonious cutting. It is not claimed that the final form of this is perfect: at least the "L" is inferior in design to that of Jenson, and the "G" almost ugly, but the type does present a very distinguished appearance, which would have gained had a first-class pressman been entrusted with the printing.

The type of the *Polifilo* made another appearance in the next year (1500) in the preliminaries of a folio Politian of 500 or more pages composed in the type of the Bembo. In the preliminaries referred to, a commendatory epistle is composed in the "Bembo" lower-case, joined to a new and much larger series of capitals. The fact seems to be—not exactly as Proctor would have it, that Aldus was a "man of phenomenal bad taste for his time"—but that his interest was rather less in typography than in scholarship. Before passing to the Aldine Italic, we may point out that the type of Bembo's *De Aetna* is the origin of that style of letter known to English printers as "old face." We have only to compare the founts of Jenson, Aldus, Garamond and Caslon to see that the forms of our present letters derive immediately from Aldus through Garamond, and that the latter did not copy from Jenson.

Italic.—In 1500, Aldus' office was cutting the sloping character described by himself as *Chancery,* and which we have grown accustomed to call *italic.* It is not a very satisfactory letter from the point of view of design, or indeed in its suitability as type; no fewer than 68 ligatures have been counted in the early volumes of the library of classics for which Aldus specified this type. It was engraved by the same Francesco (Griffi) da Bologna who cut the type of the *De Aetna* and the *Polifilo.* Owing to the warm welcome that greeted the low prices and novelty of the Aldine classics, the type in which they were set made an undeserved reputation, with the result that, though Aldus did what he could to protect it, the design was copied in many other Italian printing centres and in England, the Netherlands and France. Its artistic merit is very slight, but it "takes in" extremely economically, a supreme quality in the series for which Aldus employed it. The calligraphic deficiencies of the Aldine italic are apparent when it is placed side by side with that designed in Rome by one of the scribes employed in the Vatican Chancery, Ludovico Arrighi, alias Vicentino, and cut by the goldsmith, Bartholomeo dei Rotelli of Perugia. The fame of the Aldine italic arises from priority in time, but Arrighi's is infinitely better in design, more graceful, more legible, and more permanent in its influence. The form of italic which we employ as a companion to our "old-faces," descends from Arrighi. The extent of the use of "Italic" types cut on the Arrighi model in Italy, prepares us for its utilization by the greatest printers of Paris, Robert Estienne and Simon de Colines. A comparison of Arrighi's italic with that of Colines' shows that the French fount is directly indebted to Arrighi's design.

"Old Face."—Garamond, obviously had before him the *De Aetna* or the *Polifilo* as models for his roman, and Arrighi for the italic; and craftsmen of his generation merged these two originally independent founts into two mutually dependent constituents. Thus for France and England *roman* and *italic* were twin halves of one fount. These French designs are the originals of our "old faces"—the design which came into English printing with John Day, and which, by the medium of Voskens, van Dyck, and Caslon, is characteristic of our work until the coming of Baskerville and the moderns. Whether or not the first "Garamond" letter was designed by himself or in association with Geoffrey Tory cannot be said, but it was certainly sponsored by very high authority. The fine folio Bible of Robert Estienne (1532), which must have taken some three or four years in going through the press, contains probably the finest use of this letter.

The "Garamond" type steadily acquired influence, and in a short time actively affected the typography of Venice and Florence. Indeed, by the middle of the 16th century the Garamond letter had succeeded in deposing the Venetian design which, as we have seen, was originated by the da Spiras and Jenson. It is not easy to account for the progress of the Garamond design in Italy. Guillaume Le Bé, Garamond's pupil, was in Venice between 1546 and 1550, and doubtless supplied a certain quantity of French type to Venetian printers; but it remains curious that the merits of the Jenson design should have been overlooked in favour of the work of a newcomer. It was another Frenchman who cut punches for a new printing office attached to the Holy See: Robert Granjon went to Rome at the invitation of Gregory XIII., and remained there several years, cutting numerous orientals and romans on the Garamond model. The italic is generally of the flowing Arrighi design. Garamond made one experiment, and perhaps more, with types which deliberately reproduced the Aldine italic, and himself printed three or four books about 1545 in this face. It would appear that the taste of the day approved his effort.

Italic, in fact, from this time, tends to be reserved for preliminary matter, citation and emphasis. It should be observed, too, that by 1540 the upper case of italic founts is sloped, whereas Arrighi's and Estienne's texts were invariably worked with upright capitals.

From the middle until the end of the 16th century there was little change in type-design. The great successes in Italian printing were won between 1470 and 1520, and in French between 1525 and 1550. Christophe Plantin of Antwerp, working with types of Garamond and Granjon, produced a number of handsome works; and, though the artistry of this printer has perhaps been overrated, his Polyglot Bible is a notable achievement alike in scholarship and in typography. He contributed nothing to roman or italic type design. The range of type varieties characteristic of incunabula narrowed with the opening of the 16th century, typographical supremacy passed to Paris, and the Garamond design was stabilized for 150 years. The 17th century did little beyond reproducing these and Estienne's types, generally with some loss of beauty—an exception being the types of Christopher van Dyck, a freelance punch-cutter in Amsterdam who worked for several foundries, cutting types certainly less important to the historian than those of Garamond, but obviously more beautiful —not the only instance of types designed after the model of a historic letter being superior in design to their prototype. Thus, Garamond's design was improved upon, first by Robert Granjon, and next by Christopher van Dyck.

The reputation of Dutch types is intimately connected with van Dyck, largely because his types were used by the Elzevirs. The editions of the famous Leyden firm have not the interest of the work of the preceding century, but their types are undeniably finer in design and technique. Other engravers, such as Bartholomew Voskens and his brother Dirck, contributed to the renown of Dutch typefounding, while English craftsmanship, owing to repressive legislation scarcely existed. Books were commended by advertising that they were printed in Dutch letter. Moxon thought van Dyck's the best of all, and made a fount of similar design. When in 1660 Bishop Fell took in hand the task of procuring types for the use of the press of Oxford university he immediately turned to Holland. His agent, Thomas Marshall, procured punches and matrices from the Voskens, but unfortunately

he secured none of van Dyck's. The 18th century brings us to the types called "modern" of which Bodoni is the most notable protagonist. Giambattista Bodoni of Parma was an innovator, but he did not, as often assumed, create the "modern" serif, for the same thin, flat serif is found in codices written 300 years before Bodoni was born. Some of the letters modelled upon manuscripts of this time—those of da Lignamine—themselves possess flat, unbracketed serifs, though they are heavier in weight. The thin, flat serif is to be seen in the copybooks of several professional Venetian writing-masters; for instance, the *lettera antiqua tonda,* drawn by G. A. Tagliente, exhibits it; as do other Italian and French writing-books which we need not specify. The "modern" serif is, indeed, only a forgotten renaissance trick contemporary with the short, stubby and bracketed serif which we find in the Bembo type.

Romain du Roi.—When that most important printing institution, the Imprimerie Royale, was established in the Louvre by Richelieu in 1640, its sole types were cuttings and re-cuttings of the "old-face" originals of Garamond, Le Bé, and Granjon. The next sovereign, however, Louis XIV., approved the creation of an entirely new set of roman and italic types to be absolutely reserved to the office of the Louvre. The project was sanctioned in 1692, and a commission of experts was appointed by the Académie Royale des Sciences to study the formation of perfect roman letter. The chairman of the commission, one Jaugeon, embodied the findings in a bulky report, and a set of elaborate geometric designs in which the traditional roman forms were once more disciplined by rule and compass. Jaugeon's letters were drawn upon a field subdivided into no fewer than 2,304 small squares. The royal road to a perfect roman letter was in theory a mathematical one, but when Philippe Grandjean came to cut the punches, he elected to work with a considerable degree of independence, preferring the guidance of his own trained eye. The *romain du roi Louis XIV.,* as the new letter was called, when compared with Garamond's roman shows a sharper contrast between its thick and thin strokes, it is more regular, and better in its justification. The most important general differences are in respect to a certain condensation of form and the novelty of serif. For the first time the thin, flat, unbracketed variety appears in a type-form. In the top of the roman lower-case 'b', 'd', 'i', 'j', 'k', 'l', and 'h' the new feature extended both sides.

An interesting feature of Grandjean's italic is his departure from the ancient old-face form of the lower-case 'b' which is derived, of course, from that modification of roman square capital writing known as uncial. It is, perhaps, not so generally realized that the hooped forms of Garamond's and Caslon's italic lower-case "h" go back to a fourth century original, while the other form is no older than Louis XIV.'s time.

The *romain du roi* inevitably exercised a considerable influence. The enterprise of trade type-founders, nevertheless, was obstructed by a decree forbidding any counterfeiting. Fournier-le-jeune's way out was to narrow the proportions of his letter and slightly to modify the serifs. His italic modifications can be seen in the fine oblong folio specimen published 1742. Though the crown monopoly of the *romain du roi* was safeguarded by the enactment of penalties against its reproduction by trade type-founders, the advantage of a narrow-bodied letter was quickly observed, and Grandjean's methods were followed by Dutch founders.

J. M. Fleischman cut a new series for the Enschedés at Haarlem, 1730–68; some 20 of his alphabets were of an elongated character, with thin hair lines and thin serifs. Fournier copied these, as he admits in his description "Goût Hollandois." When Bodoni commenced to print he used these and other of Fournier's letters and ornaments. Later he made copies of his own, and later still cut new varieties in which the contrast between the thicks and thins was accentuated. There is much to be learnt from Bodoni's careful presswork and sense of style in typography, and his influence was rightly considerable on the continent and in England towards the end of the 18th century. At the same time, François Ambroise Didot, the founder of the great dynasty of printers, publishers and paper-makers, was experimenting with types cut in the style of Grandjean and of Louis Luce, cutter at the Imprimerie Royale of the first of all condensed letters.

England, slow in following new fashions, was using the founts of Caslon and Baskerville. The types which William Caslon I. cut between 1720 and 1726 were, and are, very fine renderings of the "old-face" design which came down from Aldus. The sizes—english, pica and brevier—are brilliantly cut. Certain of the larger bodies cut by William Caslon II. are at least agreeable, though every size above two-line pica contains more than one ill-formed sort. Caslon undeniably made a very handsome letter out of the Dutch models, which he manifestly had before him; but credit for initiative must go to John Baskerville—his roman is an open, legible and expressive letter possessing a great deal of individuality though the wiry, thin and pinched italic which he drew for companion use is less successful.

The refinement and precision of the Baskerville type were not much valued in England during his lifetime. Bodoni and the Didots, however, admired his presswork and paper; later the influence of Baskerville's forms was considerable in Britain, as witness the types of Fry and Wilson. One of the Caslons, also, who split away from the parent firm, made a letter similar to Baskerville's. These types are round and, though sharing sharp contrasts as between their thicks and thins, remain in the "old-face" tradition. Nevertheless, their nicety and precision of cut reflect the "modern" invention of Grandjean. In making a comparison of the merits of Caslon and Baskerville, perhaps we may summarize by saying that while Baskerville shows greater originality and personality in design than does Caslon, the latter was undoubtedly a more expert engraver. Baskerville's "modernity" lay in his printing methods rather than in his typefounding technique.

The first of the Didots who took typography as a career was François Ambroise Didot (1730–1804) who directed the French national printing office for a time, and to whom the continent of Europe owes its authoritative point system. His light-faces were engraved by the punch-cutter Waflard and take the original design of Grandjean a step farther than Fournier or Bodoni. His sons and their successors drew and redrew upon the same models, first increasing their brittle and attenuated aspect, next fattening and condensing them.

English Designs.—English modern-faces are to be early found in the books of William Bulmer (1758–1830) of the Shakespeare Press. Here is to be found a close-set, narrow-bodied letter with fine hair-lines. It possesses the curly-tailed capital "R" which never occurs in the genuine old-faces and which Grandjean, Baskerville and Bodoni preferred. These types were well cut by William Martin, and after Bulmer came many other modern-faces, all possessing extremely thin hair-lines. Ever since the days of Caxton, England had depended upon foreign types, Netherlandish or French. The first original English design of any kind to make an impression abroad was Thorne's "fat grotesque"—produced during 1800–03. It was a distinct novelty, and was taken up with great enthusiasm in France, Germany and Holland. The Imprimerie Nationale itself in 1840 commissioned Thorne to cut a like face. Bodoni fattened his large sizes, and the Paris trade was supplied with a *gras* instead of a *maigre* Didot.

After Thorne (1803) came a heterogeneous swarm of fat and lean faces. The unexampled successes of English industrialism staggered the world, and the continent, while cursing British "hypocrisy," bought British machines and copied British types. Consequently from 1820 to 1860 all printing was in a sorry condition, though, by way of exception, the London publisher, William Pickering, and his printers, the Whittinghams, produced some comely books in "modern" and "old-face" types.

But the return to decent standards was slow. Abroad, the work of a scholar-printer and publisher at Lyons is to be noted. In 1846 Louis Perrin cut the first types designed since the Renaissance upon the model of Latin inscriptions—plentiful in an ancient Roman foundation, like Lyons (Lugdunum). The lower-case roman resembles Caslon's, but the italic, deriving from Grandjean and Fournier, gains elegance by reason of Perrin's inclusion of swash capitals. Perrin's handsome printing in these *Caractères Augus-*

taux, gave the types an important influence in France. They were copied by Beaudoire (Paris), who called them by the arbitrary and confusing name "Elzevir," since applied by continental convention to all "old-faces." Beaudoire's capitals, imported by the Chiswick Press in the 'sixties while that illustrious establishment was managed by Whittingham and Wilkins, are to-day in use at their printing works in Tooks Court under the name "Lyons capitals," a curious survival unfair to Perrin.

William Morris.—The Oxford Movement in the Church of England, and Scott's novels, mediaevalism and the pre-Raphaelites, opened the way for William Morris, poet and craftsman. He had secured the printing of his *Roots of the Mountains* (1889) in an old Chiswick Press type cut by William Howard in 1858, but he now created an entirely new formula of the printed book. 1891 saw the first Kelmscott book, *The Story of the Glittering Plain.* Morris, as a typographer at least, was a mediaevalist; he admired the early printing and, naturally, his types were archaistic; he thought Jenson's the finest roman and drew a fount therefrom, the *Golden* type. The *Troy* type and the *Chaucer* came later. There followed similar experiments by others: Mr. Charles Ricketts made the *Vale* with its individualistic 'g', 'e', 'b', 'y', and obtrusive capitals. The *King's* fount, also cut for the Vale Press, is a strongly personal design. Mr. Ashbee's *Endeavour* (1901) is perhaps the most extreme of these idiosyncratic founts. Mr. Lucien Pissaro's *Brook* type is less eccentric than sophisticated, but serves to throw into welcome relief the elegance and simplicity of the *Doves* type designed on the basis of Jenson by Cobden-Sanderson and Emery Walker. Another fine letter, but too closely following an ancient model, is Mr. C. H. St. John Hornby's *Ashendene* type (1902) which reproduces the *fere-humanistica* of Sweynheim and Pannartz (Rome, 1465). Italian models were also followed by Herbert P. Horne, who cut three types between 1905 and 1909. The first, the *Montallegro,* was cut for Mr. Updike and first used in the *Life of Michelangelo Buonarroti* by Condivi (1905). The *Florence* type, cut for Chatto and Windus, came in 1909, as also the *Riccardi* for the Medici Society. All three types are agreeable and restful in composition. The capitals are better in design than the lower-case. In all the latter, the poor forms are the 'a', 'e', 'y', always difficult letters to draw. Not one of these experimenters made an italic, and an unbreakably conservative mood seems to have settled upon the English private presses after the insurgent individualism of the *Vale* and *Endeavour* types.

In the United States a similar reaction is to be noticed. Mr. Bruce Rogers, who made a new type for an edition of Montaigne's "Essays" published by Houghton, Mifflin of Boston (1903) succeeded in constructing a readable and dignified letter, though even here an unhappy lower-case 'e' may be detected. The capital 'R' varies from the Jenson model (accepted as the basis of the fount), and not for the better. There can be no two opinions, however, about the same artist's *Centaur* (1916), again based upon Jenson but improving at many points upon the Venetian model, notably in the capital 'M.'

German printing, mean and even horrible since the extinction of the Frankfurt school headed by Egenolff, improved with Unger. His quasi-Didot *frakturs,* however, depended for their effect upon better presswork than they ever received. The roman (antiqua) acquired influence when used by Karl Tauchnitz in 1825. Ever since then the *fraktur* and *schwabacher* types have been slowly undermined by the *antiqua* and *kursiv* until at the present time there is used perhaps more roman than *fraktur.* A number of the modern German roman types are excessively personal—witness the fount designed by the architect Eckmann for the Klingspor foundry. It is a fair example of the kind of type which the intelligent German put out before the introduction to Germany in 1905 of the teaching of the English calligrapher, Edward Johnston. The fine school of calligraphers which arose from this source greatly influenced all those crafts in which lettering plays any part; and the German typefounders, led by the house of Klingspor, quickly applied the skill of several masters of the new calligraphy to the designing of new roman and gothic founts. Peter Behrens, Rudolf Koch and F. H. Ehmcke are perhaps the best-known of these artists. Their types have raised the typography of German private presses from a low to a very high place in the esteem of collectors; but for the bulk of German printed books, types drawn from older English and French models prevail, varied by the occasional use of the more conservative of the new founts. Unlike ourselves, the Germans less strenuously resist experiment in books: it is perhaps for this reason that the English typefounders have ignored the new calligraphical movement. Certain it is that the English dislike novelty in typography, and many years must elapse before any British design influences the continent of Europe. It was not always so. About 1802 certain Scottish printers originated the crisply cut modern face now known by the name of *Scotch Roman.* The type remains in constant employment in Great Britain, and to an even greater extent in the United States. In 1850 Miller and Richard evolved their *Revived old-style,* which is not a revival, but an insipid original design. It found immediate favour in England, and is widely used to-day at home, in Scandinavia, Germany and the United States. These two Scottish faces represent the most popular designs in the English-speaking world. They are book types. (S. Mo.)

Advertising Type.—The rise of advertising gave a new opportunity to type designers, and it was to be expected that America, the home of advertising, would take full advantage of it. The most widely used face of the first quarter of the 20th century was the *Cheltenham* designed by Goodhue and Kimball in 1902. With its success, initiative in type design passed to the United States, and with the corps of fine designs made by the exceptionally able American designer, Mr. F. W. Goudy, and the justly appreciated *Cloister* (Jenson) and *Garamond* of the American Typefounders' Company, the English foundries become of slight consequence. The World War effectively postponed the production of new English designs and the following years witnessed advertising types imported in the main from America. Germany also led in this department for several years, and German typefounders, profiting by the liveliness of the intelligence of their designers, concentrated upon the production of grotesque and decorative advertising and publicity faces.

In America the Mergenthaler Linotype company, the Monotype company, the Intertype corporation, the Ludlow company and the various foundries have issued a profusion of type faces for advertising purposes, many of true artistic merit. Fashion in types is almost as cyclical as that in women's dress. For several years, especially after 1930, the various sans-serif faces (*Kabel, Vogue, Futura, Tempo,* etc.) were much in demand for their simplicity and modernistic appearance. Later *Girder* and *Stymie,* faces with pronounced serifs, rigidly straight, and with no variation in shading, came into prominence for both display and text, as did the script types such as *Trafton.* The Gothic faces and *Ultra Bodoni,* a heavy type based somewhat on the original *Bodoni,* are perennial favourites with advertisers. Soon or late, however, most designers of advertising return to the historic founts or modifications of them, especially *Caslon, Garamond, Baskerville, Scotch Roman,* and *Bodoni.* Among faces of late design are *Caledonia* (Dwiggins) and *Fairfield* (Ruzicka). *See* also TYPOGRAPHY. (X.)

BIBLIOGRAPHY.—Specimens of types in current use will be found in the catalogues issued by the typefounders and type-setting machine makers; specimens of superseded founts are conveniently given in the works of Updike and De Vinne. The following works should also be consulted: T. L. De Vinne, *Plain Printing Types* (N.Y., 1900); Ch. Enschedé, *Fonderies de Caractères dans les Pays-Bas* (Haarlem, 1908); P. S. Fournier, *Manuel Typographique* (2 vols., Paris, 1764–66); Edward Rowe Mores, *Dissertation upon Eng. Typographical Founders and Founderies* (1778; new ed., D. B. Updike, 1924); Stanley Morison, *On Type Faces* (1923); Talbot Baines Reed, *Hist. of the Old Eng. Letter-Founders* (1887; new ed., A. E. Johnson and Stanley Morison, 2 vols., 1929); Albrecht Seeman, *Handbuch der Schriftarten* (Leipzig, 1926); D. B. Updike, *Printing Types* (2 vols., Cambridge, U.S.A., 1922); E. Wetzig, *Ausgewahlte Druckschriften* (Leipzig, 1920); H. H. Sparling, *The Kelmscott Press and William Morris* (1924). (S. Mo.)

HAND-PRESSES USED IN GRAPHIC ARTS

History.—In the beginning the only machines used by the graphic arts were hand-presses. These machines were used before either steam or electricity were thought of as a means of providing power. Of course, in modern times, the large machines

used could not be operated by human power so it was necessary to invent something that was more powerful than the hand of man. The presses driven by steam and electricity were not expected to improve the quality of the work produced—nor have they improved it—but they were made to increase the quantity; hence, the power press.

When Alois Senefelder (1771–1834) invented lithography about the end of the 18th century, he was compelled to build some kind of a machine that would enable him to reproduce on paper what he had engraved or written on the limestone which he had used as a base for his work of printing music. He proceeded to make a machine which was called the pole-and-beam press, which, as the name indicates, was made of poles and beams. This first press that Senefelder made is said to have been completed during the year 1796. The pressure was applied by the workman standing on a treadle, his weight supplying the needed pressure—and the larger the pressman the better the impression he produced.

The pole-and-beam press was not an unqualified success and was soon discarded by the lithographic inventor and an entirely different machine was built in 1797. The new machine was called the "star press" and was patented in 1801, and, while very crude, was used by Senefelder for a number of years. Some of the parts of this press are followed in some of the hand-presses in use to-day. It was an improvement on the pole-and-beam press because of the use of a much larger stone. For many years this press was the "standard" model in the lithographing business.

There is no record of a lithographic hand-press being built between the years 1798 and 1820, but during the last-named year a machine was turned out in England called "the English hand-press." This press and other similar ones were used until the power machines came into use in 1865. After the introduction of this power-press, which was called the "steam press," the hand-press was practically discarded except for pulling proofs and working off extremely short runs. While the "steam press" has been adopted all over the world as the standard lithographic machine, it is still maintained by many lithographers that better and more perfect work can be turned out by the hand-press.

The pressure that prints the image from the stone to the paper by the hand-press is entirely different from the pressure of any other printing machine in use. It is a scraping motion. After the paper is placed on the stone a piece of hard wood is drawn across the form to be printed, with sufficient pressure to make the paper take the ink. All other lithographic presses and type presses print by pressing down on the paper by some direct means.

About 1825 a hand-press was made of iron and its operation was entirely different from any previous ones. It had a roller made of brass and operated by a handle which caused a travelling carriage, on which the stone was placed, to run under a frame to which was attached the scraper. The pressure was regulated from beneath the carriage, which was forced up by a screw to give the correct amount of impression when the scraper was applied. After the print was made the pressure was released and the carriage drawn back by hand, thus giving the operation a saving of time and greatly increasing the output.

In 1846 there was constructed in Ireland a hand-press known as the Macbrair press. It was a great improvement on the English machine mentioned before, and did good work at what was considered in those days great speed. One of these machines was brought to America and a good-sized family was supported with it for several years. The largest edition worked on this machine ran about 500 copies in one colour. This press is now said to be in a museum on exhibition as a curiosity.

In reproducing the image to be printed by any make of lithographic hand-press the principle involved is the same—that of the scraper being forced across the plate. This scraper, no matter what kind of wood it is made from, must be perfectly straight and the face, which is V-shaped, must be carefully rounded so that it will not sag or bulge when pressure is applied. The bed of the hand-press, upon which the stone that is to be printed from is placed, must be level and neither concaved nor convexed for, while the stone is not supposed to bend, a convexed bed will cause the stone to balance and move slightly with every impression, thus making it impossible to register impressions on it; while a concaved bed will wear down the corners of the stone and put it out of plumb. More work has been spoiled by presses with uneven beds than in almost any other way.

In 1905 a new kind of lithographic press was invented in the United States called the "offset press." This was a steam-driven press, but it called for a hand-press to make the transfers to be used, and make them quickly and accurately. Several inventors started to make an offset hand-press. The first one offered resembled a washing machine wringer. The proof was pulled from a stone, laid on another piece of transfer paper, and the two were run through this wringer-like machine. Some work was turned out this way, but as there were no guides to feed the sheets to, it was next to impossible to make a sheet register properly, so this proposition was abandoned and other designs taken up. Finally, an offset hand-press equipped with a large rubber-covered cylinder was offered. This same principle has lasted to the present day. This large rubber cylinder travels over the stone or plate containing the image from which it takes an impression, and then it goes on to a bed upon which is laid the paper. As the cylinder goes over the paper the image is transferred from the rubber blanket to the paper and the work of printing is done, so far as the sheet is concerned.

It occasionally happens that one wishes to pull a transfer of a piece of copper plate engraved work to use on a lithographic hand-press. From a purely mechanical point of view the construction of the copper plate press is an exceedingly simple matter. Its purpose is to produce a heavy and uniform pressure on the plate during the operation. To make a lithographic transfer from a copper plate engraving one should lay the plate face upward on the bed of the press, lay the paper on it and pass it between the two iron cylinders.

The material used in making lithographic transfers from copper plate engravings consists of transfer ink, whiting, transfer paper and a good supply of clean rags. The copper plate is first heated, but not enough to burn the ink; then the transfer ink is forced into the engraved parts until every part is fully charged. In cleaning the plate it should be carefully rubbed with a rag charged with whiting until all the surplus ink is removed. The transfer paper to be used is dampened—or commercial transfer paper may be used which is made to retain dampness—and the plate and paper used before the plate gets cold. Transfers made in this way may be used in lithographing on a hand-press.

(H. W. C. Br.)

PRIOR, MATTHEW (1664–1721), English poet and diplomatist, was the son of a Nonconformist joiner at Wimborne Minster, East Dorset, and was born on July 21, 1664. His father moved to London, and sent him to Westminster, where he was enabled by the earl of Dorset to continue his education after his father's death. At Westminster he made friends with Charles Montagu, afterwards earl of Halifax. It was to avoid being separated from Montagu and his brother James that Prior accepted, against his patron's wish, a scholarship recently founded at St. John's college. He took his B.A. degree in 1686, and two years later became a fellow. In collaboration with Montagu he wrote in 1687 the *City Mouse and Country Mouse*, in ridicule of Dryden's *Hind and Panther*. The satire made the fortune of both authors. Montagu was promoted at once, and Prior three years later was gazetted secretary to the embassy at The Hague. After four years of this employment he was appointed one of the gentlemen of the king's bedchamber. In 1697 he was secretary to the plenipotentiaries who concluded the Peace of Ryswick, and in 1698 he was sent to Paris in attendance on the English ambassador. At this period Prior could say with good reason that "he had commonly business enough upon his hands, and was only a poet by accident." His occasional poems during this period include an elegy on Queen Mary in 1695; a satirical version of Boileau's *Ode sur le prise de Namur* (1695); some lines on William's escape from assassination in 1696; and *The Secretary*.

After his return from France Prior became under-secretary of state and succeeded Locke as a commissioner of trade. In 1701

he sat in parliament for East Grinstead. He had certainly been in William's confidence with regard to the Partition Treaty; but when Somers, Orford and Halifax were impeached for their share in it he voted on the Tory side, and immediately on Anne's accession he definitely allied himself with Harley and St. John. After the return of the Tories to power in 1710, Prior was again employed, and until Anne's death he shared in all negotiations with the French court, sometimes as secret agent, sometimes in an equivocal position as ambassador's companion, sometimes as fully accredited but very unpunctually paid ambassador. His share in negotiating the treaty of Utrecht, of which he is said to have disapproved personally, led to its popular nickname of "Matt's Peace." When the queen died and the Whigs regained power he was impeached by Sir Robert Walpole and kept in close custody for two years (1715–1717). In 1709 he had already published a collection of verse. During this imprisonment, maintaining his cheerful philosophy, he wrote his longest humorous poem, *Alma; or, The Progress of the Mind.* This, with his most ambitious work, *Solomon,* and other *Poems on several Occasions,* was published by subscription in 1718. Prior died at Wimpole, Cambridgeshire, a seat of the earl of Oxford, on Sept. 18, 1721, and was buried in Westminster abbey, where his monument may be seen in Poet's Corner. *A History of his Own Time* was issued by J. Bancks in 1740. The book pretended to be derived from Prior's papers, but it is doubtful how far it is authentic.

BIBLIOGRAPHY.—See *The Writings of Matthew Prior,* 2 vol. (ed. A. R. Waller, 1905–07); *The Poetical Works of Matthew Prior,* 2 vol. (ed. R. B. Johnson, 1892); *Selected Poems* (ed. Austin Dobson, 1889); *The Shorter Poems of Matthew Prior* (ed. F. L. Bickley, 1923); also F. L. Bickley, *The Life of Matthew Prior* (1914); and L. G. W. Legg, *Matthew Prior: a study of his public career and correspondence* (1921).

PRIOR, a title applied generally to certain monastic superiors, but also in the middle ages to other persons in authority. Under the Roman Empire the word *prior* is found signifying "ancestor." In the early middle ages it was commonly applied to secular officials and magistrates, and it remained all through the middle ages as the title of certain officials in the Italian city states.

In the Rule of St. Benedict and other early rules the titles *praepositus* and *praelatus* (*see* PRELATE) are generally used, but *prior* is also found signifying in a general way the superiors and elders in a monastery; afterwards the title prior (or *claustral* prior) was restricted to the abbot's vicegerent, who was generally charged with the details of the discipline of the monastery. With the foundation of the order of Cluny in the 10th century there appeared the conventual prior, who ruled as head of a monastery. The Regular Canons, and the Carthusians and Dominicans, later gave this title of prior to the heads of their houses.

See Du Cange, *Glossarium mediae et infimae latinitatis,* new edition by L. Favre (Niort, 1883, etc.); Sir William Smith and S. Cheetham, edd. *Dictionary of Christian Antiquities* (1875–80), and the article "Prior" in the *Catholic Encyclopedia.*

PRISAGE AND BUTLERAGE, the names of ancient English customs duties which survived until the beginning of the 19th century. The oldest was a wine duty. Later it became customary to levy upon wool, woolfells and leather. This "customs" duty was known as "prisage." The earliest known prisage was levied in kind; one tun of wine being taken from every cargo of from 10 to 20 tuns, and two tuns from every cargo exceeding 20 tuns; a tun being 252 gallons. The king's man took the liberty of sampling all the wine so that the king got his tun or tuns from the best on board. Later, importers were allowed to make a money composition instead of paying in kind. Prisage was payable both by British citizens and aliens.

In the reign of Edward I., by a charter known as *Carta Mercatoria,* aliens were given liberty of trading upon paying "to Us and to our Heirs, by the name of Custom, two shillings (for every hogshead of wine) over and above the antient customs due." This duty was made payable to the king's butler, and was consequently termed "butlerage." Later, kings of England granted the produce of the duties of prisage and butlerage to certain of their subjects. In 1785 it was recommended that these duties should be re-vested in the crown. Thus, the duties of prisage and butlerage in Ireland had been granted to the dukes of Ormond, but parliament purchased those rights for nearly £200,000. In 1809 the duties were abolished by the Customs Consolidation Act of that year.

PRISCIAN [PRISCIANUS CAESARIENSIS], the celebrated Latin grammarian, lived about A.D. 500. This is shown by the facts that he addressed to Anastasius, emperor of the East (491–518), a laudatory poem, and that the mss. of his *Institutiones grammaticae* contain a subscription to the effect that the work was copied (526, 527) by Flavius Theodorus, a clerk in the imperial secretariat. His title *Caesariensis* points, according to Niebuhr and others, to Caesarea in Mauretania. Priscian was quoted by several writers in Britain of the 8th century—Aldhelm, Bede, Alcuin—and was abridged or largely used in the next century by Hrabanus Maurus of Fulda and Servatus Lupus of Ferrières. There is hardly a library in Europe that did not and does not contain a copy of his great work, and there are about a thousand mss. of it. The greater part of these contain only books i.–xvi. (sometimes called *Priscianus major*); a few contain (with the three books *Ad Symmachum*) books xvii., xviii. (*Priscianus minor*); and a few contain both parts. The earliest mss. are of the 9th century, though a few fragments are somewhat earlier. All are ultimately derived from the copy made by Theodorus. The first printed edition was in 1470 at Venice.

The *Institutiones grammaticae* is a systematic exposition of Latin grammar. It is divided into 18 books, of which the first 16 deal mainly with sounds, word-formation and inflexions; the last two, which form from a fourth to a third of the whole work, deal with syntax. He has preserved to us numerous fragments which would otherwise have been lost, *e.g.,* from Ennius, Pacuvius, Accius, Lucilius, Cato and Varro.

Priscian's three short treatises dedicated to Symmachus are on weights and measures, the metres of Terence, and some rhetorical elements (exercises translated from the Προγυμνάσματα of Hermogenes). He also wrote *De nomine, pronomine, et verbo* (an abridgment of part of his *Institutiones*), and an interesting specimen of the school teaching of grammar in the shape of complete parsing by question and answer of the first 12 lines of the *Aeneid* (*Partitiones xii. versuum Aeneidos principalium*). He also wrote two poems, not in any way remarkable, a panegyric on Anastasius and a translation of Dionysius's *Periegesis.*

The best edition of the grammatical works is by Hertz and Keil, in Keil's *Grammatici latini,* vols. ii., iii.; poems in E. Bährens' *Poetae latini minores,* the "Periegesis" also, in C. W. Müller, *Geographi graeci minores,* vol. ii. *See* J. E. Sandys, *History of Classical Scholarship* (1908), vol. i.; and A. Luscher, *De Prisciani studiis Graecis* (Breslau, 1912).

PRISCILLIAN (d. 385), Spanish theologian and the founder of a party which, in spite of severe persecution for heresy, persisted in Spain and in Gaul until after the middle of the sixth century. He was a student of the occult sciences and of philosophy. He was a mystic, and regarded the Christian life as continual intercourse with God. He argued that to make himself a fit "temple of God," a man must, besides holding the Catholic faith and doing works of love, renounce marriage and earthly honour, and practise asceticism. On the question of continence in, if not renunciation of, marriage, he came into conflict with the authorities. Priscillian and his sympathizers, who were organized into bands of *spiritales* and *abstinentes,* like the Cathari of later days, refused the compromise which by this time the Church had established. (*See* MARRIAGE: *Canon Law.*) This explains the charge of Manichaeism levelled against Priscillian and to this was added the accusation of magic and licentious orgies. Priscillian's friends included two bishops, Instantius and Salvianus, and Hyginus of Cordova; but, through the exertions of Idacius of Emerita, the leading Priscillianists, who had failed to appear before the synod of Spanish and Aquitanian bishops to which they had been summoned, were excommunicated at Saragossa in October 380.

Meanwhile, however, Priscillian was made bishop of Avila, and the orthodox party appealed to the emperor (Gratian), who issued an edict (afterwards withdrawn) threatening the sectarian leaders with banishment. On the murder of Gratian and accession of Maximus (383) Idacius fled to Treves, and secured the summoning of a synod (384) at Bordeaux, where Instantius was

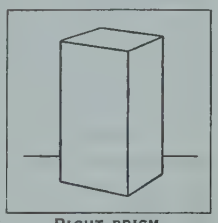
deposed. Priscillian appealed to the emperor, with the unexpected result that with six of his companions he was burned alive at Treves in 385.

The heresy, notwithstanding severe repressive measures, continued to spread in France as well as in Spain. As an openly professed creed it only disappeared after the second synod of Braga in 563.

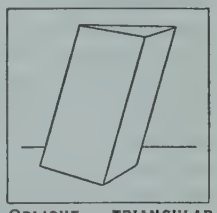
At the Council of Toledo in 400, 15 years after Priscillian's death, when his case was reviewed, the most serious charge that could be brought was the error of language involved in rendering ἀγένητος by *innascibilis*. It was long thought that all the writings of the "heretic" himself had perished, but in 1885 G. Schepss discovered at Würzburg 11 genuine tracts, since published in the Vienna *Corpus*. "They contain nothing that is not orthodox and commonplace, nothing that Jerome might not have written."

See E. C. Babut, *Priscillian et le Priscillianisme* (Paris, 1909).

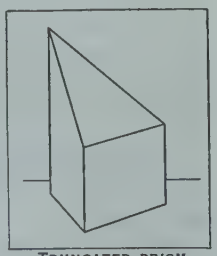
PRISM, in geometry, a polyhedron having two of its faces, known as *bases,* congruent (identically equal) polygons in parallel planes, and the other faces parallelograms equal in number to the sides of the bases. The faces, excluding each base, are called the *lateral faces,* and the intersections of these faces are called the *lateral edges,* being all equal. The perpendicular distance between the planes of the bases is called the *height* or *altitude* of the prism. If the lateral edges are perpendicular to the planes of the bases, the prism is called a *right prism;* if they are oblique to these planes, it is called an *oblique prism.* Prisms are said to be *triangular, quadrangular, pentagonal* and so on according as their bases are triangles, quadrilaterals, pentagons and so on. A prism having parallelograms for its bases is called a *parallelepiped.* If the bases and lateral faces are all rectangles, it is called a *rectangular parallelepiped.* The part of a prism included between the base and a section made by a plane oblique to the base is called a *truncated prism.* A geometric solid which has for its bases two polygons in parallel planes, and for its lateral faces triangles or trapezia (U.S., trapezoids), with one side in one base and the opposite vertex or side in the other base, is called a *prismoid,* a prism being a special case. In optics the word denotes a triangular prism. The volume of a prism of base B and altitude a is aB; of a prismoid with bases B and B', altitude a and area of a mid-cross section M, is $\frac{1}{6}a\,(B+B'+4M)$. *See* Crystallography; Light; Refraction; and Solids, Geometric.



RIGHT PRISM



OBLIQUE TRIANGULAR PRISM



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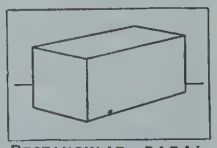

RECTANGULAR PARALLELEPIPED

PRISMOID, a solid bounded by any number of planes, two of which are parallel and contain all the vertices. The two parallel faces are called the *bases.* The volume V of such a solid was found by Thomas Simpson (1710–61) as follows: Let M be a section made by a plane parallel to the bases B and B' and midway between them, and let h be the distance between the bases. Then $V=\frac{1}{6}h(B+B'+4M)$, a formula frequently used in finding volumes and applicable to most of the elementary geometric solids, and in general to any solid bounded by a ruled surface and two parallel planes.

PRISON. In penal systems the function of the prison is threefold: custodial, coercive and corrective. The custodial function was enacted as a principle of Roman law in the *Digest* of Justinian that "a prison is for confinement, not for punishment," and in countries that followed Roman law the principle that imprisonment was not a legal punishment was dominant for 1,000 years. In England also, the high court judges went out to "deliver the gaols"—to clear them, not to fill them. The prisons of the middle ages were therefore concerned only with holding prisoners awaiting trial. To this custodial function the coercive was added when, the punishment awarded being a forfeiture of property, the prisoner might be held till the fine or compensation was paid. This function is still active in England, since those committed for nonpayment of fines or debts or for contempt of court may secure release by paying what they owe or purging their contempt.

EUROPE

In England the earliest lawful prison was the common jail, which in legal theory was the king's jail, and in 1403 it was enacted that justices should commit individuals only to the common jails. Mediaeval jails were not specially provided buildings—castle tower, abbey gatehouse or inn cellar might serve. The keeping of jails was in England farmed out to private persons, whose only responsibility was the safe-custody of the prisoners, their only interest to make the greatest profit from the fees they were permitted to charge them. To these forcing houses of contagious pestilence and moral corruption every type of prisoner was committed, with no adequate separation by age, character or even sex; and they so continued with little change and less disturbance of public conscience until the latter part of the 18th century.

Not less brutal and chaotic than the jails was the penal system they served. By the 16th century the mediaeval system of compensation was giving way to the capital penalty for major offenses, while for minor offenses fines and such punishments as whipping or the pillory were usual. But not all persons found guilty of capital offenses were executed. On the continent there was committal to the mines, galleys and fortifications. In England many escaped under "benefit of clergy" or under crown pardons on condition of agreeing to be "transported beyond the seas" to the American plantations. This practice received statutory sanction in 1679 and was regulated by a statute of 1717.

In England the social and economic conditions of the Tudor period led to a poor-relief system enforced through the local justices. Houses of correction were set up for those of the unemployed who required compulsion to work and others who required "to be corrected in their habits by laborious discipline." The first was set up in London in 1553 in the former royal palace of Bridewell, from which they derived the popular name which lingers to this day, and in 1576 justices were required to provide one in every county.

On the continent a similar movement derived from the house of correction known as the Rasp Huis, established in Amsterdam in 1595. The purpose of houses of correction was not that of criminal law, to cut offenders out of society by banishment or death, but the opposite—to bring them to good citizenship by the discipline of industry, education and religious instruction. Gradually, however, the penal implications predominated; industry as training gave way to hard labour as punishment, and during the 18th century houses of correction became instruments more of penal than of poor law. In England they became assimilated to the jails in all but name, and in 1865 the legal distinction was abolished.

Yet the idea of correction was to have continuing life, in England through the work of John Howard (*q.v.*) and on the continent through the influence of such historic houses of correction as that of Ghent, or of St. Michael in Rome—the first penal establishment to be set aside for reclaiming the young.

Beccaria, Howard and Reform.—The publication in 1764 of C. B. Beccaria's (*q.v.*) treatise *On Crimes and Punishments* laid the foundations of criminal science. His basic teaching was that the sole justification of legal punishment was the protection of society by prevention of crime and that the principle of uniform maximum severity, particularly by capital punishment, was not only wrong but ineffective. In England, under his influence, W. Eden, Sir William Blackstone, Sir Samuel Romilly and others fought for reform of the legal system and

rationalization of the use of capital punishment; yet by the end of the century capital offenses had increased to more than 200.

Failure to reform the legal system was inevitable so long as there was no effective "secondary punishment," and the use of the prisons of the time to that end was inconceivable either in principle or in practice. Howard not only awakened world conscience to the scandal of the prisons; he showed, too, how they might become an effective instrument of punishment. His publication in 1777 of *The State of the Prisons in England and Wales, with Preliminary Observations, and an Account of Some Foreign Prisons* had the same world-wide influence on principles of prison management as had Beccaria's treatise on principles of legal punishment. Prisons, he argued, should be sanitary and secure; the keeper should be the paid servant of the justices who should exercise effective supervision; to break down the physical and moral corruption of the common wards and yards, there should be separate cells for sleeping; and prisoners should have useful work in proper workshops, with regular moral and religious instruction.

Statutes were enacted from 1774 to 1791 giving effect to Howard's views, but enforcement rested with the justices, and only a few progressive magistrates, such as Sir George Paul at Gloucester and Sir T. Beevor at Wymondham, persuaded their counties to build cellular prisons. An account of the work of Beevor was to start in Philadelphia that movement for prison reform which later brought back to Europe the ideas for which Howard vainly fought in his own time.

Early 19th Century.—Necessity required many counties to provide larger jails for the growing number of prisoners, and better sanitation against jail fever, but 30 years after Howard's death another group of prison reformers found the prisons much as he had left them. The Society for the Reformation of Prison Discipline, founded in 1816, had as its most prominent members Thomas Foxwell Buxton and Samuel Hoare, leaders of a Quaker group among whom Elizabeth Fry (*q.v.*) was to live in history. Tirelessly and constructively working inside Newgate herself, and forming ladies' committees to do the same elsewhere, she showed that Howard's principles could be practically applied so as to restore criminals as useful members of society. But in parliament interest still centred on the penal system, and her work had no more immediate effect on the general state of prisons than that of Howard.

The question of secondary punishment might have been effectively faced when the loss of the American colonies had temporarily deprived the government of the resource of transportation for those felons whom it did not hang. Alternative arrangements were made in statutes of 1775 and 1778 and, though these fell through when in 1787 transportation was resumed, this time to Australia, certain novel provisions had a continuing effect on the 19th-century prison system. The first was the conception of punitive hard labour, defined as "labour of the hardest and most servile kind, in which drudgery is chiefly required. . . . such as treading in a mill or drawing in a capstern. . . . ." The second was to provide that, until they could be transported, convicts might be detained in "hulks" in harbours and river mouths. More important was the decision to build two "penitentiaries," and though nothing was then done, Jeremy Bentham (*q.v.*) here made a notable contribution. Under the utilitarian influence of Beccaria, he fought for penal and prison reform, laying special emphasis on the provision for prisoners of useful work as against sterile hard labour. In 1794 parliament adopted his novel plan for a penitentiary, which he called a "panopticon," and a site was bought at Millbank, London. But when in 1816 the new building was started on the site, Bentham's plan had been abandoned.

The first effective steps to rationalize the penal system were those taken by Sir Robert Peel (*q.v.*). The capital statutes were reduced and consolidated, benefit of clergy was abolished (1827) and for many felonies which had been clergyable there was prescribed a penalty of up to two years' imprisonment. It was now essential to make the prisons an effective instrument of punishment, and Peel's Gaol act of 1823 was the foundation of the English prison system. The justices were required to organize their prisons on a prescribed plan, with the jailer as their paid servant, to inspect them and to make reports to the home secretary. The graver abuses of the 18th century were swept away and the statute included a code of rules to be followed in every prison. Howard's principles were established, with one exception: the separate cell system was rejected in favour of classification into five groups which were to be associated in productive employment and maintained from the profits.

But the impulse which finally shaped the future of European prisons was to come from another direction. In 1776 the Quakers of Pennsylvania had taken in one stride the steps over which the old world was still to fumble for so long. Murder was made the sole capital offense, and imprisonment the primary legal punishment. The regime of imprisonment which became known as the separate, solitary or Pennsylvania system was based on Howard's cellular system, but went beyond his teaching in requiring the strict separation of the prisoners by day as well as by night. The reformative virtues of this system were held to lie in complete absence of contamination, in religious instruction and silent contemplation. But another school of thought, closer to Bentham and Howard, had greater influence on U.S. development: this required separate cells for sleeping but associated work by day, and in Auburn prison in the state of New York there was enforced, to prevent contamination, a strict rule of silence, from which this system became known as the silent or Auburn system (*see* below). As news of these developments spread in Europe there was a flow of visitors to inspect and report, and there began that battle of the systems of which the echoes have still not died away. But their common factor, the cellular prison, had come to stay, and all over western Europe, in the next 30 years, prisons were built on the new model.

In England this was a period of confusion. Some county jails of Howard's time were cellular; others had been rebuilt after 1823 for the classification plan. Some favoured hard labour and erected treadwheels, some the new silent system. Many were attracted by the profitable aspects of Bentham's useful employment; many more had changed little since Howard first saw them. The government still lacked power to create a coherent system by enforcing its enactments and the next steps were to remedy that constitutional defect and then, following the breakdown of the transportation system, to develop imprisonment as the primary legal punishment.

Central administration was strengthened by the appointment of inspectors of prisons in 1835 and of a surveyor general of prisons in 1844; and the home office, after visits by two of the inspectors to the U.S., gave a decided lead in favour of the separate system. Meanwhile public criticism of transportation had come to a head in the report of a parliamentary committee of 1837, and one of the steps taken to reform the system was to institute an initial period of 18 months' separate confinement in a penitentiary for selected convicts believed to be capable of reform. To supplement Millbank, the government in 1842 built a second penitentiary at Pentonville, London, which was also intended as a model to local authorities for the operation of the separate system. Within a few years 54 cellular prisons, with 11,000 cells, were built on the Pentonville plan.

In 1850 home office administration was further strengthened by the appointment of directors of convict prisons, to take charge of the hulks, Millbank, Pentonville and a prison built in 1839 at Parkhurst, Isle of Wight, for juvenile convicts; the first chairman of the directors was Sir Joshua Jebb. The transportation system was now crumbling under the revelations of its inhumanity and inefficiency, and the refusal of the colonies to accept any more convicts; in 1846 it was suspended and the home office had to develop a system to take its place in the prisons at home. New prisons were required to hold this new population and to replace the hulks: the old "war prison" at Dartmoor, Devonshire, was rebuilt and Portland, Dorset, and other convict prisons followed. The directors based the new system on the different stages through which a convict passed under the transportation system, and notably on the pioneer work of Alexander Maconochie in the penal settlement of Norfolk Island, where he had sought to recover the self-respect of his convicts through a progressive stage system,

based on the earning of marks for good conduct and industry. This system became one of the bases of 19th-century prison treatment; introduced by Jebb into Ireland, it was there further developed under Sir Walter Crofton and, as the "Irish system," much influenced the development of progressive reformatory discipline on the continent and later in the U.S.

To begin with in England there were three stages: (1) 12 months' separate confinement in a pentitentiary; (2) associated labour on public works in a convict prison (Portland harbour was largely built by convict labour); (3) ticket of leave to be at large in the colonies. Finally, when it became necessary that the convicts should also be released in England, a new form of sentence called penal servitude was introduced, which in 1857 was legalized for any offense punishable by transportation: the minimum period was three years. Penal servitude, after 1857, was served in three parts: (1) nine months' separate confinement in Pentonville or a local jail; (2) associated labour in a convict prison, divided into three progressive stages carrying increasing privileges to be earned by marks, while marks were also earned to qualify for release before expiration of sentence; (3) after the necessary marks were earned, release on a conditional licence.

Meanwhile, in the local prisons, the classification provisions of 1823 had in 1839 been repealed and permission given for justices to adopt the separate system, to which most informed opinion was now converted; and in 1850 a parliamentary committee had again endorsed the separate system and recommended punitive hard labour rather than useful industry. The battle of the systems was nearing its end.

19th-Century System.—Capital offenses having been reduced in 1861 to treason, murder, piracy and the burning of dockyards, imprisonment was now established in England as the primary legal punishment; in 1863 a committee of the house of lords laid down the principles which were to govern the system for more than 30 years. Meeting under the influence of an increase of serious crime and a reaction against reformative methods, the lords laid down that the object of imprisonment was deterrence by severity of punishment; and the methods should be separate confinement with punitive hard labour—"hard labour, hard fare and a hard bed." They expressed disbelief in the possibility of reform as an aim of imprisonment. Statutory effect was given to these views by the Prison act, 1865, and in 1877 parliament took the final step to ensure that they should be enforced. By the Prison act of that year the ownership and control of all local prisons were transferred to the home secretary and a board of prison commissioners was set up to manage and inspect them. The first chairman of the commissioners was Sir Edmund Du Cane, who had succeeded Jebb, so that all prisons, convict and local, were now under one management.

For 20 years the principles of 1865 were uniformly, efficiently and rigidly applied. Darkness descended on the English prisons, and the "Du Cane regime" became the classic example of a punitive prison system.

But elsewhere were new lights. On the continent the theories of Cesare Lombroso (*q.v.*) stimulated scientific study of criminology, and the formation in 1869 of the Union Internationale de Droit Pénale revived interest in the prevention of crime and the principles and practice of legal punishment. Continental systems were experimenting with variations of the progressive system; but in general the separate system was still rigidly enforced, and in France progress was retarded by the institution of transportation to the penal settlements in Guiana. In the U.S. the first American national prison congress was held at Cincinnati, O., in 1870, of which the "Declaration of Principles" is a foundation document of modern prison reform. In the same year Enoch C. Wines secured a joint resolution from the U.S. congress creating a special commissioner empowered to invite other nations to an international prison congress in London. This congress of 1872 approved the major principles of Cincinnati, that the moral regeneration of prisoners through hope, not fear, should be the primary aim of imprisonment and that any unnecessary pain or humiliation should be abolished. From this congress followed regular quinquennial congresses in the different capitals and later the International Penal and Penitentiary commission, an intergovernmental organization of official delegates, with a permanent office at Berne, Switz., whose discussions and resolutions have notably promoted knowledge and progress.

Light came again in England when, in 1895, a departmental committee, under the chairmanship of H. J. Gladstone, unsparingly condemned the system of 1865 as being ineffective for the prevention of crime. Prisoners, it was said, had been treated "too much as a hopeless and worthless element of the community . . . Prison discipline and treatment should be designed to maintain, stimulate, or awaken the higher susceptibilities of prisoners . . . and whenever possible to turn them out of prison better men and women than when they came in. . . . Prison treatment should have as its primary and concurrent objects deterrence and reformation." Separate confinement and hard labour were condemned, and proposals made for the separate treatment of young offenders under 21 and of habitual criminals.

20th-Century System.—*Before 1914.*—By the Prison act, 1898, power was given to the home secretary to provide for detailed regulation of the prison system by statutory rules, and under this more elastic procedure the development of 50 years proceeded without further legislation. Before World War I, however, the most significant changes in English penal practice lay in the steps taken to keep as many people as possible out of prison altogether. The probation system was established by the Probation act, 1907, suitable treatment of young offenders under 17 by the Children act, 1908, and of mental defectives by the Mental Deficiency act, 1913. The provision in the Criminal Justice act, 1914, requiring justices to allow time for the payment of fines caused a striking fall in the prison population. The Prevention of Crime act, 1908, provided the Borstal system of treating offenders aged 16 to 21 outside the prison system, and the separate system of preventive detention for the protection of society against the habitual criminal.

The Borstal system was the creation of Sir Evelyn Ruggles-Brise, who succeeded Du Cane in 1895 and served until 1921; it lies outside the prison system. Borstal training is carried out in Borstal institutions, which are wholly educational and reformatory in principle and in method. Borstal had a wide influence throughout Europe and the British commonwealth.

For habitual criminals in preventive detention a regime was devised suited to long sentences (five to ten years) which in principle were preventive rather than punitive, the prisoner having already served a sentence of penal servitude for the offense of which he was convicted on the occasion of having been found to be an habitual criminal. This double-track system of punishment together with other procedural disadvantages resulted in very few habitual offenders being sentenced to preventive detention, and was reviewed in 1932 by the departmental committee on persistent offenders, though effect was not given to their recommendations till 1948.

The prison systems of Europe underwent no radical change in the early years of the 20th century. On the continent separate confinement for periods of years was still general. In England there was little change in the convict prisons, but in the local prisons penal hard labour ceased, workshops were built for industrial employment and separate confinement was abolished; in effect, the silent system had returned, the rule of silence being strictly enforced at all times. The progressive stage system was based mainly on additional letters, visits and library books, with increasing gratuities in convict prisons. A classification system was instituted for convicted prisoners: (1) young prisoners, under 21; (2) star class, for those in prison for the first time and others suitable to associate with them; and (3) ordinary class, for all others. The earning of remission of sentence had by the act of 1898 been extended to persons sentenced to imprisonment, the amount being fixed at one-sixth; for penal servitude it was one-quarter. During World War II remission for all sentences was increased to one-third.

At this stage the doctrine that a prison regime must be punitive and humiliating, so as to exercise deterrence through fear both against those subjected to it and against potential

offenders in general, was still too deeply ingrained in penal thought and prison tradition for prisons to become an instrument for making better men and women.

Post-World War I.—There was active in Europe a new school of penal thought whose aims were embodied in the phrase "individualization of punishment," in reaction against the mechanical infliction of imprisonment as a standardized punishment irrespective of the condition of the offender. England, having taken the lead in providing alternatives to imprisonment, now moved toward individualization of punishment within the prison and the provision of a regime compatible with the moral and social rehabilitation of the prisoners.

Experience had shown that men and women would be made not better, but worse, by treatment designed to hurt, punish and humiliate them. It was therefore necessary to proceed from the hypotheses that general deterrence lies not in the fear of prison, but in the totality of the operation of the penal system; and that individual deterrence lies in the fact of imprisonment, with the absolute loss of personal liberty and the amenities of normal life, and subjection to forced labour and disciplinary control. The regime should then be directed primarily to the rehabilitation of every prisoner for whom it might be possible; for others, it should at least seek to avoid such deformative effects as would send them out of prison worse than when they came in, neither willing nor able to take a useful place in society.

The changes which were to follow, at first under the chairmanship of Sir Maurice Lyndham Waller (1922–28), were largely inspired by a remarkable personality, Sir Alexander Paterson, who served as a commissioner of prisons from 1922 to 1947. All deliberately humiliating features of prison life were now removed and the rule of silence disappeared. The system concentrated on training prisoners to take a useful place in society, with an organized system of assistance and aftercare on discharge. Special emphasis was laid on the personal influences of a carefully selected and well-trained staff, and also on those of men and women from the community outside, who were enlisted to provide, as a voluntary social service, both education and entertainment and to pay friendly evening visits to prisoners in their cells. The quality of industrial work was improved, the earning of small sums of money was introduced, and an adult education scheme established. Since this form of training could not be fully carried out in the unsuitable buildings of the 19th-century local prisons, with their mixed populations and diverse functions, special training prisons were set aside for prisoners eligible both by character and length of sentence; and to Wakefield, the first such prison, an open farm camp was attached.

Throughout Europe there was progress in the development of progressive reformatory systems, and many new penal codes were promulgated. The penal farm colony without walls at Witzwil, Switz., had long had a wide influence, and in Sweden, Italy and Greece prison farms were instituted as steps to complete liberty. In these developments the International Penal and Penitentiary commission continued to play a stimulating part, holding congresses in London (1925), Prague (1930) and Berlin (1935). In 1933 it published standard minimum rules for the treatment of prisoners which were adopted and recommended by the League of Nations.

Post-World War II.—The systems of western Europe, disintegrated by World War II, laboured under both material difficulties and the charge of large numbers of "collaborators" and political prisoners. In western Germany expert American and British advisers assisted the reconstruction of the prison system, as did the British Police and Prisons mission in Greece. In countries less directly affected by the war, however, progress was made. In Portugal modern prisons were built, notably the youth prison at Leiria, where novel methods of training young prisoners were introduced. In 1942 the first federal penal code came into force in Switzerland. The Swedish prison code of 1944 summarized progressive thought on the treatment of prisoners and excited wide interest; in particular it provided for the detention of as many prisoners as possible in open prisons.

The English prison system, handicapped by understaffing and overcrowding, nevertheless made progress in developing the principles and methods of training. Additional training prisons were opened and vocational training in skilled trades was extended. The isolation of the prison from the community was further minimized by placing responsibility for education with the local education authorities and making the library a branch of the local public library, with open access to the shelves; prisoners were encouraged to take correspondence courses in a variety of subjects; and in the medical services they shared fully in the benefits of the national health service. The marks system was abolished and the progressive stage system was developed on new lines, such privileges as letters and visits, library books, education and earning being allowed from the beginning. Several open prisons were established in camps and country houses, notably at Leyhill, Gloucestershire, a camp prison for about 300 men of the star class with sentences from four years up to life.

The application to prison treatment of psychological and psychiatric science, initiated before World War II, was extended and developed for use in pretrial reports to the courts, classification, and treatment of abnormal mental states.

The Criminal Justice act, 1948, and the statutory rules thereunder of 1949 gave legislative form to the principles developed after World War I. The outworn forms of sentence to hard labour and penal servitude were abolished, leaving the single sentence of imprisonment. New methods of dealing with persistent offenders were enacted: for those still apparently capable of reformation, sentences of two to four years' corrective training might be passed, to be served either in ordinary training prisons or in special prisons; for others, 5 to 14 years' preventive detention in appropriate conditions under special rules. The act also sought to minimize the imprisonment of young persons under 21 and provided additional methods of treatment for them outside the prison system, and in other ways furthered that abatement of imprisonment which has distinguished the English penal system of the 20th century. The Scottish prison system had developed in close co-operation with England, and in 1949 the Scottish Advisory Council on the Treatment and Reformation of Offenders published a report endorsing the main principles of the English system and recommending, *inter alia,* the extended use of open prisons. Similar trends were shown in reports of commissions in the Union of South Africa (1945) and the United Provinces, India (1946), and in the development of the penal systems of Australia and New Zealand. The Colonial Office Advisory Committee on the Treatment of Offenders in the Colonies continued to advise colonial governments on the appropriate application of modern methods in their penal systems.

These English-speaking and Scandinavian trends had not, by mid-20th century, been widely followed in other European systems, which still tended to adhere to separate confinement, though there was development of extramural work, of the application of psychiatric science and of the educational treatment of young prisoners. Alternatives to imprisonment, such as probation, were little developed, but many systems provided separate institutions for the special treatment of prostitutes, alcoholics or vagrants.

In the international field the International Penal and Penitentiary commission resumed its meetings in 1946; it also undertook the revision of the standard minimum rules of 1933. In 1946 the United Nations, through its social commission, assumed leadership in the field of prevention of crime and treatment of offenders, set up a social defense section of its secretariat and initiated a far-reaching program of study.

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UNITED STATES

In the American colonial period, penological practice fell almost entirely within the first stage of handling convicts, who were punished outside of institutions by means of fines and cruel and brutal corporal punishments. The only exceptions occurred within the Quaker colonies of West Jersey and Pennsylvania, and there only briefly. The Quakers were repelled by the bloody methods of corporal punishment and sought another method of handling convicts, in imprisonment at hard labour in workhouses. The latter were the first true prisons established in human history. West Jersey set up such a system in 1681 and Pennsylvania in 1682, but the British government forced the abandonment of this humanitarian innovation, and in 1718 even the colony of Pennsylvania reverted to the usual practices of corporal punishment.

The second stage of penological practice in the United States, that of providing penal institutions to punish convicts within their walls, gradually emerged between 1776 and 1800. At the close of the American Revolution, the Quakers and other humanitarians, notably Benjamin Rush, quickly restored the Quaker practice of imprisonment. These Philadelphia reformers were also influenced by the recommendations of the great English penologist John Howard and by the cellular jail which had been erected at Wymondham, Eng., in 1785 as a result of Howard's reform suggestions. Laws were passed by the state of Pennsylvania ordering imprisonment as the normal method of punishing criminals and, immediately after 1790, a small block of cells was erected in the yard of the Walnut Street jail in Philadelphia for the solitary confinement of convicts. This was the first true prison in the United States for confinement of adult felons. It was also the birthplace of the famous Pennsylvania system of prison discipline, which provided the model, with variations, for prison systems of the world during the 19th century.

Pennsylvania's first state prison, opened at Allegheny near Pittsburgh in 1826, was the first institution to provide for the solitary confinement of all inmates. But the Eastern penitentiary, opened at Cherry Hill in Philadelphia in 1829, became the classic institution in which the Pennsylvania system of solitary confinement was fully developed. From this institution the Pennsylvania system spread over the world and took firm root in Europe during the remainder of the 19th century. Under the Pennsylvania system each convict was locked up by himself in a cell and kept there without any association with other convicts until he died or was released. Hence, the Pennsylvania system was known as the solitary or separate system. Its chief purpose was punishment, but it was hoped that the reflection of the convict upon this punishment for his crimes might lead to his reformation. The Pennsylvania system thus established the second period of penology—the idea and practice of using penal institutions to punish convicts.

The other famous U.S. system of prison discipline and administration was started in Auburn, N.Y., in 1819, and was a variant of the Pennsylvania system. From 1821 to 1823 the institution was conducted according to the Pennsylvania system of constant solitary confinement. Because of the smallness of the cells ($3\frac{1}{2}$ by 7 by 7 ft.) and the total lack of exercise, many of the confined convicts went insane or died. As a result, the Auburn authorities introduced in 1825 what became known as the Auburn system, under which convicts were segregated individually in cells except during the periods of working and eating. They were allowed to leave their cells to work in prison shops and eat in a common dining room. But absolute silence was maintained at all times, and any type of communication between convicts was absolutely forbidden. Hence the Auburn system came to be known as the silent system.

From about 1825 to 1850 there was a vigorous conflict between the Pennsylvania and Auburn systems. The former was generally adopted by European countries. But, though the Pennsylvania system was experimented with briefly in Maryland, Massachusetts, Maine, New Jersey, Rhode Island and Virginia, the Auburn system had triumphed in every state except Pennsylvania before 1850. Two reasons for its triumph in the United States were that institutions on this plan were more economical to construct and administer, and they were also better adapted to the rising mechanical and shop industry than was the solitary cellular confinement of the Pennsylvania system. Perhaps even more important was the fact that Louis Dwight, secretary of the Prison Discipline Society of Boston, was an almost fanatical partisan of the Auburn system and carried on effective propaganda with state legislatures whenever the construction of a new prison was under consideration. By the middle of the 19th century the Auburn system was thoroughly established; it marked the complete triumph of the second stage of penology—the idea of punishing convicts within institutions.

The third stage of penological theory and practice in the U.S. came into being with the Irish system of prison discipline introduced in the 1850s and 1860s by Sir Walter Crofton and Sir Joshua Jebb. This system aimed primarily to reform convicts rather than to punish them, and determined the duration of imprisonment on the basis of the conduct of the convict while confined. It aroused the interest of leading U.S. penologists such as Enoch C. Wines, Zebulon R. Brockway, Gideon Haynes, Gaylord Hubbell and Franklin B. Sanborn; at the Cincinnati prison congress of 1870 these reformers advocated that it should replace both the Pennsylvania and the Auburn systems. Opposition was so strong, however, that the reformers were able to apply it only to U.S. criminal youth. The result was the creation of the Elmira reformatory system, first set up at the reformatory in Elmira, N.Y., in 1877.

The reformatories usually confined convicted young men between the ages of 16 and 30, often limiting the age group to those between 18 and 25. The system was based upon the idea of dividing inmates into graded classes, promoting them through these classes because of good conduct, providing adequate vocational education and speedily admitting worthy inmates to release under parole supervision. The reformatories were first to introduce parole into U.S. penological practice on a large scale.

By and large, the reformatory movement proved a disappointment because the high ideals of the reformers of the 1870s were not maintained. Moreover, the reformatory structures, differing little from conventional prisons, were not designed in harmony with the new treatment ideals. Actually, the program failed because it was never given a fair trial. Most reformatories degenerated into ordinary prisons for young men. In the second quarter of the 20th century, however, there was a revival of interest in the reformatory conceptions and practices. Beginning with the opening of the New Jersey reformatory at Annandale in 1929, reformatories were designed more in harmony with the ideals of the system, and better rehabilitative programs were worked out. One basic innovation was recognition of the fact that there must be two types of reformatory structures—one a relatively secure institution for the more serious types of criminal youth, and the other a more open and flexible institution for the less risky types. But both types of structure must provide complete facilities for rehabilitative programs.

In the interval between 1870 and 1930, the main beneficial influence of the Elmira system was its impact upon the conventional prisons for adult felons. Slowly and gradually, some of the Elmira ideals were introduced in the adult prison system. Among these were the increasing use of parole, speedier release upon the basis of good conduct, better provisions for inmate education and a gradual triumph, in theory at least, of the idea that the purpose of imprisonment should be the reformation rather than the punishment of the inmate. Beginning with the New Jersey prison system in

1918, the rational treatment program, generally known as the principle of classification, was developed. According to this program, the treatment of convicts was adapted not only to the needs of the major classes of convicts but also to those of each individual inmate. The conventional custodial staff was supplemented by a classification clinic or treatment staff, made up of physicians, psychiatrists, psychologists, social workers and sociologists. The "new penology" was exemplified in such state systems as those of New Jersey, Illinois and California and by the federal prison system after 1930 under the direction of Sanford Bates and James V. Bennett. The federal system made the most complete effort to apply the principle of classification in accordance with the types of inmates confined. Hence, the federal institutions became highly diversified, ranging from a supersecurity penitentiary for the more desperate type of criminals at Alcatraz, Calif., to a minimum-security correctional institution at Seagoville, Tex., at which there were no walls and in which the inmates were given relatively complete freedom of movement. An adequate classification clinic or treatment staff was provided for each institution.

Despite the advances represented by the new penology, the more realistic and progressive penologists came to recognize that the dominant ideal of reformation could never be effectively achieved within penal institutions. The public fear of escapes encourages the construction of prisons as a collection of escapeproof steel cages. Moreover, the attention of prison administrators tended to be concentrated primarily upon preventing escapes rather than reforming inmates, and the inmate attitudes produced by all these circumstances created a mental response unfriendly to the efforts of the treatment staff. The best prison community is no more than an extreme totalitarian society, and the most it can produce is a good convict, who is quite different from a good citizen. Penologists came to realize that reform of convicts must be achieved mainly by agencies operating outside prison walls, in the environment to which the convict must ultimately adjust himself if he is to become a reformed man. The result was at least a preliminary entry into the fourth stage of penological theory and practice—the conviction that reformation of convicts must be attained chiefly outside any penal institution.

Penologists estimate that 15% to 20% of all convicts are nonreformable and must be segregated in maximum-security institutions under humane conditions throughout their natural lives. All others, according to the fourth-stage theory, should be released from institutions as soon as possible and treated in the normal environment of social relationships. This means an ever greater use of probation, conditional release under close supervision, and parole. The penologist who most vigorously recommended transition to this penological practice was Howard B. Gill, who established the progressive Norfolk prison colony in Massachusetts in 1927. The first program designed to make extended application of this practice, at least among criminal youth, was the Youth Correction Authority program drafted by the American Law institute in 1940 under the leadership of John B. Waite. This was based on the principle that expert penologists should decide the treatment of all convicted youth, determining whether they should be treated in institutions or outside under probation, conditional release or parole. California adopted the program in 1941, Minnesota and Wisconsin in 1947, Massachusetts in 1948 and Texas in 1949. The federal government followed suit in 1950. In 1944 California also created an adult correction authority, envisaging application of the same principles to adult felons.

Prison Architecture.—From the time of the building of the Auburn and Sing Sing prisons and the Eastern penitentiary between 1819 and 1829, there was no fundamental change in prison architecture until well after 1900, except for the building of more secure and expensive Auburn-style prisons, with a greater array of forbidding tool-resisting steel cages. The Eastern penitentiary cost about $772,000 to construct. The Attica state prison, opened in New York state about a century later, cost nearly $11,000,000. The Eastern penitentiary was constructed according to the outside-cell layout, with radial wings; a central corridor ran through each wing, and the cells extended from the corridor to the outside wall of the wing. But, since the great majority of prisons built in the United States were erected on the Auburn pattern, it is the latter style of architecture which is chiefly of interest to students of U.S. prisons. The Auburn system discarded the radial wing layout and adopted in its place long rectangular cell houses, usually flanking the entrance to the institution. Within these cell houses, lighted by heavily barred windows in the walls, was the so-called inside-cell block made up of several tiers of heavily barred cells. These cells were located back to back, and were surrounded by a corridor extending all the way around the cell block. Because the cell house completed at Sing Sing prison in 1828 on the Auburn pattern was much larger and more impressive than the Auburn structure, the great majority of prisons erected in the United States after 1830 were based upon this Sing Sing model of long rectangular cell houses enclosing their sombre and ever more escapeproof inside-cell blocks. Hence, the prisons of the United States for more than a century were architecturally gloomy and oppressive and a constant and repressive frustration of reform efforts on the part of both the custodial staff and the inmates.

The first revolutionary advance over the Sing Sing pattern of prison architecture came with the opening of the telephone-pole prison at Fresnes, near Paris, in 1898, designed by Francisque-Henri Poussin. This split the long cell houses of the Auburn-Sing Sing pattern into two halves by means of a covered central corridor which extended throughout the length of the structure. The resulting external appearance roughly represented the arms on a telephone pole and thus gave rise to the name. This prison was a great improvement over previous structures in that it gave easy and protected access to all sections, reduced the possibility of escape, lessened the distance over which inmates had to move, made their supervision easier and facilitated the proper lighting of cell clocks.

The telephone-pole type of prison was introduced to a limited extent in the state prison at Stillwater, Minn., in 1914. But the adaptation of the layout to effective prison designing in the United States was mainly the work of Alfred Hopkins, a professional architect who in his mature years gave more and more attention to prison architecture. He began his work with a new county prison in Westchester county, N.Y., opened in 1916, but his first complete structures illustrating the telephone-pole layout were the federal penitentiary at Lewisburg, Pa., and the New York state medium-security prison at Wallkill, both opened in 1932. Other architects, notably Robert D. Barnes of the federal bureau of prisons, went further in perfection of the telephone-pole design, as best exemplified by the federal penitentiary at Terre Haute, Ind., and the federal correctional institution at Texarkana, Tex. The most notable innovation, however, was the plan drawn for the federal prison to supplant Alcatraz. This provided for elimination of the heavily barred windows of the cell houses and substituted skylighting of the cell blocks.

In the 20th century there was a tendency to diversify prison construction according to the type of inmates confined. From 1825, all prisons had been designed more or less exactly alike with the same form of cells for all offenders. Under the leadership of the federal bureau of prisons, institutions were progressively diversified to meet the needs of the very different types of convicts sent to them. In the federal system were the supersecurity penitentiary at Alcatraz, already mentioned, for the most desperate criminals; three maximum-security prisons for serious habitual criminals; two mixed-custody penitentiaries for less serious adult felons; eight medium-security correctional institutions for inmates not requiring correctional precautions for safe-custody; and one minimum-security correctional institution for inmates with good prospects of speedy reform. Housing facilities were also diversified within each institution. For example, in the federal penitentiaries at Lewisburg and Terre Haute, not more than 12% of the inmates were housed in maximum-security inside cells, with the rest detained in outside cells, dormitories and honour rooms. This diversified construction enormously reduced building costs and enabled the planners to put more money into various educational and treatment facilities to promote reformation rather than discourage it. There was also a notable tendency to spend less money on expensive walls. The wall of the Attica state prison in New York state, opened in 1931, cost $1,275,000, whereas the federal penitentiary at Terre Haute was built without any wall whatever. A heavy wire fence was found to provide a sufficiently secure enclosure. Finally, later prison planning stressed the desirability of smaller buildings. Enormous prisons like those at South Lansing, Mich., and Stateville, Ill., holding up to more than 5,000 inmates, were erected after World War I, but opinion at mid-century would limit prison capacity to not more than 1,200 inmates, approximately the number confined at Lewisburg and Terre Haute.

The design of institutions for juvenile delinquents showed comparable progress. The first institutions, erected in the 1820s, were no more than conventional prisons for children. Then came a couple of generations in which juveniles were confined in great barracklike houses of correction. In the last quarter of the 19th century some states erected large cottage institutions, with cottages sometimes of four or five stories. In the 20th century the trend was toward institutions composed of one-story cottages, housing from 15 to 25 children each.

Prison Labour.—Prison labour has played an important part in U.S. prison history, because it is intimately tied up with both the prison economy and the health and reformation of inmates. During most of the 19th century labour was carried on under various types of contracting. Contractors usually supplied the raw materials and sold the finished product, paying only for the labour of inmates. The contract stage reached its greatest prosperity in the 1870s and the 1880s, after which it became progressively restricted as the result of

opposition by businessmen and union labour. During the first third of the 20th century the public-account system dominated most U.S. prison industry. Under this system, the prison authorities manufactured and sold all prison-made products. A high degree of prosperity was attained under this system in the 1920s, but it was soon almost totally abolished by hostile legislation. The Hawes-Cooper act of 1929, the Ashurst-Sumners act of 1935 and the sweeping Federal act of Oct. 1940 destroyed the public-account system and made it necessary for all state prisons to concentrate on the production of goods required by the public institutions of the state. The result was an almost complete disintegration of prison industry between 1933 and 1942. Demoralizing idleness pervaded the prisons. During World War II, however, prisoners in both federal and state prisons were put to work producing needed war goods; they turned out more than $138,000,000 worth of such materials, and about an equal value of farm products. After the war there came a dangerous relapse into idleness which threatened again to demoralize the prison system. Laws restricting prison industry did not apply to the federal prisons, however, and the latter continued to enjoy the high productivity and prosperity reached during the wartime.

Education.—Though the history of education in U.S. penal institutions traces back to the rudimentary instruction provided at the Walnut Street jail in 1801, the educational system in penal institutions was still lamentably inadequate at mid-20th century. Not even the excellent federal prisons had a suitable educational system. In a thorough study of prison education, Austin H. MacCormick pointed out that in 1927 not a single prison in the United States had a thoroughly satisfactory program of education. He found that there was no prison school whatever in about 13 state prisons. While MacCormick's report stirred some activity in improving the situation, ten years later there were still 12 prisons without any educational provisions. Certain states like New York, Pennsylvania and California had improved the system of convict education. Probably the best U.S. prison school at mid-century was that of the Rockview penitentiary, near State College, Pa., where close relationships were maintained with the Pennsylvania State college. Prison libraries were likewise inadequate at mid-century. Here the best situation was that of the federal system, the Atlanta prison had a library of nearly 20,000 volumes, and the library facilities at Lewisburg and Terre Haute compared favourably with those in the average small college.

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(H. E. BAR.)

PRISONERS OF WAR: *see* LAWS OF WAR.

PRIŠTINA, a town in South Serbia, Yugoslavia. Pop. (1931) 16,948, about three-fourths being Albanians, and the remainder Serbs and Vlachs with a few Jews. Priština was the seat of government of Stephen Nemanya, founder of the Serbian empire, and to the west lies the famous Field of Blackbirds (*Kosovopolje*) where the empire was destroyed by the Turks in 1389.

To the southeast is the monastery of Grachanitza founded by King Milutin of Serbia (1275–1321), with some remarkable frescoes.

Priština was occupied by German troops in 1941.

PRITCHARD, CHARLES (1808–1893), British astronomer, was born at Alberbury, Shropshire, on Feb. 29, 1808. He was educated at St. John's college, Cambridge, elected a fellow of his college in 1832, and became a schoolmaster. On his retirement in 1862 he settled at Freshwater, in the Isle of Wight, and took an active interest in the affairs of the Royal Astronomical society, of which he became honorary secretary in 1862 and president in 1866. In 1870 he was elected Savilian professor of astronomy at Oxford. At his request the university determined to erect a fine equatorial telescope for the instruction of his class and for purposes of research, a scheme which, in consequence of Warren de la Rue's munificent gift of instruments from his private observatory at Cranford, expanded into the establishment of the new university observatory. By De la Rue's advice, Pritchard began his career there with a determination of the physical libration of the moon, or the nutation of its axis. In 1882 Pritchard commenced a systematic study of stellar photometry. For this purpose he employed the "wedge photometer" (*see* PHOTOMETRY: *Celestial*, and *Mem. R.A.S.* xlvii, 353), with which he measured the relative brightness of 2,784 stars between the north pole and about −10° declination.

The results were published in 1885 in his *Uranometria Nova Oxoniensis*, and their importance was recognized by the bestowal in 1886 upon him, conjointly with Pickering, of the Royal Astronomical society's gold medal. He applied photography to the determination of stellar parallax, publishing the results of his systematic measurement of the parallaxes of second-magnitude stars, in the third and fourth volumes of the Publications of the Oxford University Observatory. When the great scheme of an international survey of the heavens was projected, the zone between 25° and 31° north declination was allotted to him, and at the time of his death some progress had been made in recording its included stars. Pritchard became F.R.S. in 1840 and received many scientific honours. He died on May 28, 1893.

See *Proc. Roy. Soc.* liv, 3; *Month. Notices, Roy. Astr. Soc.* liv, 198; W. E. Plummer, *Observatory*, xvi, 256 (portrait); *Astr. and Astrophysics*, xii, 592; J. Foster, *Oxford Men and their Colleges*, p. 206; *Charles Pritchard, D.D., Memoirs of his Life*, by Ada Pritchard (London, 1897).

PRIVAS, town of France, capital of department of Ardèche, 95 mi. S.W. of Lyons. Pop. (1946) 5,620.

Privas is first heard of in the 12th century, as a possession of the counts of Valentinois, and later as the seat of a separate barony. As a Protestant stronghold, it suffered during the Wars of Religion. It passed in 1619 to the vicomte de Lestrange, a Roman Catholic noble. A general rising followed, and in 1629 it was besieged and destroyed by Louis XIII, who decreed that it should not be again inhabited; but in 1632 the inhabitants returned.

PRIVATEER, an armed vessel belonging to a private owner, commissioned by a belligerent state to carry on operations of war. The commission is known as *letters of marque*. Acceptance of such a commission by a British subject is forbidden by the Foreign Enlistment act 1870. Privateering is now a matter of much less importance owing to the Declaration of Paris, 1856 (*q.v.*), by which it was abolished. The declaration binds only the powers who were signatories or who afterward assented, and those only when engaged in war with one another. Privateers stand in a position between that of a public ship of war and a merchant vessel, and the raising of merchant vessels to the status of warships has in recent wars given rise to so much difficulty in distinguishing between volunteer war ships and privateers that the subject was made one of those for settlement by the Second Hague conference (1907). By Convention vii a converted merchant ship can not have the status of a warship unless it is placed under the direct authority, immediate control and responsibility of the power the flag of which it flies (art. 1). Converted merchant ships must bear the external marks which distinguish the warships of their nationality (art. 2). The commander must be in the service of the state and duly commissioned, and his name must figure on the list of the officers of the fighting fleet (art. 3). The crew must be subject to military discipline (art. 4). A converted merchant ship must observe the laws and customs of war (art. 5); and such conversion must be announced in the list of warships of the belligerent country.

The effective use of privateers made by the United States in the Revolutionary War and the War of 1812 bred reluctance on its part prior to the Civil War to agree to foreign proposals to abandon the practice. The United States, however, was willing to accede to the Declaration of Paris upon the condition that the right to capture enemy property, other than contraband, on the high seas should be abolished, but such an amendment was unacceptable to the European powers. In 1863, during the Civil War, congress authorized the president to commission privateers, but the power was not to be exercised unless the confederate states were successful in commissioning privateers in Europe. No occa-

sion appeared for the commissioning of privateers. During the Spanish-American War of 1898, despite the fact that neither Spain nor the United States had acceded to the Declaration of Paris, no use was made of privateers. The rise of the United States to the position of an important naval power, together with the realization that privateering belongs to the warfare of an earlier day, has disposed the U.S. to cease to incline favourably towards recognition of the practice as a method of modern warfare. Under the constitution issuance of letters of marque and reprisal is forbidden to the states and is vested solely in the national government.

PRIVET, any shrub of the genus *Ligustrum,* belonging to the family Oleaceae, and containing about 50 species, natives of temperate and tropical regions of the old world; only the common privet is a native of Europe and northern Africa. They have evergreen or nearly evergreen opposite entire leaves, and dense clusters of small, white, tubular four-parted flowers, enclosing two stamens and succeeded by small, globular, usually black fruits, each with pendulous seeds. The best-known species is the common European privet, *L. vulgare,* which makes good hedges; there are numerous varieties with variegated leaves. The so-called California privet (*L. ovalifolium*), native to Japan, is widely planted in the United States and thrives in Great Britain. *L. japonicum,* the wax privet, *L. lucidum* and *L. massalongianum* are fine evergreen species, hardy only in warm regions. Mock-privet, *Phillyrea,* a member of the same family, is an ornamental evergreen shrub, hardy only in warm places.

PRIVILEGE, in law, an immunity or exemption conferred by special grant in derogation of common right. The term is derived from *privilegium,* a law specially passed in favour of or against a particular person. In Roman law the latter sense was the more common; in modern law the word bears only the former sense. Privilege in English law is either *personal* or *real*—that is to say, it is granted to a person, as a peer, or to a place, as a university. The most important instances at present existing in England are the privilege of parliament (*see* PARLIAMENT), which protects certain communications from being regarded as libellous (*see* LIBEL AND SLANDER), and the privilege of the client by which counsel and solicitor are protected from disclosing, in judicial proceedings, information which has come to them in that relation. This does not extend to clergymen or medical attendants (*see* Observations by Mr. Justice McCardie in *The Times,* July 19, 1927). Privileged copyholders were those held by the custom of the manor and not by the will of the lord. There are certain debts in most countries which are said to be privileged —that is, such debts as must first be defrayed by the executor out of the personal estate of the deceased, in payment, for example, of funeral expenses or servants' wages. There are certain deeds and summonses which are privileged in Scots law, the former because they require less solemnity than ordinary deeds, the latter because the ordinary *induciae* are shortened in their case (*see* Watson, *Law Dict., s.v.* "Privilege"). The priority formerly possessed by specialty debts was abolished in 1869. (*See* DEBT.)

In the United States the term privilege is of considerable political importance. By art. iv. s. 2 of the Constitution, "the citizens of each State shall be entitled to all privileges and immunities of citizens in the several States." By art. xiv. s. 1 of the amendments to the Constitution (enacted July 28, 1868), "no State shall make or enforce any law which shall abridge the privileges or immunities of citizens of the United States." It will be noticed that the former applies to citizens of the States, the latter to citizens of the United States. "The intention of this clause (art. iv.) was to confer on the citizens of each State, if one may so say, a general citizenship, and to communicate all the privileges and immunities which the citizens of the same State would have been entitled to under the like circumstances" (Story, *Constitution of the United States,* 1806). The clauses have several times been the subject of judicial decision in the Supreme Court. With regard to art. iv. it was held that a State licence tax discriminating against commodities the production of other States was void as abridging the privileges and immunities of the citizens of such other States (*Ward* v. *State of Maryland,* 12 Wallace's Reports, 418). With regard to art. xiv. 1, it was held that its main purpose was to protect from the hostile legislation of the States the privileges and immunities of citizens of the United States, looking more especially to the then recent admission of negroes to political rights. Accordingly it was held that a grant of exclusive right or privilege of maintaining slaughter-houses for 21 years, imposing at the same time the duty of providing ample conveniences, was not unconstitutional, as it was only a police regulation for the health of the people (*The Slaughter-House Cases,* 16 Wallace, 36). The same has been held of a refusal by a State to grant to a woman a licence to practise law (*Bradwell* v. *The State,* 16 Wallace, 130), of a State law confining the rights of suffrage to males (*Minor* v. *Happersett,* 21 Wallace, 162), and of a State law regulating the sale of intoxicating liquors (*Bartemeyer* v. *Iowa,* 18 Wallace, 129). Suits to redress the deprivations of privilege secured by the Constitution of the United States must be brought in a United States court. It is a crime to conspire to prevent the free exercise and enjoyment of any privilege, or to conspire to deprive any person of equal privileges and immunities, or under colour of law to subject any inhabitant of a State or territory to the deprivation of any privileges or immunities (*Revised Statutes of United States,* ss. 5507, 5510, 5519).

It is sometimes difficult to distinguish between "privileges" and "rights" in the United States, but privileges are more general and the act of suffrage is considered a "privilege" rather than a "right."

PRIVY COUNCIL. The privy council, like all the British institutions of central government, excepting the House of Commons, is descended from the court of the Norman kings. This *curia regis,* composed of the king's tenants-in-chief, the household officials, and anyone else whom the king chose to summon, performed all the functions of central government without differentiating between them. According to feudal theory, tenants owed suit to their lord's court; but every great lord had also his household officials, his chancellor, his treasurer, his chamberlain and his steward to transact his daily business. Thus, too, the *curia regis* expanded or contracted according to the nature of the business under consideration. The ordinary routine would be carried out by the officials, assisted by such barons as happened to be at court; for more important business the king would secure the attendance of a greater number of his tenants-in-chief; and on really vital matters the household officials would tend to become a numerically insignificant technical element in a large feudal assembly.

As time went by the larger and smaller gatherings came to be distinguished adjectivally; later, these adjectives developed a technical significance, until at last, although still remaining for a time merely different manifestations of a one and indivisible body, the larger assembly developed into the great council and the parliament, the smaller into the king's council. In early days the presence of many barons at conciliar meetings was the mark of a strong king; later, as the barons came to realize that attendance was not merely a tiresome incident of feudal tenure but a source of political power, that obligation became a privilege. Thus, in the later middle ages there developed a struggle between king and greater barons for the control of the king's council. Was it to be feudal or expert? In the end the barons failed to secure their greater demands—exclusive membership and the control of appointment and dismissal—because they were unable to discover a means of adequately reconciling the principle of the right of all to attend with the actuality of a small assembly, because, though collectively anxious to control and individually willing to be appointed, they could never be relied upon for constant attendance, and because, with the passing of the feudal organization of society, baronial counsel ceased to be expert advice on matters of government. But the struggle was not entirely without fruit. A conciliar oath was instituted, membership became more determinate, and methods were devised, however primitive and clumsy, for enforcing responsibility.

By the time of Henry VII. this council had become the instrument of the Crown. It was composed of an inner ring of counsellors proper, who took the conciliar oath and sat at the council board, and of an outer ring of technical experts and dignitaries

(later, in the reign of Henry VIII., known as ordinary counsellors), who, though they might occasionally be called upon for advice, were not members of the board, did not take the conciliar oath, but merely that of their respective offices, and performed the technical and routine work of the central and provincial courts of the council. It was the policy of the Tudors to rule the country paternally by the prerogative exercised through the medium of the council.

Star Chamber and Privy Council.—This conception of government necessitated precision, sub-division and specialization, and thus, just as in earlier times, for analogous reasons, the undifferentiated *curia regis* had given birth and place to a number of descendent courts and councils, so in Tudor times the king's council and its functions were split up and divided between the privy council, the courts of Star Chamber, of requests and of high commission (*qqv.*), and such local offshoots as the courts and councils of the North, and of Wales and the Marches. A distinction between the council with the king and the council at Westminster had appeared from time to time during the middle ages. It now became "sharper and more permanent." The body "following the king was commonly known as the 'council at court,' while the other continued to be called 'the king's council in the Star Chamber.' The former body became the privy council."

This conciliar government was admirably suited to a period of transition. But the need of this somewhat arbitrary, if paternal, government had passed with the Tudors. Moreover, this small but all-powerful bureaucracy depended for its efficiency on a resolute and discriminating sovereign, capable of choosing the right men and of superintending their labours. The Stuarts did not possess these qualifications. The House of Commons, hitherto accustomed to follow the leadership of privy councillors, had now, with increased experience of partnership in government, developed a mind and policy of its own. Of the judicial aspect of the council's activities the common lawyers were coming to show an even more threatening jealousy, a jealousy justified by the misguided action of the Stuarts in checking the natural evolution of these courts towards independence of executive control and in using them to enforce, not justice, but policy. No wonder, then, that as religious and constitutional controversies developed between Crown and parliament the attention of malcontents became focussed on conciliar jurisdiction, nor that, when the parliamentary cause at last triumphed, in 1641, the whole system of conciliar government was swept away. Only the privy council was spared. It was never legally abolished. It perished in the interregnum (though the name was resuscitated in 1657) and revived with the return of Charles II. in 1660.

The personnel of the council was recruited from clergy, peerage and commons. The baronage, as we saw, had failed in the middle ages to secure exclusive membership. The Tudors preferred to employ men of low degree who would be wholly dependent on their master, and could be rewarded inexpensively by promotion in the Church, to the judicial bench or to other State offices, where their dignities would not become hereditary. Indeed, so professional did the council become that even the peers on it were members by virtue of office rather than of birth. The ecclesiastics also, who in the middle ages had predominated in the great offices of State, now declined in numbers and influence, partly because they had no longer a monopoly of education, and partly because, since the Reformation, they had ceased to be officials of an international hierarchy, semi-independent of secular control. Thus the majority of the council came to consist of lay commoners, and the proportion may fairly be illustrated from the council of Edward VI., which consisted of 17 commoners, two prelates and seven peers, only one of whom held a peerage of more than 12 years' creation.

Members.—Both in the middle ages and for several centuries later contemporary opinion favoured 20 as about the ideal total of conciliar membership. But seldom did practice conform with theory. When the privy councillor register begins, in 1540, we do, indeed, find 19 members, but by Henry VIII.'s death there were 29. In Edward's reign the record was 40, in Mary's 44, and, although Elizabeth reduced the numbers to between a dozen and a score, the Stuarts, as usual, were less successful. By 1623 the total had increased to 35, and Charles I.'s council averaged at about the same figure. The nucleus of principal officers, if a rough generalization be permitted, comprised the archbishop of Canterbury, the lord chancellor, the lord treasurer, the lord president (when there was one), the lord privy seal, the lord admiral, the lord steward, the lord chamberlain, the two secretaries of State, the chancellor of the Exchequer, the treasurer and the comptroller of the king's household, and the chancellor of the duchy of Lancaster. At the Restoration the problem of numbers became even more acute. Gen. Monk, we are told, presented Charles with a paper containing "the names of at least three score and ten persons, who were thought fittest to be made privy counsellors." Charles had also to remember the survival of his father's council and his own advisers, whom he had brought with him from beyond the seas. All things considered, it is not surprising that, though he managed to begin with only 28, the total had reached 47 by 1679. Temple's abortive attempt at conciliar reform temporarily reduced the figure to 33, but by 1688 it was back again at 48, by 1707 it had reached 60 and, by 1723, 67.

The Pre-eminence of the Cabinet.—In proportion as the numbers of the privy council rose, so did its powers decline. Even in Tudor times the increasing membership and the volume of work had led to the institution of committees, and already, under the early Stuarts, one of these committees, out of which was to develop the cabinet, was beginning to usurp the functions of the council. (For the development and extent of this usurpation *see* CABINET.) Unpopular as this tendency was, it could not be checked. The petition of Lords and Commons in 1642 "that matters of State proper for the privy council might be debated and concluded there" is only one instance of many unavailing protests. Charles II., after his restoration, carried caballing on official and unofficial committees beyond the limits of the nation's endurance, and was at last, in 1679, forced to submit to the first serious attempt to restore the powers of the council. Sir William Temple was the reputed father of the scheme, but it seems that the king played a, for him, not unusual part in the begetting of it. The reformed council was to consist of 15 "who shall be privy councellours by their places" and of 15 others representing the various sections of parliamentary opinion, plus princes of the blood, a lord president, and a secretary for Scotland when in England—33 in all. The scheme was, in fact, a failure from the start. Membership was still too numerous for efficiency, too diverse in opinion to be able to pursue, much less to dictate, a consistent policy; worse still, the experiment was received with cold suspicion by parliament. Charles, in spite of recent professions of loyalty to the new council, began flouting it at once. He prorogued the parliament without consulting it, dissolved the parliament contrary to the advice of a large majority, and finally, in spite of it, prevented for a year the meeting of the new parliament. Once more he had resort to caballing. Not unnaturally, the opposition members of the council ceased to attend meetings which were nothing but a farce, and with their disappearance the council may be said to have reverted to its former constitution.

The last serious attempt to restore the privy council to its former position and influence may be found in the clause of the Act of Settlement (1701), which enacted that, on the Hanoverian accession, "all matters and things relating to the well-governing of the kingdom, which are properly cognizable in the privy council by the laws and customs of this realm, shall be transacted there, and all resolutions taken thereupon shall be signed by such of the privy council as shall advise and consent to the same." But the proposal was by that date impracticable, and the clause was repealed in 1705 before it even came into force. The council board had been not merely short-circuited by the cabinet, it had even lost the power of debating such measures as came before it. In 1711 a debate on the subject in parliament elicited the remark that "the privy counsellors were such as were thought to know everything and knew nothing. Those of the cabinet council thought nobody knew anything but themselves." And the last occasion on which the council asserted its former rights was when, in 1714, as Queen Anne lay dying, certain Whig lords

forced their way in at a meeting of the lords of the committee (*see* CABINET), claimed their right to be present as counsellors of the Crown, converted the meeting into a session of the privy council and, reinforced by their conciliar colleagues, ushered in the Hanoverian succession. From the accession of George I. the privy council may be described as a purely formal body meeting on purely formal occasions to transact purely formal business. There were at mid-20th century more than 300 "right honourable lords and others of His Majesty's Most Honourable Privy Council." They were mostly dignitaries who had held, or held, high political, judicial or ecclesiastical office in Great Britain, the dominions, or the colonies; though the list occasionally included eminent persons in science or letters. Office lasts for the life of the sovereign and six months after, but it is the modern custom for the new sovereign to renew the appointment.

FUNCTIONS

The *curia regis* performed all the functions of central government without differentiating between them. Later, with the multiplication and elaboration of business, as old methods became too stereotyped and cumbersome to meet new needs, the one court gave birth and place to many. But, since differentiation was along the lines of procedure rather than of function, every true offspring of the *curia,* however much it might come in time to specialize in one particular function, tended to retain at least some traces of the others as well. Thus, by the end of the mediaeval period the king's council was coming to be thought of mainly as an executive body, but it still retained extensive judicial, fiscal and legislative powers, and portions of all these (except the fiscal) have, in diminishing quantities, descended through the ages to, and been inherited by, the modern privy council, along with certain other duties which still defy expert analysis as exclusively executive or judicial or legislative.

Executive.—The consultative and advisory functions formerly exercised by the privy council were usurped, as shown above, by a committee of counsellors, who came to be known collectively as the cabinet (*q.v.*). The duties of the other committees of the council have been handed over, to a large extent, to State departments, such as the Board of Trade, the Local Government Board, the Board of Education and the Board of Agriculture, presided over by ministers responsible to parliament. The privy council itself now acts merely as the formal medium for giving expression, by Order of Council or by Proclamation, to the measures determined on by the Crown on the advice of its ministers, in the exercise of those executive functions which it possesses either by virtue of the prerogative or by statutory authority. Orders in Council are used when new rules and regulations are approved and passed by the King in council, or for proclamations to give publicity to such matters as the summons, dissolution, or prorogation of parliament, or the declaration of peace or war. These formal meetings are attended by a few councillors, generally ministers or officials, three of whom form a quorum, and the orders of the council are authenticated by the signature of the clerk to the council.

Nevertheless, there are still committees in existence exercising important functions of a mixed kind. For instance, it not infrequently happens that parliament, faced with the difficulty of enacting long and intricate legislation, confines its attention to general outline and principle, at the same time authorizing, under the act, the privy council to fill in the details. These powers are exercised usually by committees to which matters are referred by the Crown in council. Thus two applications in connection with the attention of the statutes of the universities and colleges of Oxford and Cambridge came before the universities' committee. And it is obvious that the work of such committees involves all the functions of government, administrative, judicial and legislative.

Fiscal.—The *curia* provided no machinery for national taxation, since the latter had no place in feudal society. It was the accepted doctrine that "the king should live of his own," that is, on the rents and services due to him; and these were adequately dealt with by the Exchequer. So exclusively was it an affair between lord and tenant that Magna Carta attempted to check, or regulate, the raising of exceptional revenue by providing that whenever the sovereign wanted more than his ancient feudal dues, he should consult a gathering of his tenants-in-chief. Only with the coming of the Commons to parliament and with the growth of the idea that money is granted in exchange for redress of grievances does national direct taxation find a place in the constitutional scheme, and that place, of course, is in parliament, and in parliament alone. But in the matter of indirect taxation the position was not so clear. The regulation of trade and the vicissitudes of foreign policy necessitated, in early times, the imposition and manipulation of customs duties by the Crown in council.

Later on, the growing jealousy of parliament led to the passage of statutes which did something to restrict, but very little to define, the royal powers in this direction. For two centuries or more, however, the issue was compromised. As long as the Crown was content to leave the question of the prerogative in abeyance, certain duties were annexed to the Crown in perpetuity and others voted to every new sovereign by his first parliament for life. It was James I. who violated this understanding by issuing a new *Book of Rates,* placing impositions upon articles produced and sold within the kingdom, and making other alterations, not, as the Tudors had done, in the interests of trade and foreign policy, but for purely fiscal purposes. Charles I., in consequence, was not voted tunnage and poundage, for life, on his accession, and the whole question of prerogative levies came up for discussion and decision. At the end of a struggle in which neither party had either the law or honesty completely on its side, parliament, by the Petition of Right (1628), and the Tunnage and Poundage and Ship Money Acts (1641), finally secured absolute control over all taxation, indirect and direct.

Legislative.—Many of the so-called statutes of the middle ages have no better authority than the Crown in council. By the end of the 15th century, however, statutes are quite distinct from ordinances or proclamations (as they were coming to be called). Conciliar legislation was vaguely considered to be subordinate to statute and common law, and less permanent also, its duration being apparently limited to the life of the enacting sovereign. Nevertheless, the legislative powers of the Crown in council were still wide and undefined. The Statute of Proclamations (1539) did something temporarily to regulate them on a firm basis and with a limited range, but was repealed at the accession of Edward VI., and as, later on, parliaments became less docile, there was a natural tendency on the part of the sovereign to claim greater authority and a wider scope for proclamations. "When the common state or wealth of the people require it," it was said in the Star Chamber, "the king's proclamation binds as a new law and need not stay a parliament." Finally, the ambitious pretensions of the first Stuart king brought the matter to a head. In 1610 the Commons complained that the number and range of recent proclamations made them fear "that proclamations will, by degrees, grow up and increase to the strength and nature of laws." And Coke, consulted as to the answer to be given, laid down in the *Case of Proclamations* an authoritative limitation. "The king cannot," he said, "change any part of the common law nor create any offence by his proclamation which was not an offence before, without parliament. . . . But a thing which is punishable by the law, by fine and imprisonment, if the king prohibit it by his proclamation . . . and so warn his subjects of the peril of it . . . this as a circumstance aggravates the offence." It was too much to expect either James I. or Charles I. to observe these principles, but the later Stuarts kept to the limits laid down, mainly, perhaps, because there was no longer a Star Chamber to enforce the ultra-legal acts of a sovereign.

But there is another aspect of the legislative functions of the council. It was completely, once, and is still, in part, a component of the legislature. Parliament was originally only the fullest assembly of the *curia regis,* a re-fusion, as it has been called, of all the elements into which the old, undifferentiated *curia* was coming to be resolved. As the king was the core of the council, so the council was the core of the parliament. Those members

of the council who were lords, spiritual or lay, sat among their peers on the benches along the side walls, to right and left of the king respectively; the commoners sat on four woolsacks in the midst of the chamber. Their exact positions were regulated later by the Act for Placing the Lords (1539). But already, in the 14th century, as the parliament chamber began to develop into the house of lords, peers and bishops began to regard the commoners present as inferior persons, with inferior, if any, rights.

As the commoners lost influence, so they lost interest, and in Wolsey's time began to seek election to the house of commons; and this practice had become the rule for privy councillors, who were not bishops and peers, by the middle of the 16th century. The lord chancellor remained in the house of lords because he was its presiding officer (only since Anne's reign has he been invariably made a peer), and thus retained his woolsack, but the other councillors—by nonattendance—have forfeited their seats, and even now a privy councillor, not being a peer or bishop, who wishes to attend the house of lords, must content himself with standing on the steps of the throne. The so-called privilege of the lords to require the attendance of the judges (who still sit on the woolsacks at the opening of parliament) is no more than a survival of the judges' regular attendance in the parliament chamber as members of the *curia* and counsellors of the crown.

For the Judicial committee of the privy council *see* below.

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(F. L. B.)

PRIVY COUNCIL, JUDICIAL COMMITTEE OF. From the abolition of the Star Chamber in 1641 until 1833, petitions from overseas to the crown, whether by way of appeal or otherwise, came before a general committee of the privy council which gave advice (as does the judicial committee) on what order should be made. In that year, while the approach by way of appeal to the king remained, the procedure was systematized and a judicial tribunal and, later, rules of procedure instituted. Certain matters, such as admiralty, were subsequently transferred to the high court of justice and so, by way of appeal, to the court of appeal and the house of lords.

The Statute of 1833.—This act provided in its first section for a new juridical composition for the council, to be headed by the president for the time being thereof, and the lord high chancellor and other learned dignitaries as there set forth. These, it was enacted, "shall form a committee of his majesty's said privy council and shall be styled the judicial committee of the privy council."

In later years the personnel of the committee was changed and enlarged. It now consists of the lord chancellor, the lord president of the council and the lords of appeal in ordinary, together with certain other members. To them are added such other members of the privy council as shall from time to time hold or have held "high judicial office," that is, membership of the court of appeal and high court or court of session in the United Kingdom, and certain judges of the dominions who are privy councillors.

By the third section of the 1833 act, it was provided: "That all appeals or complaints in the nature of appeals whatever, which, either by virtue of this Act, or of any law, statute, or custom, may be brought before his majesty or his majesty in council from or in respect of the determination, sentence, rule, or order of any court, judge, or judicial officer, and all such appeals as are now pending and unheard, shall from and after the passing of this Act be referred by his majesty to the said judicial committee of his privy council, and that such appeals, causes, and matters shall be heard by the said judicial committee, and a report or recommendation thereon shall be made to his majesty in council for his decision thereon as heretofore, in the same manner and form as has been heretofore the custom with respect to matters referred by his majesty to the whole of his privy council or a committee thereof (the nature of such report or recommendation being always stated in open court)."

Appeals are by petition, and the judgment is in the form of an opinion to the king, humbly advising what judgment should be given. The judicial committee, unlike the house of lords, is not bound by previous decisions, and minority opinions are not publicly expressed.

The Commonwealth.—In 1867 the principal British North America act was passed. By sections 91 and 92 the powers of the Canadian dominion parliament and functions of the provincial legislatures were distinguished. It became evident that the task of defining the respective jurisdictions not only interprovincially but between dominion and province would be a difficult task. The authority of the judicial committee of the privy council so to act was clear from the act of 1833, but the Canadian parliament thought fit to deal further with the matter in the 47th section of their Supreme and Exchequer Courts act (38 Victoria, chap. 11) in the following terms:

"The judgment of the Supreme Court shall in all cases be final and conclusive, and no appeal shall be brought from any judgment or order of the Supreme Court to any court of appeal established by the parliament of Great Britain and Ireland, by which appeal or petitions to her majesty may be ordered to be heard: saving any right which her majesty may be graciously pleased to exercise by virtue of her royal prerogative."

The Statute of Westminster.—Under the powers vested in it, the judicial committee formerly pronounced a series of several judgments on matters of imperial importance, but later, as regards the dominions, this field of judicial activity became very restricted. The effect of the passage of the Statute of Westminster in 1931 was that dominions which had adopted it were in a position to abolish the right of appeal from their courts to the judicial committee. Acting under this power Canada in 1935 abolished appeals to the judicial committee in criminal matters.

The Supreme Court act, 1949, came into force on Dec. 23, 1949. By Section 3 the right of appeal from Canadian courts was abolished, save that appeal was preserved in respect of litigation already in process at the time. By the British North America act, 1949, Newfoundland was incorporated into Canada.

The commonwealth of Australia, a federation of six states, had not yet adopted the Statute of Westminster, but the right of appeal was limited by Australian legislation to provisions specifically reserved in the constitution, and in any case leave of the Australian high court was needed before an appeal to the committee could be brought. This leave was, in practice, rarely given.

In the Union of South Africa, with a unitary and not a federal constitution, the right of appeal, with leave from the supreme court, to the judicial committee was ended in 1950. Previously this right had existed but actually leave to appeal was almost impossible to obtain. Such appeals had never been popular since it was felt that an English court must have an inadequate knowledge of the working of the system of Roman-Dutch law prevailing in the Union.

New Zealand also had not yet adopted the Statute of Westminster, and legal opinion there continued to be strongly opposed to the abolition of the right of appeal to the judicial committee, but in fact very few appeals came to the committee from that country.

The Republic of Ireland, while yet in law a dominion, took advantage of the power to abolish the right of appeal in all cases by the Irish Free State constitution (amendment act, 1943) —a course the validity of which was approved in the case of *Moore* v. *Attorney General for Eire* (1935) A.C. 484. Appeals from Northern Ireland were to the house of lords.

In India, appeals were abolished by the Indian Abolition of Jurisdiction of Privy Council act, 1949. Courts were established in 1726, by charter of George I, in the three settlements of Madras, Bombay and Bengal, and the right of appeal to his majesty in council was given. Subsequent charters constituted supreme courts and these in time were replaced by various high courts created under the charter, Acts 24 and 25 Victoria, chap. 104. These high courts were constituted by letters patent which contained rules providing for appeals to the privy council.

Other high courts were established later, and these were also constituted by letters patent containing similar provisions as to appeals. The Civil Procedure code also gave a right of appeal under prescribed conditions and there followed an order of council of Feb. 9, 1920, which replaced a much earlier one issued under the Judicial Committee Act of 1833. So great, at one time, was the growth of Indian judicial business before the committee, that the latter had to be divided into two sections, one of which was entirely, or almost entirely, occupied with Indian appeals. By sec. 30 of the Judicial Committee Act of 1833, Indian judges were made eligible as members of the committee; in 1928 provision was made for their remuneration.

Indian business was greatly affected by the passing of the Indian Independence act, 1947, which provided for the setting up, as from Aug. 15, 1947, of two separate independent dominions, India (now a republic) and Pakistan. By reason of the Federal Court (Enlargement of Jurisdiction) act, 1949, passed by the legislature of the dominion of India, civil appeals might come to the judicial committee from the federal courts of India, but not from the high courts, while the committee remained the supreme tribunal in criminal cases where broad principles of natural justice were concerned.

Pakistan followed India in terminating the right of appeal.

In the case of the crown colonies and protected and trust territories (not being dominions under the Statute of Westminster, but including the Channel Islands and the Isle of Man) the position remained virtually the same after 1833.

General Opinions.—This procedure has not often been employed in the privy council. By sec. 4 of the act the crown may refer any matter to the judicial committee for hearing or consideration. This enabled the committee to give general opinions otherwise than on immediate facts—a power rarely invoked in British jurisprudence. Such opinions had, however, been given in boundary disputes between Canada and Newfoundland and under the Irish treaty of 1921 and on some other matters.

Ecclesiastical Jurisdiction.—The ecclesiastical jurisdiction of the king in council is derived from the statute 25 Henry VIII, chap. 19, which followed the act of the previous year, 24 Henry VIII, chap. 12, abolishing appeals to Rome. By 25 Henry VIII, chap. 19, an appeal was given from the courts of the archbishop to the king in chancery and it was enacted that upon such appeal:

"A Commission shall be directed under the great seal to such persons as shall be named by the King's Highness his heirs or successors like as in case of appeal from the Admirall Court to hear and definitely determine such appeals and the causes concerning the same."

This commission, known as the High Court of Delegates, was abolished by 2 and 3 William IV, chap. 92; and, by 3 and 4 William IV, chap. 41, ecclesiastical appeals were transferred to the judicial committee. The result was that thereafter appeals from the two courts of archbishops (*i.e.*, Arches court of Canterbury and provincial court of York) lay to the king in council.

With regard to appeals under the Clergy Discipline act, 1892 (dealing with morals), there was established an alternate right of appeal from the consistory court of bishops either to the court of the archbishop or to the king in council direct. If the appellant elected the former there was no further appeal to the king in council. On the hearing of ecclesiastical appeals under the rules made under the Appellate Jurisdiction act, 1876, five bishops were to be summoned as ecclesiastical accessors, of whom three at least had to be present. Under the Endowed Schools act, 36 and 37 Victoria, chap. 87, appeals lay to his majesty in council from schemes prepared by the board of education affecting schools subject to the Endowed Schools act. Under the Union of Benefices measure, 1923, of the national assembly of the Church of England, an appeal lay to the king in council against a scheme of the ecclesiastical commissions uniting two or more benefices.

Practice.—The following is a paraphrase of the privy council rules:

All appeals shall be brought either in pursuance of leave obtained from the court appealed from, or, in the absence of such leave, in pursuance of special leave to appeal granted by his majesty in council upon a petition in that behalf presented by the intending appellant.

A petition for special leave to appeal shall state succinctly and clearly all such facts as it may be necessary to state in order to enable the judicial committee to advise his majesty whether such leave ought to be granted. The petition shall deal with the merits of the case only so far as is necessary for the purpose of explaining and supporting the particular grounds upon which special leave to appeal is sought.

Whenever it shall be found that the decision of a matter on appeal is likely to turn exclusively on a question of law, the parties, with the sanction of the registrar of the privy council, may submit such question of law to the judicial committee in the form of a special case, and print such parts only of the record as may be necessary for the discussion of the same.

The judicial committee may order a full discussion of the whole case, if they shall so think fit, and, in order to promote such arrangements and simplification of the matter in dispute, the registrar may call the parties before him, and having heard them, and examined the record, report to the judicial committee as to the nature of the proceedings.

All petitions for orders or directions as to matters of practice or procedure arising after the lodging of the petition of appeal and not involving any change in the parties to an appeal shall be addressed to the judicial committee. All other petitions shall be addressed to his majesty in council, but a petition which is properly addressed to his majesty in council may include, as incidental to the relief thereby sought, a prayer for orders or directions as to matters of practice or procedure.

As soon as the appeal has been admitted, whether by an order of the court appealed from or by an order of his majesty in council granting special leave to appeal, the Appellant shall without delay take all necessary steps to have the record transmitted to the registrar of the privy council, and the registrar shall, with all convenient speed, certify to the registrar of the privy council that the respondent has received notice, or is otherwise aware, of the order of the court appealed from admitting the appeal, or of the order of his majesty in council giving the appellant special leave to appeal, and has also received notice, or is otherwise aware, of the dispatch of the record to England.

A petition not relating to any appeal of which the record has been registered in the registry of the privy council, and any other petition containing allegations of fact which cannot be verified by reference to the registered record or any certificate or duly authenticated statement of the court appealed from, shall be supported by affidavit. Where the petitioner prosecutes his petition in person, the said affidavit shall be sworn by the petitioner himself and shall state that, to the best of the deponent's knowledge, information, and belief, the allegations contained in the petition are true. Where the petitioner is represented by an agent, the said affidavit shall be sworn by such agent and shall, besides stating that, to the best of the deponent's knowledge, information and belief, the allegations contained in the petition are true, show how the deponent obtained his instructions and the information enabling him to present the petition.

The registrar of the privy council may refuse to receive a petition on the grounds that it discloses no reasonable cause of appeal, or is frivolous, or contains scandalous matter, but the petitioner may appeal, by way of motion, from such refusal to the judicial committee.

As soon as an appeal is set down, the appellant shall attend at the registry of the privy council and obtain ten copies of the record and cases to be bound for the use of the judicial committee at the hearing. The copies shall be bound in cloth or in half leather with paper sides, and six leaves of blank paper shall be inserted before the appellant's case. The front cover shall bear a printed label stating the title and privy council number of the appeal, the contents of the volume, and the names and addresses of the London agents. The several documents, indicated by incuts, shall be

arranged in the following order: (1) appellant's case; (2) respondent's case; (3) record (if in more than one part, showing the separate parts by incuts, all parts being paged at the top of the page); (4) supplemental record (if any); and the short title and privy council number of the appeal shall also be shown on the back.

The appellant shall lodge the bound copies not less than four clear days before the commencement of the sittings during which the appeal is to be heard.

The registrar of the privy council names a day on or before which appeals must be set down if they are to be entered in the list of business for the ensuing sittings. All appeals set down on or before the day named must, subject to any directions from the committee or to any agreement between the parties to the contrary, be entered in such list of business and shall, subject to any directions from the committee to the contrary, be heard in the order in which they are set down.

The registrar of the privy council shall, subject to the provisions of rule 42, notify the parties to each appeal by summons, at the earliest possible date, of the day appointed by the judicial committee for the hearing of the appeal, and the parties shall be in readiness to be heard on the day so appointed.

At the hearing of an appeal not more than two counsel may be admitted to be heard on a side.

In admiralty appeals the judicial committee may, if they think fit, require the attendance of two nautical assessors.

Where the judicial committee, after hearing an appeal, decides to reserve its judgment thereon, the registrar of the Privy Council shall in due course notify the parties by summons of the day appointed by the committee for the delivery of the judgment.

Conclusion.—A notable difference between British jurisprudence and the jurisprudence of Rome is that while Rome gave Roman law to its whole empire, the British empire sought to give to its component parts their own particular law. This imposed upon the judicial committee a task of great complexity. Systems of jurisprudence totally different in outward seeming, but respectively in entire accord with the historical and tribal traditions of the various populations and parts of the empire, had to be administered in such a fashion as, compatibly with British notions of natural justice, to accept and respect not only established local traditions, customs and laws but also rules of succession, rights of property and even of religion prevailing in various parts of the commonwealth.

It had been shown that the bonds of empire might be loosened without being broken, and that it was possible for countries within the commonwealth to evolve from a position of subordination to one of equality without thereby endangering the ties mutually binding the member states of the British Commonwealth of Nations. Nevertheless, the years after World War I saw a considerable reduction in the jurisdiction and business of the judicial committee, and in several instances the existence of the right of appeal to the king in council was felt to be incomparable with complete independence. The uniformity of common law principles, applicable in the past to many varying local conditions, may thus be partly lost.

In the case of ecclesiastical appeals, long a matter of religious dissension, the Church of England sought a new canon to establish its own final court of appeal.

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PRIVY PURSE is the amount set apart in the civil list (*q.v.*) for the private and personal use of the sovereign in England. During the reign of Queen Victoria it was £60,000 a year, but on the accession of Edward VII the amount was fixed at £110,000 a year, which was the amount paid to the last sovereign (William IV) who had a queen consort. Under Queen Victoria the offices of keeper of the privy purse and private secretary were combined.

These officials, with their subordinates, are of the king's personal staff.

PRIZE, in law, may be defined as the vessels or goods of the enemy or of a neutral, or of a subject of the captor's own state or of a subject of an ally, captured *jure belli* by a belligerent captor on the high seas, or in rivers, ports and harbours and even in some circumstances on land (*see* *Roumanian*, 1914, I.B. & C.P.C. 75). For England the term "vessels" includes merchantmen, lighters, rafts, tugs, boats and all other naval craft together with their appointments, such as signalling instruments (*see* the *Anichab*, 1919, 3 B. & C.P.C. 611; 1922, A.C. 235). The term "goods" includes "cargoes" which covers "choses in action" (*see* CHOSE) (the *Fredrick VIII*, p. 43, 1917); "bonds and securities" (the *Noordam* [No. 2], 1920, A.C. 904); and "moneys" (*Turkish moneys taken at Mudros*, 1916, 2 B. & C.P.C. 336). Not only goods shipped under a bill of lading (*Ten Bales of Silk at Port Said*, 1916, 2 B. & C.P.C. 13), but also goods dispatched by parcel post are carried by the term (*see* the *Tubantia*, 1916, L.R.P.C. 282). The property in prize does not pass to the captor until it has been brought within the jurisdiction and adjudicated upon. But the property in captured warships passes, on capture, to the captor, and they are only brought into the prize court in order that the prize money may be determined.

United States.—The term prize is "used as a technical term to express a legal capture." (*Miller* v. *The Resolution*, 1781, 2 Dallas Reports, 1.) The courts "assume that 'capture' and 'prize' are not convertible terms, and that for the subject of capture to be made prize for the benefit of the captors the taking must meet the conditions imposed by the statutes." (*The Manila Prize Cases*, 1903, 188 U.S. Reports, 254.)

Captures made on inland waters of the United States are not "liable to condemnation as maritime prize." (*The Cotton Plant*, 1870, 10 Wallace Reports, 577.) The act of congress of July 17, 1862, "excludes property on land from the category of prize for the benefit of the captors." (*United States* v. *Alexander*, 1864, 2 Wallace Reports, 404.) The word "ship," however, "embraces her boats, tackle, apparel and appurtenances because part of the ship as a going concern, and, for the same reason, ship or vessel of war includes her armament, search-lights, stores, everything, in short, attached to or on board the ship in aid of her operations." (*The Manila Prize Cases*, 1903, 188 U.S. Reports, 254.) Nonsea-going boats such as barges propelled by sweeps and by poling and boats having no means of propulsion are not regarded as maritime prize. (*Ibid.*) The United States long argued for the exemption from capture of private property at sea, but this doctrine was not accepted by other states or by the courts. The United States abolished prize money by an act of March 3, 1899. (30 U.S. Stat. 1007.)

Other Countries.—The French prize court will not adjudicate on the validity of captures of warships or on captures effected on lakes or other inland waters. Otherwise, prize covers the same property as in England. In Italy prize extends to captures on the high seas and inland waters which include captures in ports, quays, docks and other places in which maritime traffic is carried on. According to the German Prize code, 1909, prize includes enemy and neutral vessels and goods thereon, but not neutral public vessels. Enemy public vessels are confiscatable without other proceedings. German ships and cargoes and German goods on neutral or enemy vessels are excluded. During World War I the German prize courts declared themselves incompetent if the prize was destroyed without being first captured. Thus, claimants were deprived of their legal remedy for the sinking at sight of their vessels, which was contrary to the accepted customs of war.

PRIZE COURTS AND PRIZE LAW. In England the admiralty court had jurisdiction in matters of prize from very early times, and although since the middle of the 17th century the *instance* or ordinary civil jurisdiction of the court has been kept distinct from the *prize* jurisdiction, they were originally both administered and regarded as being within the ordinary jurisdiction of the lord high admiral. The early records of the admiralty show that the origin of the prize jurisdiction is to be traced to the power given to the court of the admiral to try cases of piracy and "spoil"; *i.e.*, captures of foreign ships by English ships.

Although the courts of common law hardly ever seem to have interfered with or disputed the admiralty prize jurisdiction, its

exclusive nature was not finally admitted till 1782; but long previously royal ordinances (1512, 1602) and statutes (1661, giving an alternative of commissioners, 1670, 1706) had given the admiralty court the only express jurisdiction over prize. The statute of Anne and acts of 1739 and 1744 give prize jurisdiction to any court of admiralty, including the courts of admiralty for the colonies and plantations in North America.

Prior to the Naval Prize Act 1864, it was necessary for the Crown to confer prize jurisdiction upon the admiralty court by a special commission at the commencement of a war; this practice although no longer necessary has, however, been continued since on the outbreak of every war (*see* the *Zamora,* 1916, A.C. 77 96). By the Naval Prize Act 1864, the high court of admiralty and every admiralty or vice-admiralty court, or any other court exercising admiralty jurisdiction in British dominions, if for the time being authorized to exercise prize jurisdiction, were made prize courts. The high court of admiralty was given jurisdiction throughout British dominions as a prize court, and, as such, power to enforce any order of a vice-admiralty prize court and of the judicial committee of the privy council in prize appeals—this power *mutatis mutandis* being also given to vice-admiralty prize courts. An appeal was given from any prize court to the sovereign in council. Prize courts were given jurisdiction in cases of captures made on land by naval or joint naval and military forces or an expedition made conjointly with allied forces, and power to give prize salvage on recaptured ships and prize bounty; and a form of procedure was prescribed. The high court was also given exclusive jurisdiction as a prize court over questions of ransom and petitions of right in prize cases, and power to punish masters of ships under convoy disobeying orders or deserting convoy. By the Naval Discipline Act 1866, power to award damages to convoyed ships exposed to danger by the fault of the officer in charge of the convoy was also given to the high court. Under other statutes it had power to try questions of booty of war when referred to it by the Crown, in the same way as prize causes, and claims of king's ships for salvage on recaptures from pirates, which could be condemned as *droits* of admiralty, subject to the owner's right to receive them on paying one-eighth of the value, and also power to seize and restore prizes captured by belligerents in violation of British neutrality, or by a ship equipped in British ports contrary to British obligations of neutrality.

All jurisdiction of the high court of admiralty has since passed to the High Court of Justice, which is made a prize court with all the powers of the admiralty court in that respect; and all prize causes and matters within the jurisdiction of that court as a prize court are assigned to the probate, divorce and admiralty division; and an appeal from it as a prize court lies only to the king in council (Judicature Acts 1873 and 1891).

By the Prize Court Act 1894 further provision is made for the constitution of prize courts in British possessions. A commission, warrant or instruction from the Crown or the admiralty may be issued at any time, even in peace; and upon such issue, subject to instructions from the Crown, the vice-admiral of the possessions on being satisfied by information from a secretary of State that war has broken out between Great Britain and a foreign State, may make proclamation to that effect, and the commission or warrant comes into effect. The commission or warrant may authorize a vice-admiralty court or colonial court of admiralty to act as a prize court, or establish a vice-admiralty court for that purpose, and may be revoked or altered at any time.

By 4 and 5 Geo. V. c. 13 the provisions of the act of 1864 specified in the schedule to the act of 1914 relating to practice and procedure were repealed and rules in substitution in pursuance of 57 and 58 Vict. c. 39, s. 3, were made by Order in Council, with the proviso that nothing shall extend s. 16 of the act of 1864 to ships of war taken a prize, see *Rules of Court in Prize Proceedings, Order in Council, Aug. 5, 1914,* which were subsequently amended by Order in Council issued as "Statutory Rules" on Nov. 28, 1914; Feb. 3, 1915; April 29, 1915; and Dec. 21, 1917.

British Prize Law.—The law to be administered by British prize courts is laid down in the commissions issued from time to time to the lord high admiral (now the lords of the Admiralty) "to empower the high court of admiralty (now the High Court of Justice and the judges thereof) to take cognizance of and judicially proceed upon all and all manner of captures, seizures, prizes and reprisals of all ships, vessels and goods that are or shall be taken, and to adjudge and condemn the same according to the course of the admiralty and law of nations; as also ships and goods liable to confiscation pursuant to the respective treaties with His Majesty and other princes and States" (Burchett's *Naval History,* 1719). The "course of the admiralty" was understood to mean the maritime law and customs of the sea, as recognized and applied by the maritime nations of Europe. "The law of nations" was wider. It included also treaties, the decisions of courts and the writings of jurists. Later it included international conventions, such as the Geneva Convention of 1906, Hague Conventions of 1899 and 1907, the Declarations of Paris 1856, and London 1909. Consequently British prize courts are bound to administer international law, but since they are municipal courts drawing their authority from the king in the parliament, they are bound by an act of parliament, even if it be contrary to the law of nations. They are not, however, bound by Orders in Council although they will act on them when they amount to a mitigation of the rights of the Crown in favour of the enemy or neutral (*see* the *Zamora,* 1916, 2 A.C. 77; 2 B. & C.P.C. 1). Precedents are followed, but not blindly. As Sir Samuel Evans said in the *Odessa* (1914) 1 B. & C.P.C. at p. 175, they "should be treated as guides to lead and not as shackles to bind." By the Prize Court Rules 1914, captors may support their case by any evidence derived from extrinsic sources. In many cases of continuous voyage, for instance, it was only possible to detect and prove contraband trading by the interception of letters, cables and wireless messages.

See also *Prize Cases Decided in the United States Supreme Court, 1789–1918* (1923). (X.)

The United States.—The Constitution of the United States vests the judicial power of the United States "in one Supreme Court and in such inferior courts as the Congress may from time to time ordain and establish." The judicial power shall extend "to all cases of admiralty and maritime jurisdiction" and the Supreme Court has appellate jurisdiction in prize cases. (Constitution, Art. III.) The Federal district courts have original jurisdiction "of all prize brought into the United States; and of all proceedings for the condemnation of property taken as prize." (42 U.S. Stat. 634.)

Art. I., section 8, of the Constitution provides that Congress shall have power "to declare war, grant letters of marque and reprisal and make rules concerning captures on land and water." Under this provision Congress has from time to time acted. On Jan. 15, 1780, even before the Constitution was adopted, it was resolved that a court of appeal be established which should hear appeals "in case of capture." The U.S. courts in the early days followed the recognized precedents as Mr. Justice Wilson said in 1796: "When the United States declared their independence, they were bound to receive the law of nations, in its modern state of purity and refinement." (*Ware* v. *Hylton,* 3 Dallas, 199.)

This applied to maritime capture as was said by Chief Justice Marshall in 1815: "The law of nations is the great source from which we derive those rules, respecting belligerent and neutral rights, which are recognized by all civilized and commercial states throughout Europe and America." (*Thirty Hogsheads of Sugar* v. *Boyle,* 1815, 9 Cranch, 191.) An early decision, in 1795, had said: "A prize court is, in effect, a court of all the nations in the world, because all persons, in every part of the world, are concluded by its sentences, in cases clearly coming within its jurisdiction." (*Penhallow* v. *Doane,* 1795, 3 Dallas, 54.) Mr. Justice Story in 1815 stated in the opinion of the Supreme Court: "The Court of Prize is emphatically a court of the law of nations, and it takes neither its character nor its rules from the mere municipal regulations of any country." (*The Adeline,* 9 Cranch, 244.) The aims of prize courts from the American point of view were stated from time to time by the Supreme Court in later decisions, as in 1882, when Justice Gray said: "Prize Courts are not instituted to determine civil and private rights, but for the purpose of trying judicially the lawfulness of captures at sea, according to the

principles of public international law, with the double object of preventing and redressing wrongful captures, and of justifying the rightful acts of the captors, in the eyes of other nations." (*Cushing* v. *Laird*, 107 U.S. 69.)

The United States has also negotiated many treaties with the States of Central and South America which contain articles similar to the following of 1887 with Peru:—

Article XXV.

It is further agreed, that in all prize-cases, the courts especially established for such causes in the country to which the prizes may be conducted shall alone take cognizance of them. And whenever such courts of either party shall pronounce judgment against any vessel, merchandise, or property claimed by the citizens of the other party, the sentence or decree shall set forth the reasons or motives on which the same shall have been founded; and an authenticated copy of the sentence or decree, and of all the proceedings connected with the case, shall, if demanded, be delivered to the commander or agent of the said vessel, merchandise, or property, without any excuse or delay, upon payment of the established legal fees for the same. (25 U.S. Stat. 1444.)

In 1900 the Supreme Court, speaking through Justice Gray in regard to exemption of coast fisheries in time of war, said: "This rule of international law is one which prize courts, administering the law of nations, are bound to take judicial notice of, and to give effect to, in absence of any treaty or public act of their own government in relation to the matter." (*The Paquete Habana*, 175 U.S. 677.) In this same case it was said:—

"International law is part of our law, and must be ascertained and administered by the courts of justice of appropriate jurisdiction, as often as questions of right depending upon it are duly presented for their determination. For this purpose, where there is no treaty, and no controlling executive or legislative act or judicial decision, resort must be had to the customs and usages of civilized nations; and, as evidence of these, to the works of jurists and commentators, who by years of labour, research and experience, have made themselves peculiarly well acquainted with the subjects of which they treat. Such works are resorted to by judicial tribunals, not for the speculations of their authors concerning what the law ought to be, but for trustworthy evidence of what the law really is." (G. G. W.)

Other Countries.—The French court is an administrative not a judicial tribunal, with a *conseiller d'État* as president and six members chosen from the *maîtres des requêtes* and officials of the Ministries of Marine and Foreign Affairs. An appeal lies to the *conseil d'État*. The law is contained in treaties, national laws and decrees, custom and practice and in decisions of the prize courts. The latter are not regarded as binding and are not followed if they would entail inconvenient or inequitable results. The law has been codified in the "Instructions to Naval Officers" of Dec. 9, 1912 and Jan. 10, 1916 (see *Revue générale de Droit Inter. Public*, vol. 25, 1918; Fauchille, *Jurisprudence Française en Matière de Prises Maritimes*, 1919). Prize courts were established in Belgium during the World War. The court of first instance consists of two judges of the court of appeal and four members representing the navy and commerce. In cases exceeding 20,000 francs an appeal lies to the court of appeal, Brussels. The law administered is similar to that in France. The Italian prize court is also only partly judicial. It is composed of members appointed on the recommendation of the Ministries of Justice, Marine and Foreign Affairs. Appeal lies to the Supreme Court of Cassazione. The law administered is that contained in the law merchant and the naval instructions, the latest of which were issued on March 25, 1917. The court is bound by decrees duly promulgated (*see* Fauchille and Basdevant, *Jurisprudence Italienne en Matière de Prises Maritimes*, 1918). In Portugal the tribunal of commerce at Lisbon enjoys jurisdiction in prize automatically. Appeals lie to the Supreme Court of Justice.

During the World War prize courts were established for the German empire at Hamburg and Kiel composed of a judge as president and one legal member, a naval officer and two members representing shipping and commercial interests. Appeal lay to the superior court of prize sitting in Berlin, consisting of three judges, a naval officer and two lay members representing shipping and commercial interests. The law to be administered is contained in the prize code (*Prisenordnung*) of Sept. 30, 1909, and the prize court ordinance (*Prisengerichtsordnung*) of April 15, 1911, both of which were promulgated on Aug. 3, 1914, the latter being amended by an ordinance of March 26, 1916. By article 440 of the Treaty of Versailles, 1919, the Allied and Associated Powers reserved the right to examine all decisions and orders of the German prize courts whether affecting their own subjects or those of a neutral Power (*see* Fanchille and De Visscher, *Jurisprudence Allemande en Matière de Prises Maritimes*, 1922).

During the World War, prize courts were established by the Russian Government at Sebastopol, Kronstadt and Vladivostock. Each court was composed of an official of the Maritime Judicial Administration, two naval officers, two officials nominated by the minister of justice and one by the Foreign Office. An appeal lay to the admiralty council. The law to be administered was that contained in the prize code of 1895, amended in 1904 and revised in 1914. By an imperial ukase of Sept. 1, 1914, the Declaration of London, subject to some modifications, was declared obligatory and was, subject to some further modifications, applied by the courts. The Japanese prize court at Sasebo was composed of a judge as president and eight councillors selected from the navy and from the naval, legislative, foreign and diplomatic departments. Appeals lay to the higher prize court at Tokyo composed of a privy councillor and eight councillors. The law administered is contained in the Regulations issued in 1894, 1904 and 1914. The latter enacted that the principles of international law should be applied, subject to any national law, regulation or treaty, and in any event to reciprocal treatment (see *Rules of Naval War of Japan; Bulletin de l'Institut Intermédiaire International*, vol. XI. p. 9, 1924; Hurst and Bray, *Russian and Japanese Prize Cases*, 1912). By the Chinese Prize Courts Rules of Oct. 30, 1917, district prize courts were established with a personnel similar to that of the Japanese courts. An appeal lay to the high prize court composed of the president of the Supreme Court and eight members, representatives of the judicial, naval and administrative departments. The law to be administered is contained in the Chinese Prize Court Rules and Regulations, and when these are silent in the "law, treaties and international usage." The Hague Conventions II. and VI. were found by the courts to be binding (see *Chinese White Book*, 1918; F. T. Cheng, *Judgments of the High Prize Court of China*, 1919). Prize courts were established in Siam by the law of July 20, 1917. It was held by the Bangkok prize court that the law to be administered was the law of nations and not the municipal law (see *Reports of Prize Decisions* in the Fry library, London School of Economics).

An International Prize Court.—After much discussion, more particularly by the Institute of International Law and the International Law Association, a Convention for the institution of an international prize court was adopted by the Hague Peace Conference of 1907. By Convention XII. the court was to be a court of appeal from the prize court of a belligerent captor "upon the ground that the judgment was wrong either in fact or in law." In the absence of a treaty by the parties to the proceedings the court was to apply the rules of international law, and if no generally recognized rule existed, the court was to give judgment in accordance with the general principles of justice and equity. Owing, however, to the alleged uncertainty of the law the Convention was not ratified by any of the Powers, and a naval conference was held in London in 1908 for the purpose of codifying "the acknowledged principles of international law." The resulting Declaration of London purported to embody these principles in the rules which it formulated on blockade (*q.v.*), contraband (*q.v.*), unneutral service, destruction of neutral prizes, transfer to a neutral flag (*see* NEUTRALITY), enemy character, convoy (*q.v.*) resistance to search (*see* VISIT AND SEARCH), compensation.

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PRIZREN, a town of S. Serbia, Yugoslavia. Pop. (1931), 18,952, chiefly Albanians, with some Serbs, Greeks and Vlachs.

Prizren is beautifully situated 1,424 ft. above sea level among the Shar Planina mountains, and has an excellent water supply. The city is the seat of a Roman Catholic Archbishop, and a Greek bishop, and there is also a Serbian theological seminary. Its chief buildings are the citadel and many mosques, one of which is an ancient Byzantine basilica, originally a Serbian cathedral.

Prizren has sometimes, though on doubtful evidence, been identified with the ancient *Tharandus* or *Theranda*. In the 12th century it was the residence of the kings of Serbia. From the 13th century to the 16th Prizren had a flourishing export trade with Ragusa. The town was taken by the Serbians in 1912, and assigned to them by the Treaty of Bucharest (1913). Soon after the outbreak of World War I the government and the Serbian army retired there, followed by thousands of homeless refugees. Italy occupied Prizren during World War II.

PRJEVALSKY [PRZHEVALSKY], **NIKOLAI MIKHAILOVICH** (1839–1888), Russian traveller, born at Kimbory, in the government of Smolensk, on March 31, 1839. He was educated at the Smolensk gymnasium, and in 1855 became a subaltern in an infantry regiment. In 1856 he became an officer, and four years later he entered the academy of the general staff. From 1864 to 1866 he taught geography at the military school at Warsaw, and in 1867 was admitted to the general staff and sent to Irkutsk, where he explored the highlands on the banks of the Usuri. This occupied him until 1869, when he published a book on the Usuri region, partly ethnographical in character. Between Nov. 1870 and Sept. 1873, accompanied by only three men, he crossed the Gobi desert, reached Peking, and explored the Ordos and the Ala-shan, as well as the upper part of the Yangtsze-kiang. He also penetrated into the then closed country of Tibet, reaching the banks of the Di Chu river.

On his second journey in 1877, while endeavouring to reach Lhasa through east Turkestan, he re-discovered the great lake Lop-nor (*q.v.*). On his third expedition in 1879–80 he penetrated, by Hami, the Tsai-dam and the great valley of the Tibetan river Kara-su, to Napchu, 170 m. from Lhasa, when he was turned back by order of the Dalai Lama. In 1883–85 he undertook a fourth journey in the mountain regions between Mongolia and Tibet. On these four expeditions he made valuable collections of plants and animals. He discovered the wild camel and the early type of horse, now known by his name (*Equus prjewalskii*). In Sept. 1888 he started on a fifth expedition to Lhasa, but on Nov. 1 he died at Karakol on Lake Issyk-kul. A monument was erected to his memory on the shores of the lake, and the town of Karakol (*q.v.*) was renamed Przhevalsk.

The English translation of the account of his first journey, *Mongolia, the Tangul Country, and the Solitudes of Northern Tibet* (1876) was edited by Sir Henry Yule; the account of his second journey, *From Kulja, across the Tian-Shan, to Lop-nor*, was translated into English in 1879.

PROA (Malay, *prau*), the general term in the Malay language for all vessels, from the *sampan* or canoe to the square-rigged *kapal*, but in western usage confined to the swift-sailing craft that the pirates of the Indian Ocean made familiar to sailors in eastern waters. The chief points which characterize these vessels are that while the weather-side is rounded the lee-side is flat from stem to stern, that both stem and stern are exactly similar in shape, and that there is a small similarly shaped hull swung out from the side of the main hull on poles, which acts as an outrigger and prevents the vessel heeling over. The main hull carries the mast rigging and an enormous triangular-shaped sail.

PROBABILISM, a term used both in theology and in philosophy with the general implication that in the absence of certainty probability is the best criterion. Thus it is applied in connection with casuistry for the view that the layman in difficult matters of conscience may safely follow a doctrine inculcated by a recognized doctor of the church. This view was originated by the monk Molina (1528–1581), and has been widely employed by the Jesuits. In philosophy the term is applied to that practical doctrine which gives assistance in ordinary matters to one who is sceptical in respect of the possibility of real knowledge: it supposes that though knowledge is impossible a man may rely on strong beliefs in practical affairs. This view was held by the sceptics of the New Academy (*see* SCEPTICISM and CARNEADES). Opposed to "probabilism" is "probabiliorism" (Lat *probabilior*, more likely), which holds that when there is a preponderance of evidence on one side of a controversy that side is presumably right.

PROBABILITY (in Logic) is commonly contrasted with certainty. Some of our beliefs or judgments are entertained with certainty, others there are of which we are not so sure. The degrees of confidence with which the logic of probability is concerned are those which are correlated with different kinds of objective evidence, different degrees of objective cogency, not with the confidence which depends on mere feeling, or arises we know not how. In other words, we are concerned with degrees of *rational* belief or confidence. Again, the degrees of confidence attach to the beliefs or the judgments, or the propositions expressing the beliefs or judgments, so that strictly speaking the probability refers to the judgments or propositions, not to the things or events to which these refer. Things just are, and events just happen—there is no certainty or probability in *them*. Only our judgments about them can be more or less probable.

Cases of calculable probability are of two main types, namely, those which can be calculated *a priori*, or deductively, and those which can only be calculated *a posteriori*, or inductively. The *a priori* type is that in which the calculation can be made by reasoning deductively from the nature of the case, and without reference to actual observations of the kind of events under consideration. The *a posteriori* type consists of those cases in which the calculation can be made only with the aid of previous observations of similar events.

The A Priori Calculation of Probability.—In order to be able to calculate the probability of an event deductively from the nature of the case, the following conditions must be satisfied: (*a*) We must know the total number of mutually exclusive possibilities, one or other of which must be realized. (*b*) These possibilities must be equally likely. And (*c*) we must know how many of these possibilities are favourable to the event contemplated, that is, in how many of them it will be realized. The probability of the event in question is then expressed by means of a fraction in which the numerator gives the number of possibilities favourable to the event, and the denominator states the total number of equally likely possibilities. Clearly, the greater the total number of possibilities, the smaller is the probability (or chance) of any special one of them being realized; that is, if p represents the probability of an event and t the total number of equally likely events of which it is one, then p and t will vary inversely. For example, the chance of throwing head when tossing a coin is greater than that of throwing face six when throwing a die, because the former result is one of two possibilities, whereas the latter is only one of six. On the other hand, the greater the number of possibilities that are favourable, the greater is the probability. For instance, when throwing a die the probability of getting an even number is greater than that of throwing face six in particular, because there are three even numbers and only one six on a die. In this way, if the number of favourable possibilities be represented by f, we get the following general formula for probability: $p=f/t$.

A word may also be said about "odds" and "chances," terms which are more in popular favour than is the term "probability." The term "chances" is used sometimes for "probability" and sometimes for "odds." By "odds" is meant the ratio of favourable to unfavourable possibilities. By the odds *against* an event is meant the ratio of the unfavourable to the favourable possibilities.

In the case of simple events, like those of throwing a die or tossing a coin, there is no difficulty whatever in determining the values of favourable possibilities and of the total number of equally likely events and therefore of probability. With complex events (that is, those in which two or more separate events can be distinguished) care has to be exercised. The total number of possibilities in such cases is not the *sum* of the possibilities of the separate events, but their multiple, *e.g.*, if a die is thrown twice the total number of possibilities is not 6+6, but 6×6 or 36, because for *each* possible result of the first throw there are six possibilities with the second throw. Now, the probability of a complex event

may, according to circumstances, be either greater or less than the probability of the separate component events. The probability is less if the complex event contemplated is one in which certain component events must occur in a certain order, say *1* followed by *6* in two throws of a die, for either of the component events might happen without the other also happening, and then one of the component events would be there but not the compound event. In such cases the probability is obtained by multiplying the fractions expressing the separate probabilities of the several component events. On the calculations of probability *see* PROBABILITY AND ERROR.

Equally Likely Possibilities.—Why is it stipulated that the alternative possibilities must be equally likely? The point can be made clear by comparing two simple cases. Suppose one were to argue that a properly balanced coin when tossed must either throw head or not, so that there are two alternatives, of which head is one, and therefore its probability must be *1/2*. The answer would be true, but the reasoning would be wrong, as may be seen from the next case. Suppose one were to argue that a properly constructed die, when thrown, must either show face six or not, so that there are two possibilities of which face six is one, and therefore its probability is *1/2*. Here the answer is obviously wrong. But why? Because the possibility "not-six," that is, of face six not showing, really represents five different possibilities against the one "six," and must therefore be weighed accordingly as having a value five times that of "six." The probability of "not-six" is really *5/6*, while that of "six" is *1/6*. It was a mere accident that in the case of the coin "not-head" happened to represent only one alternative, namely, "tail." If no attention were paid to the equality of the alternative possibilities, then any statement, the truth of which we are not in a position to judge, would be judged to be as likely to be true as not—some logicians have actually assigned it a truth-probability of *1/2*! It would be just as accurate to say that there is a probability of *1/2* that an unknown marksman will hit the bull's eye—an absurd estimate when it is remembered that there are innumerable places, on and off the target, which are all included under "not bull's eye" as against the very limited area of "bull's eye." If the available data are insufficient, why estimate the probability at all? Why not suspend judgment? There is no particular virtue in emulating Bagehot's village maiden who must have an opinion about everything under the sun.

The next question is, how is one to make sure whether the alternative possibilities really are equally likely, or at least approximately so? Sometimes this is not very difficult to determine. In the case of a coin, or a die, *e.g.*, it is not impracticable to examine them sufficiently closely and ascertain whether or no they are properly balanced. And if properly balanced, the possibilities which they offer would be adjudged to be equally likely. But suppose one cannot be sure. Is there not some other way of testing the equality of the possibilities? Well, there is—namely, by actually tossing the coin, or throwing the die, a great many times, and noting the results. If, on an average, each side of the coin, or of the die, appears approximately an equal number of times, then the alternative possibilities would be regarded as equally likely. But the significance of this kind of test must be noted carefully, if only because of its bearing on the inductive, or *a posteriori* calculation of probability.

This kind of test is not direct but indirect, or inverse, in the sense in which induction is said to be inverse deduction. The logic of the test is this. We argue that if the possibilities represented, say, by the several faces of the die, are really equally likely, then when the die is cast a sufficiently large number of times, each face should, on an average, and in the long run, appear approximately once in six throws. This rate of appearance is called its *frequency*. So that this mode of procedure may be described as consisting in testing the equality of the possibilities by reference to the frequency which seems to be implied in the probability calculated on the assumption of their equality.

Now, in calculations of probability, "frequency" and "probability" are so frequently identified or confused that it is important to mark their difference. When the *a priori* probability, say, of face six appearing when a die is cast, is given as *1/6*, what this really means is that "the appearance of face six is one of six equally likely possibilities"; and so always *f/t* simply has reference to possibilities, which may never be tested at all. One never thinks of adding the expression "in the long run" to the fraction expressing a probability. On the other hand, when a frequency is stated, even or especially when it is expressed by the same fraction as the corresponding probability, the phrase "in the long run" is essential, otherwise the frequency given would be wrong, in view of the series of long runs of some one number, which are so common.

We may now turn to the *a posteriori* calculations of probability, a method the true character of which has already been suggested in the preceding remarks.

THE A POSTERIORI CALCULATION OF PROBABILITY

In many and most important cases, it is impossible to calculate the probability *a priori*, because the alternative possibilities cannot be regarded as equally likely. Take, for instance, the case of a sick man. What is the probability of his recovery from his illness? This cannot be calculated *a priori*. It is true, of course, that there are only two alternatives—either he will recover or he will not. But these two alternatives cannot be regarded as equally likely, without special evidence. If they could be so regarded, why then the chance of recovery from cerebral meningitis would be the same as that of recovering from a common cold—which is belied by actual results. And if the alternative possibilities are not equally likely, as indeed they are not, then the probability cannot be estimated *a priori*. How, then, shall it be calculated? Well, it can still be calculated *a posteriori* if the results of a sufficiently large number of cases have been observed, that is to say, if we know the *frequency* of the type of case under consideration. For then, just as it is possible, as we have seen it is possible, to derive the frequency of an event from its probability, where the probability can be calculated *a priori*, so it is possible *by a reverse process* to derive the probability of an event from its observed frequency, even in cases in which the probability cannot be obtained *a priori* at all. Suppose, for instance, that, in the above-mentioned case of the die, face six did not in the long run appear in approximately one out of six throws, but, say in one out of nine throws. Then by treating this frequency as an index to its probability we should say that the probability of face six turning up is *1/9*, which means that it behaves *as if* it had an *a priori* probability of *1/9*, or as if it had been one of nine equally likely possibilities—which, of course, it is not. In this way, provided we have sufficient data to determine their frequency, the calculus of probability can be applied to all sorts of otherwise incalculable events, such as birth, marriage, death, and the thousand and one ills that flesh is heir to.

Writers on probability are frequently inclined to regard the *a posteriori* method of calculating probability as the fundamental method. They would either like to banish *a priori* calculations altogether or only tolerate them as more or less intelligent anticipations, or frequencies. But this theory (known as the frequency theory) of probability is hardly tenable. Frequencies show considerable variations with the number of cases observed, *e.g.*, when tossing a coin the proportion of heads to tails varies remarkably, accordingly as one stops at the 100th, 1,000th, 10,000th or 20,000th toss. One might obtain almost any proportion by stopping at the right moment. Hence the need of the saving clause "in the long run"—*in the long run* a die will throw six in one of the six throws, and so on. Even so the element of arbitrariness is not entirely disposed of. As here conceived, the fundamental form of the calculus of probability is the *a priori* form, of which, as already explained, the *a posteriori* method is simply an inverse process, which treats frequency as a measure of probability, although the two are really different things. There is nothing unusual in the use of the inverse process, or the resort to "as if" fictions. Our view of the calculable cases of probability makes it possible to keep together all types of probability without any artificiality or straining. In all cases alike the uncertainty arises from the presence of other possibilities than those contemplated.

In some cases these other possibilities can be allowed for by some direct or indirect calculation; in other cases they cannot be estimated at all, except in a very rough and unpractical manner. On the other hand, the frequency theory of probability does not really apply to non-measurable cases. Even in its modified form, in which frequency is taken to mean the truth-frequency of certain classes of propositions, it seems unsatisfactory. One is asked to determine the probability of a judgment by ascertaining the probability of the class of propositions to which it belongs. But suppose the proposition cannot be assigned to its proper class unless its probability is known?

The Use of the Calculus of Probabilities.—One may ask, in conclusion, what is the practical use of calculations of probability? Some people have exaggerated ideas on the subject. The exaggeration is due in great part to the common confusion of probability with frequency. Frequencies, when treated with the necessary precautions, may be of great practical value when we are dealing with large numbers of facts of the same kind. This is evident from their use in connection with all varieties of insurance schemes, etc., in which the certainty of large numbers can be relied upon to atone, in some ways, for the uncertainty in the lot of the individual. But whereas frequencies are always concerned with large groups, or with long series of events, or with what happens "in the long run," probability is also concerned with individual cases, or small groups of events. This makes all the difference, as may be seen, say, in roulette. The bank, doing business with a great many players, can rely on frequencies. The individual player, limited to a comparatively small number of hazards, relies on the ambiguous calculus of probability (when he is not guided by sheer superstition). The calculus is always right, even when the player loses. For the actual events are matters of frequency, not of mere probability. There are ingenious gambling systems based on frequencies; but even these systems have their day and cease to be. The best of them depend on "the long run," which easily outruns the resources of the average individual. For similar reasons, even in legitimate insurance business, the company has a great advantage over the individual client. But the practical exigencies of life induce responsible individuals to prefer high risks for comparatively small amounts rather than small risks for large amounts. No mere calculation can eliminate the uncertainty of the probable when individual cases are involved. Here, in the last resort, the only safe, or least unsafe, method of ascertaining its probability consists in a close examination of the actual conditions by a suitable expert. Even life insurance companies probably put more faith in the medical report on each case than in their statistical life-tables.

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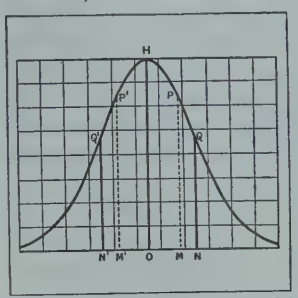
PROBABILITY AND ERROR. The theory of probability is that branch of mathematics which deals with the objective numerical measurement of probability. The theory of error, or the consideration of the frequency-distribution of errors, is the main link between the theory of probability and the theory of statistical frequency.

THEORY OF PROBABILITY

1. Rough estimates of relative probability are often easily made. I draw a ball from a box containing one red ball and four white ones: if I say that I am more likely to draw a white than the red, the statement is intelligible. But can I be more precise? Can I give a numerical measure to the probability of drawing the red ball?

A question of this kind might perhaps be parried by the question: Why should anyone want a numerical measure of the probability? The answer may be, in some cases, that it is a matter of scientific interest; or it may be, in other cases, that questions of this kind are important in games of chance. The study of the theory of probability was, in fact, in the first instance, the scientific study of gambling; though the primary question was not the numerical measure of a chance but its money value. Suppose, in the case of the five balls, that I am to receive £50 if I draw the red ball, but nothing if I draw a white; then (subject to certain conditions) my chance is worth £10. This suggests a numerical measure of probability. Suppose there is a prize W in a lottery, and my chance of winning it is worth V; then V is pW, where p is some fraction between 0 and 1. If the prize W were doubled, the conditions remaining the same, the value V of the chance would be doubled, and so on. Thus, the conditions of the lottery remaining the same, V bears a constant ratio to W; and this ratio, which is a fraction between 0 and 1, might be called the chance, or probability, of my winning the prize. The value of my chance is then found by multiplying the prize by this chance or probability. This definition, however, is not entirely satisfactory; for, the value V being based on, at best, a general agreement, its ratio to W cannot be regarded as a definite objective measure. We need some method of measurement that is based on facts, not on opinions. Two methods have been suggested (secs. 2 and 4).



STANDARD NORMAL FIGURE OF FREQUENCY
The relative frequencies of deviations are from the mean value, ON or N'O representing the "standard deviation." The ordinates M' P', OH, MP divide the area of the figure into four equal portions

2. **Unitary Method.**—The first method to be considered involves a definition which is stated in various ways, but can perhaps be best stated as follows. If an event will happen in one, and only one, of c ways, all of which are equally likely, and if a of these ways are called favourable, then the probability or chance of the event happening favourably is a/c. Thus, in the case of a ball being drawn from a box containing one red and four white balls, the event is the drawing of a ball, and the ways of the event happening are the drawing of a red ball and the drawing of one of the white balls; if all the balls are equally likely to be drawn, the probability of the red being drawn is 1/5, and the probability of a white being drawn is 4/5. Since the basis of the method is the supposition that the happening of the event can be subdivided under a number of ways, each of which is equally likely, and the chance of the event happening favourably is found by counting the number of the favourable ways, we can call it the *unitary* method.

3. **Defects of the Method.**—While the definition is a simple one as regards a good many problems, it has defects, of which the following may be mentioned.

(i.) It applies only to probabilities of subsequent events, not to those of concurrent or antecedent events (sec. 12).

(ii.) The phrase "equally likely" is not defined. If this means that the probabilities of the different ways are all equal, we are working in a circle. If it means that we do not see any reason why one way should occur rather than another, we are basing the definition on ignorance.

(iii.) There are a great many cases in which the possibility of an event happening cannot be split up into a number of ways all of which are equally likely, however this may be defined. If a box contains an equal number of red balls and white balls, and the red are of the same size as the white but are slightly heavier, the statement that a white is more likely to be drawn than a red is intelligible, but it is difficult to bring the case under the definition. A statement as to probability can here only have a statistical meaning, as explained in sec. 4.

4. **Statistical Method.**—The alternative to the unitary method is the *statistical* method. Suppose that an event (or fact or set of conditions, etc.) C might occur in a large number N of cases, and that whenever it might occur it would necessarily be associated with one of two or more mutually exclusive events E, E', E''...; "mutually exclusive" meaning that on each occasion only one of these events can occur. Of the total number N of cases, suppose that E would occur in pN cases, E' in $p'N$ cases,

E'' in $p''N$ cases .... Then p, p', p'' ... are said to be the probabilities of C being associated with E, E', E'' .... It is clear that $p+p'+p''+\ldots = 1$.

In reference to cases of this kind we should use the word "probability" rather than "chance," since the question is not necessarily as to the happening of some future event. The definition can be applied equally to the probability of a future or a present or a past event. The numerical probability is in each case the result of grouping the C-cases into classes according as they are associated with E or with E', etc., and taking the probabilities to be proportional to the numbers in the different classes. If, for instance, in the case considered in sec. 1, we say that the probability of the red ball being drawn is 1/5, we mean that in the long run (sec. 8), or on the average, the red ball will be drawn about once in five times.

If an event E occurs in m cases out of n, m is called the *frequency* of occurrence of E, and the ratio m/n is its *relative frequency*. Thus the probability of an event is the same thing as its relative frequency when the number of cases considered is very large.

5. **Observations on the Definition.**—The following are points in reference to the definition.

(i.) We say that the red ball will be drawn "about" once in five times, because we can never know the exact probability of any event; and it is, indeed, doubtful whether there is any exact probability of anything. We may throw a die 100,000 times, and note the number of cases in which a 6 occurs; but if we throw another 100,000 times we shall get a slightly different result. The study of variations of this kind forms part of the theory of error, which, again, is part of the general theory of frequency distributions.

(ii.) We proceed, however, as if any probability with which we are dealing has a definite value. For practical purposes, therefore, we should not use actual observations as the means for determining a probability unless we have made a fairly large number of observations; until we have done so, we may have to depend on *a priori* considerations.

(iii.) The determination of the probability of an event, on the statistical basis, involves a process of classification. A man comes to have his life insured for a year. We require, at least, to know his age. Knowing this, we put him into a certain class or category, namely, the category of men of that age; and we find that, of men of that age, 99 out of 100, on the average, survive for a year. We therefore say that his chance of surviving is 99/100. But this does not imply that there is such a thing as chance, in the ordinary sense; nor is it a statement as to the individual, as distinct from the rest of the class. We do not treat him as an individual, but as one of the class, taken at random. Further information may alter the chance. We find that he will be working in an unhealthy climate: this means a further limitation, defining more strictly the class in which he is to be placed; and so on. The ultimate probability assigned to him is the probability of survival for a year in the class in which he is ultimately placed.

6. **Illustrative Example.**—As a basis for illustration of the statistical definition, let us take a concrete case. A man being called short or tall according as his height is under or over 67½ in., suppose that, in a community in which every man has one son who attains maturity, the statistical relation between height of father and height of son, in a representative (sec. 15) 1,000 pairs of father and son, is given in Table I. This table, if our supposition is correct, provides us with various statements as to probability, of which the following are examples.

TABLE I.

(Adapted from K. Pearson and A. Lee, *Biometrika* ii. [1903], 415)

	Father short	Father tall	Total fathers
Son short	250	89	339
Son tall	215	446	661
Total sons	465	535	1,000

(i.) The probability that a father is tall is 535/1,000. (This is a short way of saying: if a father is taken at random, the probability that he will be one of the tall fathers is 535/1,000. The phrase "at random" is considered in sec. 9.)

(ii.) The probability that a son is tall is 661/1,000.

(iii.) The probability that a tall father has a tall son is 446/535.

(iv.) The probability that a short son has a tall father is 89/339.

7. **Relation Between the Two Methods.**—To some extent the two methods—unitary and statistical—supplement one another. On the one hand, as was stated in sec. 5, a priori considerations may have to be brought into account in order to obtain a rough value of a probability. On the other hand, we may use the results of experience to check our *a priori* estimate of a probability. Consider, for example, the throwing of a die. The die is approximately a cube; it has six faces, so that, on the unitary system, we should say that the chance of a 6 being thrown is 1/6, or at any rate is about 1/6. But it should be observed that what is really of importance to us, if we are frequently risking money on the throwing of a die, is not the probability, as estimated by the unitary method, of a particular face appearing, but the proportion of cases in which, in the long run, it actually does appear. If we record these, we may find that the 6 appears rather oftener than we had expected. We can then do either of two things. We can base our probability on the actual experience, or we can consider in what respect our original estimate was faulty. We must then take account of the fact that the pips of the die are hollowed out, so that the die is lighter on the 6-side and heavier on the opposite side. It would be very difficult to estimate the effect of the hollowing-out of the pips, and we should thus be driven to the statistical method, *i.e.*, to basing our probability on experience.

It will be assumed, throughout this article, that we are dealing with probability according to the statistical method. If, for example, we say that there are five balls in a box, and that they are all equally likely to be drawn, this is to be interpreted as meaning that in N drawings, where N is very large, each ball is drawn approximately $1/5 \cdot N$ times. Similarly, if it is said that the probability that a man will survive for a year is p, this is to be taken as meaning that, out of N men who would be put into the same class, the number who will survive for a year is about pN.

8. **"The Long Run" and "Series."**—The use of the phrase "in the long run," and the description of a number of events as a "series" (*e.g.*, "a Poisson series"), are not to be taken as implying a definite arrangement, in time or otherwise. We might, of course, wish to observe the succession of observations, *e.g.*, the succession of colours at roulette; but in this case the succession is the event we are observing, and the order in which the individual events occur is not relevant. Phrases such as "in the long run" merely imply that the number of cases observed is very large.

9. **Randomness.**—In the statement of a problem in probability the expression "random" or "at random" is often used. Thus, in the case of balls in a box it may be stated that "a ball is drawn at random from the box." This may be regarded as merely an indication that we are dealing with a question in probability. On the other hand, the idea of randomness is implied in any statement as to the numerical measure of a probability. When we say "If a card is drawn from a pack, the probability that it will be a court card is 3/13," we really mean "If a card is drawn at random from a pack, the probability that it will be a court card is 3/13."

10. **Addition and Multiplication of Probabilities.**—The mathematical treatment of probabilities involves the addition and multiplication of their numerical measures. These are performed according to certain rules.

(i.) The *rule for addition* is as follows. Let E and E' be two mutually exclusive events which might be associated with C, and let the probabilities of their being so associated be p and p'

respectively: then the probability that either E or E' will be so associated is $p+p'$. This follows easily from the definition.

(ii.) The *rule for multiplication* is that, if C and D are two separate events, both of which occur, and if the probability of C being associated with E is p, and if, in the cases in which C is associated with E, the probability of D being associated with G is r, then the probability that C will be associated with E and D with G is pr. For, if N is the total number of cases in which C and D both occur, the number in which C is associated with E is pN, and the number of these in which D is associated with G is $r \times pN = prN$.

For an illustration of the multiplication rule, we can have recourse to Table I. If we take a father at random (which is the same thing as taking a pair, father and son, at random, since father and son go together), the probability that he will be short is 465/1,000; and, if a father is short, the probability that he has a tall son is 215/465. Hence, if we take a pair, father and son, at random, the probability that the pair consists of a short father and a tall son is 215/1,000; which agrees with the table.

If r has the same value whether C is associated with E or not, or, to put it differently, if the probability of C being associated with E and D with G is the product of the separate probabilities of C being associated with E and D with G, the associations of C with E and of D with G are said to be *independent*.

11. **Scope.**—The earlier studies of probability led to the development of the theory of combinations and permutations; and the more simple problems of chance are largely concerned with applications of this theory. Many such problems are dealt with in text-books, as well as in previous editions of this work, and it is not necessary to give examples here. The part of the subject with which we are more particularly concerned may be taken as beginning with the theory of error, its stages being marked by the successive inclusion of frequency-distributions generally, and of correlation. Before dealing with these aspects, it is necessary to give brief consideration to the theory of probability of causes.

PROBABILITIES OF CAUSES

12. **Direct and Inverse Probability.**—Questions as to the respective probabilities of a specified event having been due to various possible causes have in the past produced a good deal of difficulty, and have been placed in a separate category as questions of *inverse* probability; questions as to probabilities of a specified cause leading to different events are then described as questions of *direct* probability. That difficulties should have arisen is not to be wondered at, as no clear definition of the probability of a cause seems to have been given: until we know what we mean by "probability," we cannot give a numerical value to it. A more serious cause of difficulty, in many cases, was the absence of sufficient information as to the antecedent probabilities of the causes themselves. The final death-blow to the classification of questions of probability under the heads of "direct" and "inverse" was given by the statistical treatment of correlation, which led to the study of probabilities of concurrent phenomena. What is the probability that a tall man has a tall wife? What is the probability that a boy who is good at arithmetic is good at composition? What is the probability that a girl with fair hair has blue eyes? Questions such as these found no place in the earlier classification. These difficulties have been met by the adoption of a statistical basis for the measurement of probability.

13. **Typical Example.**—The following may be taken as a typical question in inverse probability. A box contains 5 balls, and it is known that 1 of the balls is white and 3 are red, and that the remaining one is either white or red. A ball is drawn and is found to be white. What is the probability that the box contained 2 white and 3 red balls? It is impossible to answer this question without further information. The box has been filled in some way: the method of filling having led to the box containing 1 white and 3 red balls, we require to know the probability that it has led to the other ball being white or red, respectively. When we know this, the problem is a straightforward one.

Let us call the box a "W-box" or an "R-box" according as the other ball is white or red; and let us suppose that the probabilities, or relative frequencies (sec. 4), of W-boxes and of R-boxes are in the ratio of 3:2. Then the problem can be stated as follows. There are W-boxes containing 2 white and 3 red balls, and R-boxes containing 1 white and 4 red balls; their frequencies being in the ratio of 3:2. A box is taken at random; and a ball is drawn from it and is found to be white. What is the probability that the box is a W-box?

The ordinary method of answering the question is an application of the rule that, if an event E has happened which may be due to any one of the causes $C_1, C_2 \ldots$, and if the *a priori* probability of occurrence of the cause C_f is P_f, and if whenever C_f occurs the probability that it will lead to E is p_f, then the probability that E is due to C_f is proportional to $P_f p_f$, *i.e.*, is $P_f p_f / (P_1 p_1 + P_2 p_2 + \ldots)$. In the present case we have $P_1 = 3/5$, $P_2 = 2/5$, and $p_1 = 2/5$, $p_2 = 1/5$; whence $P_1 p_1 : P_2 p_2 = 6:2 = 3:1$, *i.e.*, the probability that the box is a W-box is $\frac{3}{4}$.

For statistical treatment, a tabular arrangement is useful, as in Table II. This table shows a representative frequency-distribution (sec. 15) for 1,000 drawings. The figures in brackets indicate the order of entry in the table. Of the total 1,000 boxes, 600 will (on the average) be W-boxes and 400 R-boxes. Of the 600 W-boxes, 240 (on the average) will give a white ball at a single drawing; of the 400 R-boxes, 80 will give a white ball. In the cases, therefore, in which a white ball is drawn, the probability of the box being a W-box is $240/(240+80) = \frac{3}{4}$.

TABLE II.

	From W-boxes	From R-boxes	From all boxes
White ball drawn	(3) 240	(3) 80	(4) 320
Red ball drawn	360	320	680
Total drawings	(2) 600	(2) 400	(1) 1,000

If the question had been "There are W-boxes containing 2 white and 3 red balls, and R-boxes containing 1 white and 4 red balls, their frequencies being in the ratio of 3:2; a box is taken at random and a ball is drawn from it; what is the probability that the ball will be white?" the question would have been a "direct" one; but the one table would have been applicable to the two questions. We have already seen this in reference to Table I. (sec. 6); the same table enables us to answer the two questions, "What is the probability that a tall father has a tall son?" and "What is the probability that a tall son has a tall father?" though one of these might be regarded as a question of direct and the other of inverse probability.

FREQUENCY-DISTRIBUTION OF ERRORS

14. **Frequency-distribution and Frequency-polygon.**—Suppose that, when an event happens, it may happen in either of two ways, which, in G. U. Yule's notation, we will call A and α; so that α is an abbreviation for "not-A." Let the event happen n times, and let the result be A in m cases and α in $n-m$ cases. Then this distribution of the n cases as m A's and $n-m$ α's is called a *frequency-distribution*. More generally, suppose that the event may be classed under the $k+1$ heads $A_0, A_1, A_2 \ldots A_k$, and that, out of the total n, the numbers coming under these $k+1$ heads are respectively $m_0, m_1, m_2 \ldots m_k$; then the distribution of the n in this way is called a frequency-distribution. The number of heads is taken to be $k+1$ because the sum of the numbers $m_0, m_1, m_2 \ldots m_k$ is necessarily n, so that if we know k of the $k+1$ numbers we know the remaining one. The numbers $m_0, m_1, m_2 \ldots$ are the frequencies of $A_0, A_1, A_2 \ldots$; their ratios to n, *i.e.*, the ratios $m_0/n, m_1/n, m_2/n \ldots$, are the relative frequencies (sec. 4).

If on a line OX we take points $M_{-1}, M_0, M_1, \ldots M_k, M_{k+1}$, at successive intervals h, and at the points $M_0, M_1, \ldots M_k$ erect ordinates $M_0P_0, M_1P_1, \ldots M_kP_k$ whose ratios to a unit of measurement U are $m_0/n, m_1/n, \ldots m_k/n$, these ordinates constitute the graph of the relative frequencies. If we draw lines

joining the points M_{-1}, P_0, $P_1 \ldots P_k$, M_{k+1}, we get a closed figure whose area (*see* MENSURATION) is

$$h(M_0P_0+M_1P_1+\cdots+M_kP_k)=hU.$$

This figure may be called the *frequency-polygon*. It is not, of course, a graph of anything; the graph of the relative frequencies consists of the ordinates. It is usual to omit the units of measurement h and U, and say that the area of the figure is 1.

15. **Representative Distribution.**—Let the probability of occurrence of A_0, considered alone, *i.e.*, its probability when the division of cases is into A_0 and not-A_0, be p_0. Then, by the definition of probability, we should expect that in a very large number N of trials the number of cases of A_0 would be about Np_0. Provisionally—for reasons which will be seen later (sec. 18)—we might similarly expect that when the smaller number n of trials is made the number of cases of A_0 would be about np_0; and similarly for A_1, $A_2 \ldots$ with probabilities p_1, $p_2 \ldots$. The frequency-distribution which gives the numbers under the heads A_0, A_1, $A_2 \ldots$ as np_0, np_1, $np_2 \ldots$ is called a *representative* distribution. The definition applies whether these numbers are integers or not. The differences between these numbers and the actual numbers m_0, m_1, $m_2 \ldots$ which occur when n individuals are taken at random are the *errors* or *errors of random sampling* of m_0, m_1, $m_2 \ldots$.

We might have defined a representative distribution as a distribution in which the numbers under the different heads are proportional to the numbers which would "in the long run" come under these heads.

16. **Law of Frequency of Error (Simplest Case).**—Denoting, as before, "not-A" by α, suppose that the probability of A is p, and that that of α is $q \equiv 1-p$. Then as the result of n trials the number of A's might be any number from n to 0, the number of α's being the remainder out of the n. What are the respective probabilities of these different numbers?

Consider the probability of m A's and $n-m$ α's. For a simple example, take $n=6$, $m=4$. Then the probability of 4 A's and 2 α's occurring in the order $AAAA\alpha\alpha$ is $pppp qq = p^4q^2$; and the probability of their occurring in any other specified order is similarly p^4q^2. But there are ${}_6C_4$ orders in which they may occur; ${}_nC_m$ denoting the number of combinations of n things m together. Hence the total probability of 4 A's and 2 α's is ${}_6C_4p^4q^2$. Similarly the probability of m A's and $n-m$ α's is ${}_nC_mp^mq^{n-m}$. Taking the values of m from n to 0, we see that the probabilities of n, $n-1$, $n-2 \ldots 0$ A's (and 0, 1, 2 $\ldots n\alpha$'s) are the successive terms in the expansion

$$(p+q)^n = {}_nC_np^n+{}_nC_{n-1}p^{n-1}q+{}_nC_{n-2}p^{n-2}q^2+\cdots+{}_nC_0q^n. \quad (16\cdot1)$$

If ${}_nK_m$ is the probability that in n trials there will be m A's and $n-m$ α's, then

$${}_nK_m = {}_nC_mp^mq^{n-m}. \quad (16\cdot2)$$

In a representative distribution of N sets of n trials the numbers of cases in the $n+1$ categories (n A's, $n-1$ A's and 1 α,...) would be found by multiplying the terms in (16·1) by N; *i.e.*, the number of cases of m A's and $n-m$ α's would be $N \times {}_nC_mp^mq^{n-m}$.

Suppose, for example, that $p=0{\cdot}6$, $q=0{\cdot}4$, $n=6$. Then it will be found that in a representative distribution of 1,000,000 cases the numbers of cases in which there are 6, 5, 4, 3, 2, 1, 0 A's would be 46656, 186624, 311040, 276480, 138240, 36864, 4096. The respective probabilities (relative frequencies in a representative distribution) are the ratios of these numbers to 1,000,000. A distribution of the above kind, showing the frequencies (theoretical or actual) with which an event happens n, $n-1$, $n-2 \ldots$ times out of n, is called a *binomial* distribution.

17. **Mean, Standard Deviation, and Mode.**—Suppose that the categories of a frequency-distribution correspond to values Y_0, Y_1, $Y_2 \ldots Y_k$ of a variable Y; thus, in the case we have just been considering, the Y's are the numbers n, $n-1$, $\ldots$ 0 of A's or the numbers 0, 1, 2 $\ldots n$ of α's. Then the *mean* value of Y is found by multiplying Y_0, Y_1, $Y_2 \ldots Y_k$ by the numbers m_0, m_1, $m_2 \ldots m_k$ in the corresponding categories, adding the results, and dividing by the total number $m_0+m_1+m_2+\ldots+m_k$; *i.e.*, if $\overline{Y}$ is the mean Y, and $m_0+m_1+m_2+\ldots+m_k=n$, then

$$\overline{Y} = (m_0Y_0+m_1Y_1+\ldots+m_kY_k)/n. \quad (17\cdot1)$$

Similarly the *mean square* of Y is the mean value of Y^2, *i.e.*, is

$$(m_0{Y_0}^2+m_1{Y_1}^2+\ldots+m_k{Y_k}^2)/n. \quad (17\cdot2)$$

The mean cube, mean fourth power, etc., are defined in the same way.

The deviation of Y from $\overline{Y}$ is $Y-\overline{Y}$. The mean square of the deviation from the mean is therefore

$$\begin{aligned}&\{m_0(Y_0-\overline{Y})^2+m_1(Y_1-\overline{Y})^2+\ldots+m_k(Y_k-\overline{Y})^2\}/n\\ &=(m_0{Y_0}^2+m_1{Y_1}^2+\ldots+m_k{Y_k}^2)/n\\ &-2\overline{Y}(m_0Y_0+m_1Y_1+\ldots+m_kY_k)/n\\ &+(m_0\overline{Y}^2+m_1\overline{Y}^2+\ldots+m_k\overline{Y}^2)/n\\ &=(\text{mean square of } Y)-2\overline{Y}\overline{Y}+\overline{Y}^2\\ &=(\text{mean square of } Y)-(\text{mean of } Y)^2. \quad (17\cdot3)\end{aligned}$$

The square root of this quantity is called the *standard deviation* or *dispersion:* in the cases in which the Y is an error, it was formerly called the *error of mean square*. The above definitions apply, and (17·3) holds good, whether we are dealing with a representative distribution or with an actual distribution.

In some cases the numbers n_0, n_1, $n_2 \ldots$ in the categories of a representative distribution gradually increase up to a value n_f and then decrease. In such a case n_f is the *maximum frequency;* and the corresponding value of Y, namely Y_f, is called the *modal value* or *mode*. Thus in the example in sec. 16 the modal number of A's is 4. There might in some cases be two or more modes; in other cases there might be none—if, *e.g.*, the frequencies decreased throughout the whole range.

18. **Mean, etc., for Binomial Distribution.**—For a representative binomial distribution (sec. 16) in which ${}_nK_m$ is the probability that in n trials there will be m A's and $n-m$ α's, it is not difficult to show that, the probability of A at each trial being p:—

(a) the mean value of m is np, that of $n-m$ being $n-np=nq$;
(b) the mean square of m is n^2p^2+npq; and therefore
(c) the standard deviation (dispersion) of m is $\sqrt{npq}$.
(d) To find the modal value of m, we have

$${}_nK_m/{}_nK_{m-1} = \frac{n-m+1}{m}\,\frac{p}{q},\quad {}_nK_{m+1}/{}_nK_m = \frac{n-m}{m+1}\,\frac{p}{q}.$$

These ratios decrease as m increases; and the first ratio will be >1, and the second <1, if $(n+1)p$ lies between m and $m+1$, *i.e.*, if m is the integral part of $(n+1)p$. Taking m to have this value, ${}_nK_m$ is greater than ${}_nK_{m-1}$ and also greater than ${}_nK_{m+1}$, *i.e.*, it is the maximum frequency. Thus in the example in sec. 16 we have $p=3/5$, $n=6$, and therefore the modal value of m is 4. If $(n+1)p$ is an integer, and we take $m=(n+1)p$, then ${}_nK_{m-1}$ and ${}_nK_m$ are equal, each having the maximum value.

19. **Errors of Frequencies of Error.**—In Sec. 16 we really began with a representative distribution, namely, that in which the number of cases of "A" was np out of a total number n; and we considered the probabilities of the various possible deviations from this distribution, *i.e.*, we considered the entries in a representative frequency-distribution of the errors. We found that the frequencies, for N sets of n trials, would be given by the terms of a certain binomial expansion, each multiplied by N. Thus the frequency of the cases of 3 A's and 3 α's, p being 0·6, would be $N \times {\cdot}276480$. But it is to be observed that this is a representative distribution: we should not expect, in any particular group of N sets of n trials, to find exactly $N \times {\cdot}276480$ of these cases, just as in n of the original trials we should not expect to get exactly np A's and nq α's. If we took $\underline{N}$ groups of N sets of n trials, we should again get errors of random sampling. But these errors become relatively less as the numbers involved become greater.

20. **Frequency for Continuous Variation.**—(i.) We have hitherto been considering the frequency of occurrence of some

definite number of events, *e.g.*, of m events out of n. This is a case of discontinuous variation, and the graph of variation is composed of a limited number of ordinates. We shall presently have to consider the class of cases in which Y is a quantity which varies continuously, the number of its possible values being indefinitely great, and the probability of occurrence of any particular value indefinitely small. For these cases we require a different treatment of frequency. Let the probability that the value of the variable lies within limits $Y \pm \frac{1}{2}dY$, *i.e.*, lies between $Y-\frac{1}{2}dY$ and $Y+\frac{1}{2}dY$, be $U'dY$; and let U be the limit of U' when dY is made indefinitely small. Then the expression of U in terms of Y is the *equation to the frequency-distribution* of Y. The graph of U with respect to Y will then be a plane figure with a continuous boundary, which can be regarded as drawn on such a scale that its area is 1. The area of the portion of this figure which lies between ordinates corresponding to any values Y_1 and Y_2 of Y will be proportional to the probability that Y lies between Y_1 and Y_2. This figure is the *figure of frequency* of Y.

To represent an actual distribution graphically, suppose that we have observed the number of cases in which Y lies between Y_r and Y_{r+1}. Let M_r and M_{r+1} be points on the base-line Oy corresponding to Y_r and Y_{r+1}. Then the ratio of this number of cases to the total number can be represented by a rectangle whose base is M_rM_{r+1} and whose area is this ratio. The aggregate of these rectangles is a figure called a *histogram:* its area is 1, *i.e.*, is the same as that of the figure of frequency. This latter figure may be regarded as the limit of the histogram of a representative distribution when the intervals M_rM_{r+1} are made indefinitely small.

(ii.) But instead of expressing U in terms of Y, we might express Y in terms of certain total probabilities. The usual method of doing this is to regard the figure of frequency as divided into 100 equal parts by ordinates: the values of Y corresponding to these ordinates, with the two extreme values of Y, are called the *percentile* values. The important values, on this system, are the *median* and the *quartile* values. If M_1P_1, M_2P_2, M_3P_3 are ordinates dividing the figure of frequency into four equal parts, the value of Y which corresponds to M_2P_2 is the median value, and the values which correspond to M_1P_1 and M_3P_3 are the quartile values.

21. **The Normal Law of Error.**—(i.) The result obtained in sec. 16 gives the true law of frequency of error for the type of case considered, namely the law that ${}_nK_m$, the probability of occurrence of m A's and $n-m$ α's, is ${}_nC_m p^m q^{n-m}$. When n is small there is no difficulty in calculating any particular value of ${}_nK_m$ or even all the values; thus in sec. 16 we have seen that, if $p=0{\cdot}6$, the probabilities of occurrence of the values 6, 5, 4, 3, 2, 1, 0 of m are 0·047, 0·187, 0·311, 0·276, 0·138, 0·037, 0·004. But, when n is large, the single probabilities are very small, and we have to take them in groups. We therefore require a formula which will enable us to calculate the sum of the probabilities in any particular group, *i.e.*, the probability that the value of m will lie between any two stated values. An approximate formula—less or more correct according as n is smaller or larger—is given by the *normal law of error*. This law is also known as the *Gaussian* law of error, though it was discovered by Laplace: or as the *law of large numbers*. It would more correctly be called the *normal law of frequency of error* or the *law of large frequencies*.

(ii.) The method consists, essentially, in replacing a sum by an integral. To see how this happens, let us take p to have some definite value, and let us see how the form of the frequency-polygon (sec. 14) for a representative distribution alters as n increases. There are $n+1$ ordinates; as n increases, the number of ordinates increases, and their size decreases. If the interval between successive ordinates is always h, the frequency-polygon becomes wider and flatter. If, on the other hand, we take the interval to be h/n, so that (n being large) the breadth of the polygon is practically constant, it becomes higher and narrower in the middle. We can obtain regularity by adopting a middle course. We have seen in sec. 18 that the standard deviation, which is a convenient measure of the dispersion of the values about their mean, is $\sqrt{npq}$, *i.e.*, is proportional to $\sqrt{n}$. For purposes of comparison let us keep the maximum ordinate fixed in position, and take the interval between consecutive ordinates to be $h/\sqrt{npq}$ instead of h, the ordinates themselves being multiplied by $\sqrt{npq}$, so as to keep the area of the polygon unaltered. Then it will be found that the heights of the ordinates in any particular position, fairly near the maximum ordinate, alter comparatively slowly, and that the tops of the ordinates tend to lie on a certain curve, which is the limit of the upper boundary of the frequency-polygon. This curve is the *normal curve of error;* and the figure bounded by it, which is the limit of the frequency-polygon, is the *normal figure of frequency*.

The following short table (Table III.) illustrates this, so far as the maximum ordinate is concerned; p being taken to be 0·6.

TABLE III.

n	6	20	100	1,000
Max. prob.	·311	·180	·081	·026
$\sqrt{npq} \times$ max. prob.	·373	·394	·398	·399

The ordinate, in each case, is the unit U multiplied by the probability or relative frequency and by $\sqrt{npq}$. The actual limit of the numbers in the last line is (*see* sec. 22) $1/\sqrt{2\pi}=0{\cdot}399$.

(iii.) Algebraically, we proceed as follows: We want to find the sum of a number of consecutive values of ${}_nK_m$: let us say, the values for which m lies between $s-\frac{1}{2}$ and $t+\frac{1}{2}$. We therefore want to find a convenient expression for

$$S \equiv {}_nK_s + {}_nK_{s+1} + \ldots + {}_nK_{t-1} + {}_nK_t. \qquad (21{\cdot}1)$$

We can do this, subject to certain assumptions as to the magnitudes of n, p, q, and m; it being remembered that (*see* ii. above) the standard deviation of m from its mean value np is $\sqrt{npq}$. We assume that

(1) n is very large;

(2) neither p nor q is very small, so that np and nq and npq are very large;

(3) m is very large, but

(4) $m-np$ (taken positively) is, at its greatest, not a large multiple of $\sqrt{npq}$.

On these assumptions, it may be shown that S is approximately equal to the area, from $m=s-\frac{1}{2}$ to $m=t+\frac{1}{2}$, of a figure whose ordinate corresponding to m is

$$u = \frac{1}{\sqrt{2\pi npq}} e^{-\frac{1}{2}V}, \qquad (21{\cdot}2)$$

where

$$V = \frac{(m-np)^2}{npq}; \qquad (21{\cdot}3)$$

i.e., approximately,

$$S = \int_{s-\frac{1}{2}}^{t+\frac{1}{2}} \frac{1}{\sqrt{2\pi npq}} e^{-\frac{1}{2}(m-np)^2/(npq)} dm. \qquad (21{\cdot}4)$$

The figure given by (21·2) and (21·3) is the normal figure of frequency.

(iv.) The figure is symmetrical about a central ordinate; and it admits of any value of m, positive or negative, so that its range is from $-\infty$ to $+\infty$. In these respects it differs from the (discontinuous) graph of ${}_nK_m$; and, as already stated, it is only for moderate values of $m-np$ that a portion of its area represents the sum of a number of K's. It may, however, be noted that the figure agrees with the graph of ${}_nK_m$ in the following respects:

(a) the mean value of m, for the figure, is np;

(b) the standard deviation of m is $\sqrt{npq}$;

(c) the complete area of the figure is 1.

(v.) Since (sec. 15) $m-np$ is the "error" of m, we denote it by the symbol ϵ; and (21·2) can then be written

$$u = \frac{1}{\sqrt{2\pi npq}} e^{-\frac{1}{2}\epsilon^2/(npq)} \qquad (21{\cdot}5)$$

We can also write it in another form. For a representative distribution of n cases between A and α, let n_0 and n_1 be the numbers of A's and of α's respectively; and let the actual numbers be $n_0+\epsilon_0$ and $n_1+\epsilon_1$, so that $\epsilon_0+\epsilon_1=0$. Then $n_0=np$, $n_1=nq$, $n_0+\epsilon_0=m$, $n_1+\epsilon_1=n-m$. With this notation, (21·2) and (21·3) give

$$u=\frac{1}{\sqrt{2\pi}}\left(\frac{n}{n_0 n_1}\right)^{\frac{1}{2}} e^{-\frac{1}{2}\chi^2}, \qquad (21\cdot6)$$

where

$$\chi^2=\frac{\epsilon_0{}^2}{n_0}+\frac{\epsilon_1{}^2}{n_1}. \qquad (21\cdot7)$$

(vi.) The equation to the figure can be written in the general form

$$u=\frac{N}{\sqrt{2\pi}\cdot c}\, e^{-\frac{1}{2}(Y-a)^2/c^2}, \qquad (21\cdot8)$$

where Y is the variable, a and c are its mean and standard deviation, and N is the area of the figure. A variable Y, of which this represents the frequency, is said to be *normally distributed.*

22. **Standard Normal Figure.**—(i.) For practical application of the above result, we usually write—

$$Y=a+cx,$$

where x is numerical. If we make this substitution in (21.8), and treat x as the abscissa in the resulting figure, we are altering the unit of measurement of abscissa in the ratio of $c:1$, and must therefore alter the unit of measurement of u in the ratio of $1:c$. Writing

$$u\equiv z/c,$$

we get

$$z=\frac{1}{\sqrt{2\pi}}\, e^{-\frac{1}{2}x^2}, \qquad (22\cdot1)$$

which is the equation to the *standard normal figure.* The figure extends from $-\infty$ to $+\infty$; it is symmetrical about the axis of z; and its central (or maximum) ordinate is approximately ·39894.

(ii.) The portions on the two sides of the central ordinate are bisected by the ordinates for which $x=-\cdot67449$ and $x=+\cdot67449$ respectively; these are the quartile values of x. Similarly, for the more general form in (21·8), the quartile (including the median) values of Y are $Y=a-\cdot67449c$, $Y=a$, $Y=a+\cdot67449c$.

The form of the figure, with ordinates increased in the ratio 10:1, is shown on page 531. OH is the central ordinate; $M'P'$ and MP are the quartile ordinates. $N'Q'$ and NQ are the ordinates at $x=-1$ and $x=+1$; Q' and Q are points of inflexion on the bounding curve.

23. **Second Approximation.**—In obtaining the above results we have assumed that n is so large that we can regard $1/\sqrt{n}$ as a small quantity, and have ignored terms in $1/n$. For a closer approximation we should take account of these latter terms. This gives as the equation to the figure of frequency

$$u=\frac{1}{\sqrt{2\pi}.D}\left\{1-\tfrac{1}{2}k\left(\frac{X}{D}-\tfrac{1}{3}\frac{X^3}{D^3}\right)\right\} e^{-\frac{1}{2}X^2/D^2},$$

where X is the deviation from the mean, D is the standard deviation, and k is (mean cube of deviation from mean) $\div D^3$. This is sometimes called the *generalized law of error.* It should be observed that the figure is *skew*, *i.e.*, unsymmetrical.

24. **Frequencies of Improbable Events.**—In secs. 21–23 we have been dealing with cases in which the probability of an event happening is neither very small nor very large, *i.e.*, is neither very nearly 0 nor very nearly 1. We have now to consider the class of cases in which the probability of an event happening is very small, and yet, in consequence of the number of trials being very large, we should not be surprised if it happened occasionally. As before, we take p to be the probability of A, so that $q\equiv1-p$ is the probability of not-A or α; we assume that p is very small but n is so large that np is not negligible; and we want to see what is the probability of A occurring occasionally in n trials.

The probability of no A's is q^n, that of one A is npq^{n-1}, and so on; the probabilities being the terms in the expansion of $(q+p)^n$. Now

$$q^n=(1-p)^n=\{(1-p)^{1/p}\}^{np},$$
$$npq^{n-1}=np\{(1-p)^{1/p}\}^{(n-1)p},$$

and so on. But, since p is small, $(1-p)^{1/p}$ is approximately equal to $1/e$. Hence the terms in the expansion are approximately

$$e^{-np},\ npe^{-np},\ \frac{(np)^2}{1\cdot2}e^{-np},\ \ldots.$$

If therefore we write $\mu\equiv np$, so that (sec. 18) μ is the mean number of times that A occurs in n trials, then the probabilities of A occurring never, once, twice, three times ... are (approximately) the terms of the series

$$e^{-\mu}+\mu e^{-\mu}+\frac{\mu^2}{2!}e^{-\mu}+\frac{\mu^3}{3!}e^{-\mu}+\ldots.$$

This theorem is due to Poisson; it is known as *Poisson's exponential law* or as the *law of small numbers.*

We can easily verify that the formula is consistent with the statement that μ is the mean number of times that A occurs; for this mean number is found by multiplying the terms of the series by 0, 1, 2, 3... and adding; and the result is

$$\mu e^{-\mu}+\frac{\mu^2}{1!}e^{-\mu}+\frac{\mu^3}{2!}e^{-\mu}+\ldots=\mu e^{-\mu}\left(1+\frac{\mu}{1!}+\frac{\mu^2}{2!}+\ldots\right)=\mu.$$

OTHER FREQUENCY-DISTRIBUTIONS

25. **Genesis of Normal Distributions.**—The normal figure of frequency has been obtained as the limit of the frequency-polygon for errors of random sampling from two categories. But it has other important relations.

(i.) If a quantity Y is distributed according to the normal law about a mean value a with mean square of deviation c^2, and n values of Y are taken at random, the mean of these values is distributed according to the normal law about the mean value a with mean square of deviation c^2/n.

(ii.) If a quantity Y is distributed according to (almost) any law whatever about a mean value a with mean square of deviation c^2, and n values of Y are taken at random, the mean of these values is distributed about the mean value a with mean square of deviation c^2/n, and the distribution is approximately normal; the approximation being less or more close according as n is smaller or greater and according as the original distribution of Y is less or more similar to a normal distribution.

(iii.) In the frequency-distribution of a quantity Y, suppose that the deviation of any individual value of Y from the mean Y is the total effect of a very large number of very small deviations, due to causes which operate independently of one another. Then (in general) the distribution of Y is approximately normal.

26. **Observation of Distributions.**—The pioneer in the systematic study of actual frequency-distributions was L. A. J. Quetelet, the Belgian astronomer. In works published in and after 1835 he showed that variations in many kinds of phenomena—temperature, price of grain, astronomical observations, heights and chest-measurements of men—were distributed about a mean value in a manner similar to the binomial distribution (sec. 16). His standard distribution, with which distributions of the above kind were to be compared, was that due to drawing 999 balls from an urn containing white and black balls in equal proportions; it was therefore a symmetrical distribution, very close to the Gaussian distribution, but discontinuous. As an example of the frequency-distributions to which Quetelet called attention, we may take the following table (Table IV.) of chest-measurements of 5,732 soldiers in Scottish regiments.

TABLE IV.

Chest in inches	33	34	35	36	37	38	39	40
Number of men	3	19	81	189	409	753	1,062	1,082
Chest in inches	41	42	43	44	45	46	47	48
Number of men	935	646	313	168	50	18	3	1

27. **Laws of Distribution.**—For comparisons similar to those made by Quetelet, the normal law was usually taken as a basis. But it had two obvious defects (*cf.* sec. 21 [iv.]). One was that it assumed the possibility of an infinite range of variation. The more serious defect was that it implied symmetry, whereas in many cases there was a definite asymmetry or *skewness*. The generalized law, mentioned in sec. 23, allows for skewness, but does not provide for restricted range of variation. Provision was therefore required for other types of frequency-distribution. This was necessary for two reasons. When we are studying a particular distribution, it is desirable to obtain a formula which fits it as closely as possible: for, when we have obtained a closely-fitting formula, the actual distribution can conveniently be represented by the constants of this formula. But there is a further question. We are studying, let us say, the distribution of men's heights in a fairly homogeneous population; the variations of height being produced by a number of small variations which are distributed by intermarriage and are being supplemented by new variations of the same kind. We find a formula, containing a few parameters or "arbitrary constants," which can be fitted very closely to the observations by obtaining suitable values for these parameters. But we are at any time studying only a limited number of persons, though this number may be a large one; and the result of this limitation of number is some irregularity as between the numbers in the various categories of classification—*e.g.*, the numbers of men of different heights, measured in inches. As the number of persons measured increases, these irregularities become relatively smaller. The question which thus arises may be stated as follows. We adopt the hypothesis that, as the number of observations is increased, not merely actually, but also potentially by supposing the causes of variation to be extended to a very large number of individuals, there is a tendency to a definite statistical law of variation. The question then is: Can the irregularities which appear in our data for n individuals be regarded as due to errors of random sampling of the n individuals from a hypothetical universe of this kind?

Thus the study of a frequency-distribution falls mainly under the following heads: (1) the choice of a suitable formula, (2) the determination of the constants of this formula from the data, (3) enquiry whether the data may reasonably be regarded as the result of random sampling from a universe in which the variations are distributed according to the formula chosen. There are also certain minor matters of consideration: in particular, the question (4) whether the data can really be regarded as homogeneous, or whether individual excessive variations—giants or dwarfs—ought to be excluded, either as not really belonging to the universe we are postulating, or as being sports, or, possibly, as being the result of incorrect observation.

28. **Some Types of Formula.**—The most familiar types of formula which have been fitted to observations are those given by Karl Pearson's extension of the Gaussian formula. This latter formula is essentially based on the differential equation

$$\frac{1}{u}\frac{du}{dx} = (\text{const.})x.$$

Pearson's extension takes

$$\frac{1}{u}\frac{du}{dx} = \frac{x+a}{b_0+b_1x+b_2x^2}.$$

This gives a great variety of forms; and the increase in the number of arbitrary constants gives greater elasticity.

Pareto's formula

$$u = (\text{const.})x^{-c}$$

is included in Pearson's types.

Another form, of importance in vital statistics, is Makeham's formula, obtained from the differential equation

$$-\frac{1}{u}\frac{du}{dx} = a+bc^x.$$

29. **Determination of Constants.**—(i.) There are various ways of fitting a formula to a particular distribution by finding suitable constants. The most usual method is that of equating moments. The number of individuals being n, and the equation of the figure to be fitted being $nu=nf(X, a, b, c\ldots)$, so that $f(X, a, b, c\ldots)\,dX$ is the proportion of individuals for which X lies within the limits $X\pm\frac{1}{2}dX$, and $a, b, c\ldots$ are the constants to be determined, we equate the 1st, 2nd, 3rd... moments of nu to those of the actual distribution, and thus obtain equations for determining $a, b, c\ldots$. In doing this, it must be remembered that the values of X are (usually) not given exactly for the observed individuals, since these latter are grouped in classes, *e.g.*, in the case of heights, they may be given to the nearest inch. The individuals in each class are therefore treated as having all the same X, and certain corrections are applied (*see* MENSURATION).

(ii.) If we want to find the *most probable* values of the constants, the problem becomes one of inverse probability, and we have to make some assumption as to the *a priori* probabilities of different values of the constants. When the number of individuals is large, this presents no difficulty. If, for instance, the distribution is of heights of men, and we require the most probable value of their mean, the range of practically possible values is small, and we can assume that within this range all values are equally likely. But caution is necessary when we are dealing with small numbers. In the case of a Gaussian distribution, the most probable values, on the above assumption, are obtained by taking first and second moments; subject to some qualification in view of the fact that measurements are grouped.

(iii.) When a value g has been found for a parameter, note should be made of the "probable error" of g. This is a quantity ϵ such that it is an even chance that the true value of the parameter lies between $g-\epsilon$ and $g+\epsilon$.

30. **Test of Closeness of Fit.**—When we have chosen a formula, we have still to satisfy ourselves that it is a suitable one. The method of doing this belongs properly to correlation (sec 33), since it deals with the probability of joint occurrence of a number of variations. There are two classes of cases. In the one class the formula is completely settled *a priori*, and there are no constants to be determined. In the case of throwing a die, for instance, our hypothesis may be that all faces are equally likely to be uppermost; we test the hypothesis by comparing the actual numbers of throws of 1, 2...6 with the theoretical numbers, namely $1/6\cdot N$ for each face, and see whether the *discrepancies* between hypothesis and fact are such as might be due to random sampling. In the other class of cases there are unknown constants. Whatever values are taken for these constants, there will be discrepancies between the theoretical frequencies calculated from them and the actual frequencies; and there will be the same enquiry as to these discrepancies. Both cases are usually dealt with by a method due to K. Pearson, and known as the "χ^2" method.

31. **Exclusion of Extreme Values.**—Occasionally, in a set of observations of a group supposed to be homogeneous, extreme variations—giants or dwarfs—will occur. If the probability of their occurrence as the result of random sampling is extremely small, regard being had to the total number n, are they to be excluded? Their inclusion or exclusion may make a good deal of difference not only in the deduced values of the constants but also in the measure of closeness of fit. Several forms of criterion for exclusion have been proposed. But these relate to exclusion from a particular distribution. If we deal statistically with a number of distributions of the same kind, the extent to which these extreme variations occur may be an important element in our enquiries.

CORRELATION

32. **Regression.**—The importance of correlated variation in individuals was emphasized by Darwin, and the correlation of deviations from the average in parents and in offspring must have long been a matter of common observation, but it was

Francis Galton who, in papers leading up to his *Natural Inheritance* (1889), first stated a law governing the frequencies of such deviations. The special aspect to which he called attention was *regression* towards the mean. The sons of tall men are—on the average—tall, but not so tall: the sons of short men are short, but not so short. But this does not mean that the parents of tall men are taller, or the parents of short men shorter. The regression works both ways.

Suppose, for simplicity, that heights, in both generations, are distributed about the same mean value a with the same standard deviation c, the distribution in each case being according to the normal law. Then, if we group together all the fathers whose heights are $a+\xi$, the average height of their sons (one son to each father) will not be $a+\xi$ but $a+r\xi$, where r is (in this case) somewhere about 0·5. And, if we group together all sons whose heights are $a+\eta$, the average height of their fathers will not be $a+\eta$ but $a+r\eta$, where r has the same value as in the preceding sentence.

In the general case, suppose there are a large number of individuals having measurable attributes A and B, their measures being X and Y, and that the values of X are distributed about a mean value a with standard deviation c, and those of Y about a mean value b with standard deviation d; subject to an assumption mentioned below. (In the case considered above, the individual is the pair, father and son, and the attributes are the height of the father and the height of the son.) Then Galton's law of regression is that, if we group together all individuals for which X has the value $a+xc$, the mean value of Y for these individuals is $b+rxd$; and also, if we group together all individuals for which Y has the value $b+yd$, the average value of X for these individuals is $a+ryc$: where r is the same in the two cases and is between -1 and $+1$. The ratio $rxd/xc=rd/c$ (which is not necessarily a numerical ratio, since A and B may be different kinds of quantities) is the *coefficient of regression* of B on A, and the ratio $ryc/yd=rc/d$ is the coefficient of regression of A on B.

The whole of the above is based on the assumption that the values of X and of Y are normally distributed and normally correlated. The algebraical expression of normal correlation is considered below: its general character can be seen from Table V., which is a *correlation-table* showing the relation between brother and sister as regards span.

TABLE V.—*Correlation of brother and sister*

(Adapted from K. Pearson and A. Lee, *Biometrika* ii. [1903], 449.)

Sister's span in inches	Brother's span in inches								Total brothers
	58–61	61–64	64–67	67–70	70–73	73–76	76–79	79–82	
52–55 .	..	1	2	4	..	..	..	..	7
55–58 .	..	2	10	11	1	..	..	..	24
58–61 .	..	15	78	121	44	9	3	..	270
61–64 .	1	8	87	193	173	52	5	..	519
64–67 .	..	..	31	122	171	69	11	2	406
67–70 .	..	..	2	19	62	51	11	..	145
70–73 .	..	..	..	2	4	5	4	3	18
73–76 .	..	..	..	..	..	1	3	..	4
Total sisters	1	26	210	472	455	187	37	5	1,393

33. **Normal Correlation.**—The form of the equation to a normal frequency-distribution was obtained (sec. 21 [iii.]) by considering the frequencies of deviations from a representative distribution in the case of alternatives A and α. The normal law of distribution of these latter frequencies having been obtained, we can easily deduce the corresponding formula for distribution in any number of categories, and thence obtain the general formula for a normal frequency-distribution of any number of variables. For the present we can limit ourselves to the case of two variables, which means three categories.

(i.) Suppose there are three categories P, S, T, the relative frequencies of which are p, s, t, so that a representative distribution of n individuals would give np, ns, nt in the three categories. Denote these by n_0, n_1, n_2, so that $n_0+n_1+n_2=n$. Then the probability of joint occurrence of numbers $n_0+\epsilon_0$, $n_1+\epsilon_1$, $n_2+\epsilon_2$ in the three categories (so that $\epsilon_0+\epsilon_1+\epsilon_2=0$) is approximately proportional to $e^{-\frac{1}{2}\chi^2}$, where

$$\chi^2=\frac{\epsilon_0^2}{n_0}+\frac{\epsilon_1^2}{n_1}+\frac{\epsilon_2^2}{n_2}.$$

By replacing ϵ_0 by $-\epsilon_1-\epsilon_2$, we get χ^2 as an expression involving ϵ_1^2, $\epsilon_1\epsilon_2$, ϵ_2^2.

(ii.) We therefore define the *normal law of correlation* of two attributes A and B as being such that the frequency of joint occurrence of deviations X and Y from the respective means a and b is proportional to $e^{-\frac{1}{2}U}$, where U is of the form

$$U=FX^2-2GXY+HY^2;$$

F and H being positive, and $FH>G^2$.

(iii.) By taking mean squares c^2 and d^2 of X and Y, and mean product of X and Y, it will be found that U can be expressed in the form

$$U=\frac{1}{1-r^2}\left(\frac{x^2}{c^2}-2r\frac{XY}{cd}+\frac{Y^2}{d^2}\right),$$

where $r=$(mean product of X and Y)$\div cd$. Hence it follows (by fixing X in the one case and Y in the other) that the coefficient of regression of B on A is rd/c, and that of A on B is rc/d. Thus r is the same r that we considered in sec. 32. It is called the *coefficient of correlation;* its value is between -1 and 1. The correlation is said to be *positive* or *negative* according as r is positive or negative.

34. **Determination of Constants.**—When the joint distribution of two variables X and Y is supposed to follow a certain law, we proceed in exactly the same way as for the distribution of a single variable. We find values for the constants from the data; and we examine the discrepancies between the data and a corresponding distribution deduced from chosen values of the constants, in order to see whether these discrepancies can be reasonably regarded as due to errors of random sampling.

In the case of normal correlation, where the data are distributed in a sufficient number of categories formed by taking values of X at equal intervals, and values of Y also at equal intervals, the values of the means and standard deviations as found from the data are taken to be those of the distribution, and the mean product of the deviations from the means is taken to be the product of the standard deviations and the coefficient of correlation. Values of the constants having been determined, we must pay attention to the "probable errors" of these values. There are, however, numerous kinds of cases in which this method cannot be adopted. We can only consider them briefly.

35. **Other Kinds of Cases.**—The assumptions we have hitherto made are that

(i.) the measures X and Y are normally distributed and normally correlated, so that the regression is linear;

(ii.) the number of observations is very large;

(iii.) they are distributed into a fairly large number of categories, by tabulation at intervals in X and Y.

Actual cases, in which the attributes under consideration are clearly correlated, in the general sense of the term, and we should like to have some measure of the correlation, may present difficulties, especially in one or more of the following ways.

(1) The distributions may not be normal; or, even if they are normal, the correlation may not be normal;

(2) In addition, the regression may not be linear;

(3) The number of cases may be small;

(4) The number of categories may be very small;

(5) The attributes considered may not be continuously varying quantities.

36. **Special Methods.**—The following are some special methods for treatment of cases of the kind mentioned in sec. 35.

(i) If we are dealing with quantities which have continuous variation, but the correlation is not normal, we can still define r as the ratio which the mean product of the deviations from the

respective means bears to the product of the standard deviations. This applies whether the regression is linear or not.

(ii.) The definition may still hold, even if the number of categories is so small that we cannot determine the means, etc. Table I., for instance (sec. 6), gives sufficient data for us to find r on the assumption that the two sets of heights are normally distributed and normally correlated.

TABLE VI.—*Correlation of Hair-colour and Eye-colour in Men*

Eye-colour	Hair-colour				Totals
	Fair	Brown	Black	Red	
Blue . . .	1,768	807	189	47	2,811
Grey or Green .	946	1,387	746	53	3,132
Brown . . .	115	438	288	16	857
Totals	2,829	2,632	1,223	116	6,800

(iii.) A common class of cases is of the kind shown in Table VI. (quoted from Yule, p. 61). Here there is clearly some correlation; the number of men with fair hair and blue eyes, for instance, would, if hair-colour and eye-colour were independent, be about $2829\times2811\div6800=1169$; actually it is 1768, and the discrepancy is far too great to be due to error of random sampling. But there is nothing to suggest continuous variation of the measure of an attribute. For cases of this kind—usually called *contingency* cases—we must fix some definition of the ratio which is to be the measure of correlation. The usual ratio is K. Pearson's *mean square contingency coefficient*, which may be defined as follows. Divide the square of the number in each compartment of the main table by the product of the corresponding subtotals (*e.g.*, divide 1768×1768 by 2829×2811), and add the results. Let their sum be S. Then the coefficient is defined as being $\sqrt{\frac{S-1}{S}}$.

(iv.) A particular case of contingency is *association*, which is the relation exhibited by a *tetrachoric* classification, *i.e.*, one in which there is only a distribution of A and not-A under B and not-B. The contingency coefficient defined in (iii.) can be used for these cases; but various other methods have been suggested.

(v.) The last class of cases to be mentioned is that in which we are concerned with two attributes A and B which can be approximately represented by magnitudes X and Y, but the number of individuals is so small, and the laws of frequency of X and Y are so doubtful, that we cannot apply ordinary statistical methods. If, however, the individuals can be arranged in order according to their values of X, and also according to their values of Y, C. Spearman's "rank" method can be adopted. Suppose, as an example, that there are n boys, and that we want to calculate the correlation between their abilities in subjects A and B. Arrange them in order according to their ability in A, and give them the ranks 1, 2, 3...n. Do the same for B. Let d denote, for each boy, the difference between the ranks in the two subjects. Then the *rank coefficient of correlation* is

$$\rho=1-\frac{6\Sigma d^2}{n(n^2-1)},$$

where Σd^2 denotes the sum of the squares of the n d's.

37. **Multiple Correlation.**—The methods which we have been using for dealing with correlation between two attributes can be extended to cases in which there are three or more correlated attributes. The normal formula expressing frequency of joint occurrence of deviations x, y, z...from the respective means involves an expression $e^{-\frac{1}{2}U}$ where U is a quadratic function of x, y, z....This leads to the consideration of partial correlation, *i.e.*, correlation between two of the variables when the remaining variables are taken to have fixed values.

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PROBATE refers to the formal proof of a will, which in England has to take place at Somerset House, London, or at a district registry. The early jurisdiction of the English ecclesiastical courts over the probate of wills of personalty is discussed under WILL and ECCLESIASTICAL JURISDICTION. The Court of Probate Act 1857 transferred the jurisdiction both voluntary and contentious of all ecclesiastical, royal peculiar, peculiar and manorial courts to the court of probate thereby constituted, created a judge and registrars of that court, abolished the old exclusive rights in testamentary matters of the advocates of Doctors' Commons, and laid down rules of procedure. Contentious jurisdiction was given to county courts when the personal estate of the deceased was under £200 in value. The Judicature Act 1873 merged the old court of probate in the probate divorce and admiralty division of the High Court of Justice. Probate may be taken out either in *common* or *solemn* form. In the former case, which is adopted when there is no dispute as to the validity of the will, the court simply recognizes the will propounded as the last will of the deceased. This formality is necessary to enable the executor to administer the estate of his testator. Probate in this form is granted simply as a ministerial act if the attestation clause declares that the formalities of the Wills Act have been complied with, or if other evidence to that effect is produced. Such grant is liable to revocation, but it is provided that any person dealing with an executor on the faith of a grant of probate in common form, shall not be prejudiced by its revocation. The executor may within 30 years be called upon to prove in solemn form. A person who doubts the validity of the will propounded may enter a caveat which while in force prevents any probate other than in solemn form. Separate representation may be granted in respect of real estate since the administration of Estates Act 1925, and of a trust estate only, but except or regards trust estates a separate representation may be granted of a known insolvent estate. Under the Law of Property Act, 1925, S. 11, probate and letters of administration convey the legal estate to the personal representative, and this makes the real estate directly available for payment of debt. Probate in solemn form is a judgment of the court in favour of the will propounded, and is only revocable by the discovery of a later will. In order, therefore, to obtain such grant proceedings have to be taken by action, and witnesses produced in support of the will, and the action proceeds in the usual way.

The principal rules now obtaining as to probate are these. Probate, which since the Land Transfer Act 1897 (*see* New Administration of Estates Act, 1925, ss 79, 80) must be taken out for wills of realty as well as wills of personalty, may be granted either in the principal or in a district registry, and should be obtained within six months after the testator's death. When no executor is named the will is not now invalid, as was once the case, but administration *cum testamento annexo* is granted. The same course is pursued where the executor renounces or dies intestate before administering the estate of the deceased. After probate, the probate itself (as the official copy of the will is called) becomes evidence, the original will being deposited in the principal registry at Somerset House, London. On grant of probate, estate duty is payable on the gross value of the personal estate and the English real estate (*see* ESTATE DUTIES). The act of 1881 enables any officer of inland revenue to grant probate where the personal estate does not exceed £300.

In 1867 an act on lines similar to the English act was passed

for Ireland and under the Irish Judicature Act of 1877 the then existing court of probate was merged in the High Court of Justice.

In Scots law *Confirmation* includes both the probate and letters of administration of English procedure. It forms the executor's legal title to ingather the estate. Originally confirmation of testaments of movables fell, as in England, under the cognizance of the Church courts. It is now part of the jurisdiction of the sheriff courts and is regulated by statutes, the principal of which are, the Confirmation and Probate Act 1858, the Sheriff Courts Act 1876, and Executors Act 1900. When the will is attested and probation alluding to sects, forms for the execution of deeds, it proves itself, and the onus is on the person challenging it. In other cases the executor may be required to prove the validity of the will in the proceedings for confirmation.

UNITED STATES

Special Courts.—Probate is granted in some States by the ordinary chancery or common law courts, but more frequently by courts of special jurisdiction, such as the prerogative court in New Jersey, the surrogates' court in New York, the orphans' court in Pennsylvania.

"In a great majority of the States the original equitable jurisdiction over administrations is in all ordinary cases—without any special circumstances such as fraud, or without any other equitable feature such as trust—either expressly or practically abrogated. The courts of equity, in the absence of such special circumstances or distinctively equitable features, either do not possess or will not exercise the jurisdiction, but leave the whole matter of administrations to the special probate tribunals" . . . so that "unless the case involves some special feature or exceptional circumstances of themselves warranting the interference of equity, such as fraud, waste, and the like, or unless it is of such an essential nature that a probate court is incompetent to give adequate relief, or is one of which the probate court having taken cognizance has completely miscarried and failed to do justice by its decree, the courts of equity will refuse to interpose and to exercise whatever dormant powers they may possess, but will leave the subject matter and the parties to the statutory forum which the legislature plainly regarded as sufficient and intended to be practically exclusive" (Rice's *Probate Law*, pp. 4 and 5). For the old law on probate, *see* G. W. Marshall, *Ancient Courts of Probate* (1895).

Jurisdiction as to wills and their probate as such is neither included in nor excepted out of the grant of judicial power to the courts of the United States (*i.e.*, the *Federal* as distinguished from the State courts). So far as it is *ex parte* and merely administrative it is not conferred, and it cannot be exercised by them at all until in a case at law or in equity its exercise becomes necessary to settle a controversy by reason of the (diverse) citizenship of the parties. An action to set aside the probate of a will of real estate may be maintained in a Federal court when the parties on one side are citizens of a different State from the parties on the other side (*Ellis* v. *Davis*, 109 U.S. Reports, 485). Probate in solemn form, *i.e.*, after due notice to all parties in interest is the almost universal form in use in the United States. One reason for this no doubt is that all documents affecting title to real estate must be recorded and probate in solemn form concludes all parties to the proceeding and thus tends to establish the title to all real estate passing under the will.

In the United States wills of real property must be separately proven in the proper probate court in each State in which the real property is situated, unless statute dispenses with separate probate (each State being "foreign" to every other for this purpose). Copies of such will and probate should be filed also in the office of the register of deeds of each county in the State in which any real property belonging to the testator is situated.

In the State of *New Jersey* it has been held that an unprobated will is capable of conveying an interest in the property devised, and when a conveyance is made under a power in the will before probate, a subsèquent probate validates the conveyance (1906, *Mackey* v. *Mackey*, 63 Atl. Rep. 984).

In *Illinois* a court of equity has no *inherent* power to entertain a bill to contest a will (1906, *O'Brien* v. *Bonfield*, 220 Ill. Rep. 219).

In *Missouri* a foreign (New York) will of real estate in Missouri, probate of which was duly recorded in Missouri, cannot be *collaterally* attacked, and cannot be set aside by direct proceeding after being filed for record more than five years in Missouri (1907; *Cohen* v. *Herbert*, 104 So. W. Rep. 84).

PROBATION. The principle on which the probation system is based originated in, and was a development of, the idea of the suspended sentence. Under this the accused person was adjudged to be guilty and his sentence determined upon, but it remained suspended, to be eventually cancelled, if the accused made a serious effort in the meantime to redeem his character. Some countries still retain this practice, but it is obvious that its efficacy must depend upon the reliability of the information furnished as to the conduct of the accused during the period of suspension. In order to provide this information it was essential to appoint some person who would be in a position to supply it accurately, and it soon became the function of this official, not only to keep observation, but to give advice, encouragement and assistance to those over whom he exercised supervision. These are precisely the duties which a probation officer now fulfils.

The credit for the earliest creation of these officers would appear to rest with the principal authorities of Boston, U.S.A., who appointed a number of them in the year 1878. The principle received legislative recognition in England in 1887, when the First Offenders Act became law. The value of the system was soon completely demonstrated. The Probation of Offenders Act of 1907 in Great Britain permitted the use of probation, not in the case of first offenders only, but also in that of persons who had been previously convicted, provided the circumstances justified such a course.

It is greatly to the credit of the Police Court Mission that its managers should have at once provided the required agents by offering their own missionaries for this purpose. The offer was accepted, and in very many provincial and in all the metropolitan police courts of Great Britain, the missionaries of the society are appointed to act as probation officers. In London, and a few other cities, special probation officers are appointed to devote themselves solely to the children's courts. In the metropolis these officers are appointed and paid directly by the Home Office, and are subject to no religious tests. A uniformity of system in this respect would seem to be ultimately necessary. There is a National Association of Probation Officers which exists to safeguard the interests of its members and to strengthen and standardize the system.

Under the act of 1907 the appointment of probation officers was not compulsory and, as many districts made inadequate provision, and some no provision at all, full advantage was not taken by the act. This defect has now been remedied by the Criminal Justice Act, 1925, which renders obligatory the appointment of a probation committee for every probation area. This area may be either that comprised in the jurisdiction of a single petty-sessional court, or a combined area of several such courts, approved by the secretary of State.

It is impossible at present to give statistics, of any real value, of the success of probation, but that it has been successful to an extraordinary degree is unquestionable. It would, however, be most helpful if a uniform test of "success" or "failure" could be adopted as applicable to each individual case. If the test used is only good behaviour during the probation period, the number of successes would, of course, be very much greater than if the period were extended to a term of years after the order had ceased. The terms "success" and "failure" likewise need definition. A single relapse does not necessarily imply failure.

Probation work among children (*see* JUVENILE DELINQUENCY) differs materially from that amongst adults and is of even greater importance. It is essential that a child offender should, at first, be under very careful supervision; that his mental, physical and psychological characteristics should receive the closest study; that most friendly relations should be established between the parents and the probation officer; that the child should be brought in touch with outside agencies, such as boy scouts, clubs, etc., and that he should feel that in his own officer he has a real friend to whom he can always look for advice, sympathy and help. About half the number of children charged before the juvenile

courts are now placed on probation. Where, however, this fails, there should be no hesitation on the part of the probation officer in bringing the child again before the court in order that he may be sent to a certified school. (W. C. Ha.)

United States.—Every State in the union now has probation in more or less successful operation. The results obtained vary and are dependent largely upon whether trained probation officers are employed and upon whether these officers have assigned to them more cases than can be handled at one time with efficiency. Fifty cases are generally considered a maximum for a single officer. Rural communities are generally backward in providing probation officers. Generally speaking, however, the results of probation, as a principle, have been excellent. Apparently 75 to 85% of probationers do well while subject to probation, according to official reports. Adequate statistics are not available on the extent to which further relapses occur after the probationary period ends, but studies made seem to show that only a negligible portion of those who do well under probation subsequently succumb to criminal tendencies.

Probation has more than justified its value as an instrumentality of preventive penology and has received increased public approval. In this regard it is in marked contrast with parole with which it is closely related and with which it should not be confused. Probation, as stated, is an outgrowth of the suspended sentence and is a substitute for punishment, while parole is a part of penal discipline, akin to probation in its methods, to be employed after punishment is partly accomplished. Probation has obviously the larger chance of success.

In the first place, probation cases are generally those in which the prospect of social rehabilitation is more hopeful. Its cases, moreover, are more likely to co-operate with probation officers' services with a gratitude born of a consciousness of punishment avoided rather than, as in the case of those paroled, resentful in a present recollection of punishment endured. As a social agency in human reformation, probation still has great undeveloped possibilities and constitutes one of the great experimental fields for all the forces which deal with the understanding and prevention of crime.

PROBLEM, a question proposed for discussion and answer. (Greek *πρόβλημα*, from *προβάλλειν*, to throw before; a question placed before one for consideration.) In mathematics, a solution to be effected, such as that of the construction of an equilateral triangle having a given line segment as a side, or the finding of the mean proportional between two given numbers. In geometry it is usually a statement of a construction to be effected, whereas a theorem is a statement which is itself to be proved, as that the angles opposite the equal sides of an isosceles triangle are equal. The Greek geometers divided their propositions into theorems (*q.v.*), problems and porisms (*q.v.*). Pappus (*q.v.*) tells us that they recognized three classes of problems: (1) plane, (2) solid and (3) linear. The construction lines permitted were respectively (1) the straight line and the circle, (2) the conic sections ("solid loci") and (3) such higher curves as the conchoid, cissoid and quadratrix. (*See* CURVES, SPECIAL.) In solving a problem there is usually given (1) a statement of the construction to be effected with respect to a certain figure, (2) a statement of the steps in the construction and (3) a proof that the construction is correct.

PROBOSCIDEA, the scientific name of an order of Eutherian mammals represented at the present day by the African and Indian elephants. These animals (*see* ELEPHANT) differ very widely in their structure from all other living mammals but fossil remains of similar structure have long been known. Only during the 20th century, however, have primitive Proboscidea been discovered capable of comparison with other mammalian forms. The leading characteristics of the living elephants are as follows.

The animal is of large size with pillar-like limbs. The neck is short and the large head is provided with a proboscis, a long flexible muscular organ capable of being turned freely in all directions, and provided with one or two finger-like processes at its tip which can be used to handle articles as small as a penny. The trunk can also be employed as a prehensile organ by being wrapped as a whole round a large object. It is capable of very considerable accuracy of movement and is used in feeding. The trunk represents the whole anterior part of the face, that is the nose and also the upper lips, the strip of skin along its ventral surface being essentially a part of the palate. The two nostrils lie at the extremity of the trunk and lead into great canals which perforate the whole of that organ opening into olfactory chambers at its base. The mouth is short, placed below the trunk and provided with thick fleshy lower lips meeting anteriorly so as to form a short spout. The eye is small, laterally directed and provided with a pair of eyelids often bearing stiff eyelashes. The pinna of the external ear is large, becoming enormous in certain races of the African elephants. It is usually carried close to the side of the neck but can be erected so as to stand out perhaps a yard from the side of the head. The female bears two teats placed on the pectoral surface just between and behind the forelegs. Most living adult elephants possess very few hairs; there are normally a certain number on the forehead and cheek and always a tuft of long extremely thick hairs at the end of the short tail.

The skeleton of an elephant is as peculiar and characteristic as his external appearance. The skull is very short from back to front, deep, and built up of spongy bone full of air-spaces. Within the great mass of bone there lies a relatively small, though actually large brain cavity, and the olfactory chambers form great perforations which with the naso-pharyngeal ducts penetrate obliquely through the skull uniting only quite posteriorly. The skull of the new-born elephant differs from that of the adult in that whilst the head increases greatly and disproportionately in size, the brain undergoes much less expansion. Thus during the period of growth of the animal the external surface of the skull, by the development of the great air-spaces in its middle layer, becomes more and more widely separated from the layer of hard bone which surrounds the brain. The bony lamellae which separate these air-spaces run radially so as to buttress the external surface. The great size of the adult skull is necessary in order to give adequate areas for the attachment of the immense neck-muscles which support and move the very heavy trunk and tusks, and take the great strains which are produced when these structures are used in digging up and tearing down trees.

The jaw-bones of the elephant and the whole structure of its palate are modified so as to receive and afford adequate support to the tusks and cheek teeth. The bony nostrils lie very high up and are overhung by very small nasal bones to which some of the muscles of the base of the trunk are attached. This attachment is brought as far back as possible in order to increase the range of action of the proboscis.

The dentition of an adult elephant consists of a single pair of exaggerated incisors, the tusks, and either one or two molars on each side of the upper and lower jaws. These molars are built up of a series of plates each composed of a core of dentine surrounded by a layer of enamel; the individual plates, continuous with one another at their base, are held together and supported by an infilling of cement. In the elephant the milk incisors, little teeth about two inches in length, are shed and replaced by the permanent tusks, but the milk molars instead of being pushed out by a permanent pre-molar which develops underneath them, replace one another from behind as follows. The new tooth is developed deep down in the posterior part of the jaw and travels obliquely forwards and towards the mouth, so that more and more of it cuts the gum as the preceding tooth is worn down to its root, until finally the latter is shed and its successor is well in wear. A living elephant in this way works through six teeth in each side of each jaw during its lifetime, wearing down a total thickness of nearly a yard of tooth over an area which increases from about half a square inch to nearly 30 sq. in. on each side of its mouth. This extraordinary dentition is unparalleled, but the process by which it came into existence is fortunately completely known from fossil material.

The elephant's backbone possesses a neck of seven very short vertebrae, the number of dorsals varies from 19 to 21, the anterior having exceedingly long neural spines for the attachment of the nuchal ligament which passes forwards to the back of the skull. There is a short lumbar region of three or four vertebrae and the

sacrum is a compact bone built up by the fusion of four vertebrae: there are about 30 caudals. The ribs are of enormous length surrounding the very capacious thorax. The shoulder girdle consists of a very large triangular scapula placed vertically on the side of the thorax. The humerus is longer than the forearm so that the elbow of an elephant lies at a point relatively only a little higher than the wrist of a horse. The radius and ulna are peculiar in that their surfaces of articulation with the carpus are nearly equal, whilst the upper end of the radius is relatively small and lies in front of the ulna, the two bones crossing one another as they are traced downwards. The carpus of an elephant is unusual in that the bones of the two rows of which it is composed do not alternate but are superimposed on one another. In this feature the elephants resemble the Hyraxes. The elephant walks on the extreme tips of his fingers and toes, but the palm of the hand and the sole of the foot are swollen out into great pads of connective tissue which transmit the weight of the animal to the ground directly and so reduce the load carried by the phalanges. The elephant's pelvis is remarkable for its extraordinary width, the ilia being expanded into transversely placed sheets of bone from whose posterior surface muscles pass down to the hind-leg, whilst their margins give attachment to the muscles of the body-wall which support the weight of the viscera within the abdominal cavity. As in the fore-limb the upper segment of the leg is considerably longer than the lower one, and in the tarsus the astragalus is flattened, as a weight carrying adaptation, whilst the calcaneum is produced into a short heel directed backwards and downwards.

The anatomy of the soft parts of the elephant has been repeatedly described but presents few features of special interest except those which result from the modification of the nose and upper lips into the trunk. The animal is peculiar in that there is no pleural cavity. The fact that the testes are abdominal, the uterus bicornuate, and the placenta zonary and deciduate are of importance because similar conditions occur in the Sirenia which may have sprung from an early Proboscidean stock.

The most primitive and earliest known ancestors of the elephant belong to the genus *Moeritherium* and are found in Upper Eocene deposits in the Fayûm of Egypt. *Moeritherium* was an animal resembling in its external appearance and size the living tapir. The eye was placed far forward and the head was low and elongated, probably the end of the snout was slightly flexible and it may have been produced into a short proboscis. The legs were considerably more bent than those of the modern elephants but are still rather incompletely known. *Moeritherium* possesses three upper and two lower incisors of which the second pair are enlarged, those in the upper jaw projecting straight downwards, whilst the lower teeth are directed forwards so that their tips bite against those of the upper incisors. There is a small and very reduced canine tooth; three pre-molars are present in each jaw and there is evidence that each of these vertically replaced a milk predecessor. Three permanent molars occur in both upper and lower jaws, each consisting of two transverse ridges.

The next stage, represented by *Palaeomastodon* from the Lower Oligocene of Egypt, presents a great advance on *Moeritherium*. There are several species of which the largest is not very much smaller than a small elephant, whilst the smallest is little bigger than the largest *Moeritherium*. The back of the skull begins to show the separation of the outer surface from the brain-cavity by air-spaces, which is carried to an extreme in the living elephants. The bony nostril has shifted backwards to a point in the middle of the cheek-teeth, and in front of it the pre-maxillae form an open channel in which lay the base of the trunk. The second incisor is very much enlarged and directed forwards and downwards. The lower jaw is so much longer than the skull that the incisors, which lie horizontally, project forwards several inches in front of the upper jaw, and even extend beyond the tips of the upper incisors. The single "second" lower incisor is enlarged, and with its fellow forms a shovel-shaped termination to the lower jaw. The shape of this tooth is such as to show that its upper surface was worn by contact with some part of the animal and the only explanation of its structure is that the nose, upper lip and palate projected so far forward as to overhang the front of the lower jaw and form there a movable proboscis. The lower incisors are, however, worn all round in a way which suggests that the creature used them for grubbing about in the ground to secure food. There are three upper pre-molars each of which replace a milk tooth, whilst in the lower jaw the three milk molars are replaced only by two pre-molars. Both upper and lower molar teeth have three transverse ridges, thus differing from those of *Moeritherium*. The body of the animal was much like that of a small elephant but the neck was longer.

In the next stage, which is represented by *Gomphotherium angustidens* from the Miocene and Pliocene of Europe, North America, Africa and Baluchistan, we have an animal somewhat larger than the largest *Palaeomastodon*, with a completely elephant-like body, though with a somewhat longer and more flexible neck. The skull is much more elephant-like than that of *Palaeomastodon* because of the increased bulk of the air-cavities in its bones. It supports a pair of immense incisors, which, unlike the tusks of living elephants, are still down-turned and are provided with a belt of enamel lying on the outer surface of the ivory of which they are composed. The lower jaw is even longer than in *Palaeomastodon*, nearly half its length projecting in front of the bony skull. The lower tusks are directed forwards and bear a wear facet on their upper surfaces made by friction against a pad on the flexible and unsupported anterior part of the face, soon to be, if it had not already become, a true trunk. *Gomphotherium* still possesses milk molars which are replaced vertically by pre-molars, but these latter are comparatively small teeth soon displaced by the cutting of the second and third molars, which push their way forward from the cavity in the hinder part of the jaw in which they are formed. This process is carried so far that the adult has only two molars, the second and third, in position in each jaw. The individual teeth though larger than those of *Palaeomastodon* have still only three ridges, except in the case of the third, which has five. It seems evident that the enormously elongated jaws of *Gomphotherium* developed as an adaptation to allow the animal to reach the ground, when as a whole it was increasing in height while its neck was becoming shorter.

In the next stage represented by such forms as *Gomphotherium longirostris*, the elephants gave up the attempt to reach the ground and came to depend on their trunks both for eating and drinking. As the elongated lower jaw is thus no longer necessary, and must have interfered with the free use of the trunk, its anterior extension becomes very rapidly reduced in size so that it no longer extends in front of the bony upper jaw. In these animals only one milk molar is replaced by a pre-molar and the first two molar teeth have each four or five transverse ridges. The lower tusks are short and rounded whilst the upper tusks become still larger and outwardly directed. In these forms the shortening of the lower jaw allowed the trunk to fall down vertically, as it does in modern elephants and in external appearance they must have been entirely elephantine.

The later mastodons pass gradually into the elephants by a still further reduction of the lower jaw, the lower tusks becoming quite small and eventually disappearing altogether, finally the front of the lower jaw becomes reduced to a very small down-turned spout which is retained in the living elephants. In the later forms the milk teeth are no longer replaced vertically by pre-molars, whilst such teeth when they do occur must have been pushed out almost immediately by the forward movement of the molar teeth. At the beginning of the series, the second molar tooth in either jaw has four or five ridges, separated from one another by deep valleys in which there is no cement. In an intermediate stage, *Stegodon*, the number of ridges varies from 6 to 12 in different forms and the valleys between these ridges become filled up with cement. In the true elephants the ridges are not only more numerous but much higher and the cement forms a plate lying between them. Continuation of this process leads to the most highly specialized of all elephants, the mammoth, in which the number of ridges in the second molar may be as high as 16, and the whole tooth was extraordinarily deep.

The history of the evolution of the elephant set forth above is a mere outline. It is really greatly complicated by the existence of

a large number of side branches, many of which migrated into North and some even into South America. Of these side branches much the most striking is that represented by *Deinotherium*, an animal with an elephant-like body, apparently with exceptionally long limbs and a trunk. This animal is remarkable because its molar teeth throughout the whole history of the genus have only two transverse ridges and are very low crowned. The upper tusks are completely absent while the large lower tusks are directed downwards at right angles to the lower jaw. This animal is probably of African origin and is found only in that continent and in Europe and India.

(*See* ELEPHANT; MAMMOTH; MASTODON.)

See H. F. Osborn, *Proboscidea*, 2 vols. (1936–42).

(D. M. S. W.; X.)

PROBOSCIS MONKEY, a large, long-tailed, red Bornean species (*Nasalis larvatus*) characterized by the prolongation of the nose of the adult male, which hangs down in front of the upper lip. In the females and young the nose is less developed. This monkey is a leaf eater, nearly allied to the langurs. (*See* PRIMATES.)

PROBUS, MARCUS AURELIUS, Roman emperor A.D. 276–282, was a native of Sirmium in Pannonia. At an early age he entered the army, where he distinguished himself under the emperors Valerian, Claudius and Aurelian. He was appointed governor of the east by the emperor Tacitus, at whose death he was proclaimed his successor by the soldiers. Florianus, who had claimed to succeed his brother, was put to death by his own troops, and the senate ratified the choice of the army. The reign of Probus was mainly spent in successful wars by which he re-established the security of all the frontiers, the most important of these operations being directed to clearing Gaul of the Germans. Probus had also put down three usurpers, Saturninus, Proculus and Bonosus. In time of peace he kept the soldiers at work, which made him unpopular, and while superintending draining operations at his native town he was killed by his own soldiers. Scarcely any emperor has left behind him so good a reputation; his death was mourned alike by senate and people, and even the soldiers repented and raised a monument in his honour.

Life by Vopiscus; Zosimus i, 64; Zonaras xii, 29; Aurelius Victor, *Caes.* and *Epit.* 37; H. Schiller, *Geschichte der römischen Kaiserzeit* (1883), vol. i; E. Lépaulle, *Étude historique sur M. A. Probus d'après la numismatique* (1885); Pauly-Wissowa, *Realencyklopädie*, ii, 2516 (Henze).

PROBUS, MARCUS VALERIUS, of Berytus, Roman grammarian and critic, flourished under Nero. His criticisms on Virgil may be preserved in the commentary on the *Bucolics* and *Georgics* which goes under his name. We possess by him part of a treatise *De notis*, probably an excerpt from a larger work. It contains a list of abbreviations used in official and historical writings (especially proper names), in laws, legal pleadings and edicts. Other works have been wrongly attributed to him.

See J. Steup, *De Probis grammaticis* (1871); Teuffel-Schwabe, *Hist. of Roman Literature* (Eng. trans.) 301.

PROCACCINI, a family of Italian painters of the Bolognese school. ERCOLE THE ELDER (1520?–1591?) was born in Bologna but moved to Milan where he began a school of painting known as the Academy of the Procaccini, in which many fine painters were trained. He himself was a student of Annibale Carracci (*q.v.*), a founder of the eclectic school of painting. His best works are in the churches of Bologna.

CAMILLO (1546–1629?), GIULIO CESARE (1548?–1626) and CARLO ANTONIO (1555–1605?), his three sons studied with their father; Camillo also studied in Rome. The two elder sons painted principally religious subjects in the tradition of Correggio (*q.v.*). Camillo was a more successful colourist than his father, and Giulio Cesare followed the style of Correggio most perfectly of the three. Their paintings are found in the churches of Milan, Bologna, Genoa and other Italian cities and hang in the galleries of most European capitals. They died in Milan. The youngest and least talented son painted still life and landscapes.

ERCOLE THE YOUNGER (1596–1676) was born and died in Milan. He studied with his uncle Giulio Cesare and was best known for his still life pictures. On the death of Giulio Cesare, he became director of the academy.

PROCEDURE, in law: *see* PRACTICE AND PROCEDURE.

PROCELLARIIDAE: *see* SHEARWATER; FULMAR.

PROCESS: *see* PRACTICE AND PROCEDURE.

PROCESS ENGRAVING: *see* PHOTO-ENGRAVING.

PROCESSING MACHINERY. The machinery described under this heading is for preparing crops for market, storage, feed and food. The machines for the most part are belt driven by an internal combustion engine, tractor or electric motor, and occasionally by a steam engine.

Threshers.—When small grain is harvested with a header, binder or reaper it must be threshed before it is ready for market. This is the purpose of the thresher which performs three main functions—threshing or flailing the grain out of the heads, separating the grain from the straw, and cleaning the grain. Threshing is accomplished by the cylinder (tooth, rasp sometimes called fluted or rub-bar, or flail type) and concaves, which knock the grain out of the heads, part of it falling through the grates underneath the rear portion of the cylinder. The remainder passes with the straw which is directed onto the oscillating or vibrating straw racks or strawwalker by a beater, where separation takes place. A grain pan underneath catches the grain from the cylinder and straw rack and passes it on to the chaffer, sieves and screens. This, aided by a fan, is the cleaning mechanism which removes the weed seeds, dirt and chaff. The grain then gravitates to the grain auger, thence successively to a vertical conveyor, weigher and bagging or wagon spout. Another auger directs any unthreshed heads or tailings to an elevator which delivers them back into the cylinder. A wind stacker mounted at the rear of the machine blows the chaff and straw through a pipe onto a stack.

To facilitate feeding, self-feeders and conveyors are frequently used for carrying the bundles or sheaves to the cylinder, volume governors for effecting uniform feeding, band cutters for cutting the bands and various other features according to the make of machine.

For threshing soybeans, peas, beans and similar crops where low-cylinder speeds (400 to 600 r.p.m. in place of the normal 1,000 to 1,200 r.p.m.) are required to avoid excessive cracking of the seed, attachments are available. They comprise change-over parts to obtain proper speed of cylinder and other parts of the thresher as well as changes in concaves and screen equipment.

For threshing kaffir corn and the various varieties of sorghum grains which require a cylinder speed of between 800 and 850 r.p.m. special attachments are also to be had. Some makes of machines have special attachments for threshing rice, clover, alfalfa, peanuts, etc., while some manufacturers furnish machines especially designed to handle these crops. The size of the thresher is determined by the width of the cylinder and the width of the machine at the rear. The smallest thresher is about 20x28 in. (20-in. cylinder and 28-in. width of machine) and the largest are about 40x62 in. The foregoing applies to the machines used mainly in the United States and Canada.

In England and continental Europe more care is taken of the straw, both in threshing and afterward. Often the bands are cut by hand and the bundles are hand-fed into the cylinder. The fluted bar cylinder which does not break the straw so badly as the spike cylinder is more commonly used. What light material there is, however, such as chaff and short straws (cavings) is discharged from the thresher and not allowed to get into the straw. This leaves clean straw which is usually delivered directly into a press or trusser which bundles and ties it and passes the bundles up a chute into the mow or for loading onto a wagon. However, balers patterned after the United States type of construction are used to some extent in place of the presses. The standard size thresher in England is 54 in. which is the width of the cylinder and is also the approximate width of the machine. Although in the main the work accomplished by U.S. and British machines is more or less the same, a few features occur in the British that do not appear in the American, such as the awner and chobber, the second cleaning fan, the rotating screen and the extra grain spouts. The awner and chobber, which are enclosed in a housing with an adjustable opening at one end, consist of a shaft upon which are mounted in succession two or three turns of

an auger, a series of spirally arranged knives (the awner) and two disks of different diameters fitted with several bar elements with projecting teeth giving the appearance of a cone. When threshing barley, the grain is conveyed to the awner by an elevator and an auger, for removing the awns and then is passed to the chobber for further rubbing. The second cleaning fan is to further clean the grain already partially cleaned by the first fan, after which it is passed into the rotary screen for grading and falls into grain spouts to correspond. Usually three grades are provided for.

Silo Fillers (Ensilage Cutters).—Silage or ensilage is herbage stored in a green, moist state. Silage possesses certain advantages as a feed-stuff, and the practice of growing succulent fodder crops such as corn (maize), alfalfa, oats, grass, etc., for making it, particularly in humid regions, is common. Silage may be stored in pits, picket silos or tower silos. For making silage the crop is mowed green and usually cut up into short lengths by a portable combined silage cutter and blower. The material to be cut is deposited on a conveyor which carries it to a pair of feeding rolls, the lower one fixed, the upper one floating, thence to the knives of flywheel or lawn-mower type. From the knife housing, the chopped material is generally blown into the silo through a vertical sheet-metal pipe leading into the top of the silo often 50 to 60 ft. high and frequently higher. Sometimes, however, an endless belt or chain conveyor is used for grass silage. Some machines are provided with a molasses pump and distributing system for adding molasses or other preservative to crops deficient in sugar. A safety device is usually provided consisting of a bail (inverted U-shaped lever) which controls a gear-shifting mechanism for starting, stopping and reversing the feed mechanism. When the bail is forward toward the operator the conveyor moves toward the cutter; when the bail is pushed part way by the shoulder the conveyor is stopped; and further pushing reverses it.

Hay and Straw Cutters (Chaffcutters).—The chaffing or chopping of hay and straw into short lengths is done to facilitate mixing with other feeds and to assist in the feeding of livestock. In a chaffcutter the hay or straw is fed into a long chopper or a trough, at the bottom of which is a moving belt for conveying the uncut fodder to toothed rollers: these rollers hold the stalks while the knives descend and cut the fodder. The knives which may be curved or straight are usually attached to the spokes of the flywheel (which is connected to the driving mechanism by a spindle or shaft), and so set that they cut the fodder against the mouth or shear plate of the machine as it is pushed forward by the feeding rollers, which are driven by gearing from the driving shaft of the machine. The length of cut is varied by adjusting the speed of the conveyor. The speed of the knives can be varied to suit the cut, and some machines have three-speed gearing for this purpose. The upper feeding roller is usually kept in position by a spring so that it can adjust itself to uneven thicknesses of fodder.

Power-driven chaffcutters in Great Britain are required to have a cover over the knives and a device to prevent the hand or arm of the operator being drawn into the machine. In hand-fed machines there is usually a device for reversing the direction of rotation of the feeding rollers in the event of the operator's arm being drawn along with the fodder. As an additional safeguard, idle rollers may be placed on the outside of the feeding rollers. Large machines may have dust extractors and bagging attachments or blowers for conveying the cut fodder into storage.

Baler or Baling Press.—Where hay or straw is baled from the stack a portable (two-wheel or four-wheel) baler is used. As a charge of hay is placed on the platform and pushed into the hopper it is forced into the baling chamber by the feeder head. The plunger then moves forward and compresses this charge and returns momentarily to its initial position while another charge is being placed in readiness. Grooved blocks inserted at intervals by the operator determine the length of the bale. Baling wires or ties are pushed through the grooves to secure the bale, and then tied. Some machines are provided with a bell for signalling the time to drop the divider blocks. As the bales are forced from the press the blocks drop to the ground ready for use again. The tightness of the bale may be controlled by hand screws at the discharge end of the baling chamber. Power is supplied in some instances through sweeps drawn by work animals, but more generally by an internal combustion engine. The more common sizes of the baling chamber in the United States are 14x18 in., 16x18 in., and 17x22 in.

Straw Press.—This may be considered a modified type of baler used considerably in England and continental Europe. As stated under "thresher" it is placed at the discharge end of the thresher and receives the straw as the grain is threshed. A belt from the thresher drives the press through a large belt pulley. As the straw is deposited in the hopper a swinging plunger (used on one type) pushes the straw forward through the straw channel to form the bundle or bale. Two needles tie it with binder twine. A series of feeder arms automatically force the straw from the hopper into the channel when the plunger returns to the starting point of its stroke. Bundle after bundle is pushed up a chute into a mow or wagon.

Husker-Shredder.—In regions of the United States where corn is harvested for the stover (stalks) as well as the grain, frequent use is made of the husker-shredder (fig. 1). As in the case of the mechanical corn picker the cornstalks with ears attached go through the snapping and husking rolls (these may be combination rolls, the lower or forward end snapping and the upper end husking) where the ears are snapped off and husked. The ears are

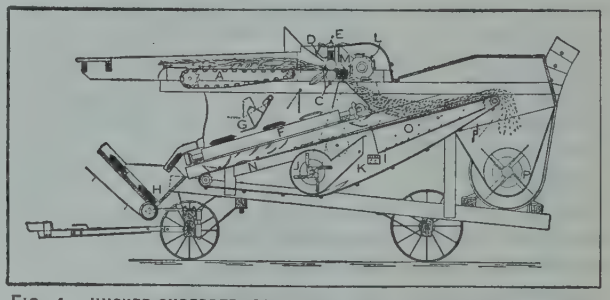


FIG. 1.—HUSKER-SHREDDER EQUIPPED WITH CONVEYOR-TYPE FEEDER (A); C, horizontal snapping rolls; D, snapping-roll springs and adjusting nuts (E); F, husking rolls; G, ear-corn kicker and carrier (H); O, cleaning shoe and fan (J); I, K, cross shake and screen; L, cutter head; M, shear bar; N, slatted conveyor; P, blower

then delivered by an elevator into a wagon or the crib and any shelled corn passes through a cleaning unit similar to a thresher and thence to a discharge spout for sacking or other disposal. The husks and stalks pass through the shredder head where they are shredded and then disposed of through a blower. This material is used for feed or bedding. As bedding it has excellent absorptive qualities.

Mills (for Crushing, Grinding, Kibbling).—These machines are used principally for milling cereals, maize, pulse, etc., before feeding to livestock, so as to aid digestion, as, for example, in the case of crushed oats, or to facilitate mixing with other fodder, *e.g.*, ground ear corn or chaffed hay or straw. The degree of grinding is very coarse compared with flour, though some mills used by farmers can grind wheat sufficiently fine for making whole-meal bread. In the United States the machines described above are known as "feed grinders" or "feed mills" and may have attachments for cutting pea vines, peanut hay and other roughage previous to being ground. Such machines are often fitted with bagging or blowing devices.

Crushers or kibblers are used mainly for oats, maize and linseed, which are bruised, broken or flattened without being ground into a meal. The essential components are two roughened or fluted rollers which crush the material as it passes between them. One roller is fixed and the other adjustable so that different grains can be crushed or the fineness of crushing varied. In some machines the fixed roller has a much larger diameter than the other and serves as a flywheel. The grain is fed from a hopper by gravity and the machine may be either hand- or power-driven.

Grist or grinding mills are invariably power-driven and utilize small disks (smooth, rough or fluted) revolving at a high speed in a vertical plane for grinding grain fed from a hopper. The mill is placed on a suitable stand and must be firmly fixed to a solid

foundation. Stone was originally used for the grinding disks, but chilled metal and artificial stones are now commonly employed. The disks may be flat or conical and provision is made for adjusting them to vary the fineness of grinding. Where a farmer desires to grind whole-meal flour the mill may be provided with a meal-sifter. Combined crushing and grinding mills are also made: the essential components resemble those described above, but the hopper is usually divided into two compartments so that both operations may be carried on simultaneously.

Hammer Mills.—In the United States the hammer mill is, to a considerable extent, replacing the burr mill for grinding all small grains including wheat, oats, barley and shelled corn, as well as ear corn and dry roughages. The grain is fed by gravity from a hopper or by a conveyor into rapidly revolving hammers which pulverize the material and force it through the grinding liners or screens encircling the revolving hammers. The size of the holes in the screen determines the degree of fineness of the meal. As the material passes through the screen a blower blows it into a cyclone (separator) where the dust settles. From here it gravitates into sacks or is conveyed to a bin. For grinding roughage, such as cornstalks, auxiliary knives are provided to chop it into short lengths before it contacts the hammers.

Corn (Maize) Shellers.—For shelling corn in the ear, use is made of the corn sheller—the cylinder type for large capacity and the spring type for small capacity. In the *cylinder type* the ears are fed into the sheller by a conveyor and feeding spiral where the conical-shaped lugged cylinder revolving within the shelling cage causes the kernels to be rubbed off the cob. The shelled corn falls onto a cleaning screen, exposed to an air blast, and then is discharged into bags or a wagon. A large capacity suction fan draws off the pieces of husks and other light materials and the cobs are moved by a so-called cob walker and discharged through a chute.

The *spring type sheller* may be of the one-, two-, four- or six-hole size. The one- or two-hole type may be operated by a hand crank or a small electric motor, but the larger ones require more power. The shelling is effected by a shelling wheel fitted with projections. The corn is fed into the hole or holes as the wheel revolves and with the aid of a rag iron under spring pressure for holding the ears against the wheel, the kernels are removed and fall into the shelled corn outlet through an air blast. The cobs

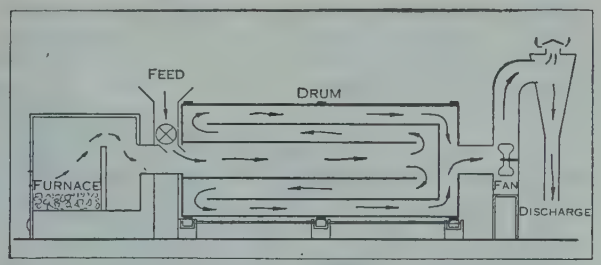
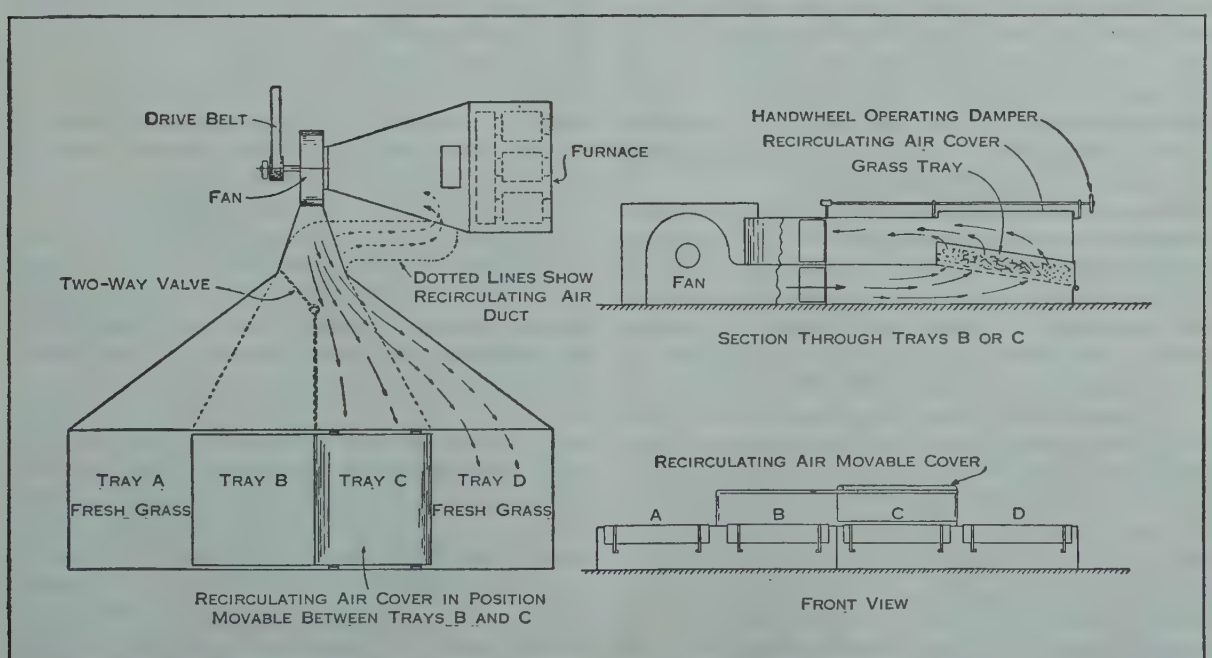


FIG. 2.—REVOLVING-DRUM TYPE OF FORAGE DRIER, TRIPLE-DRUM DESIGN

are usually discharged at the opposite end from the feed. The spring type sheller is not adapted to shelling unhusked or "snapped" corn and is sometimes used for shucking black walnuts.

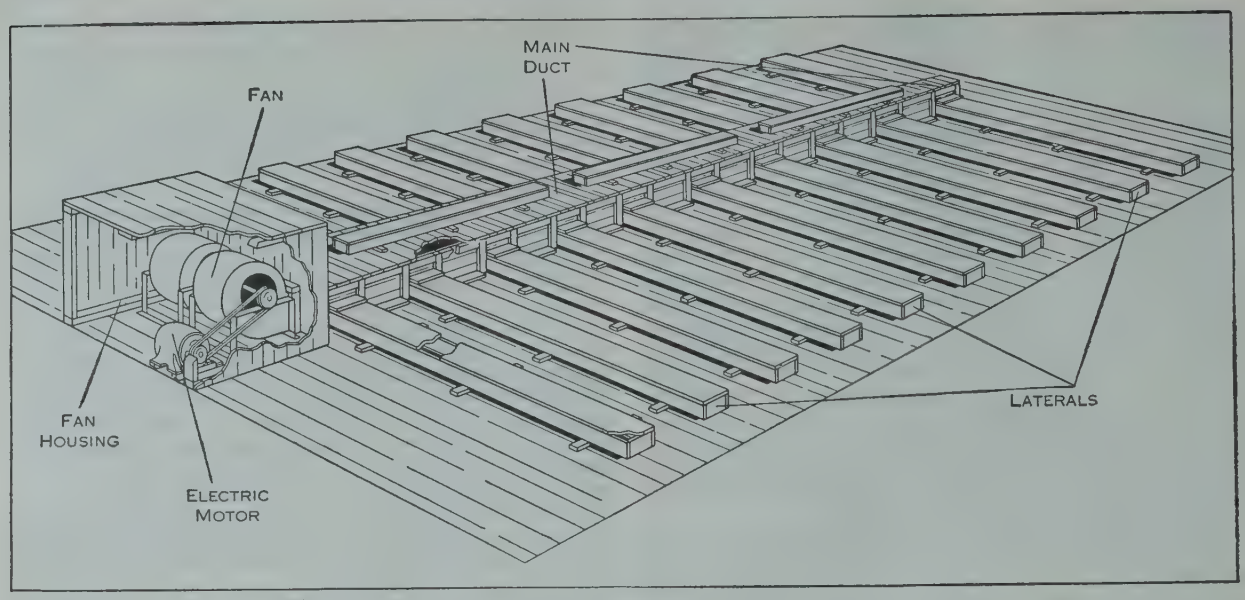
Cake Breakers.—These machines, for hand and power operation, consist of a feeding slot and one or two pairs of toothed or spiked metal rollers which break linseed cake, soybean cake or similar feed material as it passes between them. The distance between the rollers can be varied to alter the size of the broken pieces called nuts; these are passed over a riddle in order to separate the meal and fine particles from the nuts. The breaking rollers are guarded and the gears used for driving the rollers are encased by a metal covering.

Root Cleaners, Cutters and Pulpers.—These machines are used mainly to chop up swede turnips which are hard. Mangels and white or soft turnips are usually fed whole, though they may occasionally be sliced. *Cleaners* consist of a number of iron bars joined together in the form of an open cylinder which can rotate in an inclined plane. The roots are fed into a hopper at one end and pass by gravitation as it rotates along the cleaner into the cutter or pulper, any loose soil falling through the iron bars in the process. The rate of cleaning is regulated by altering the inclination of the cylinder to the horizontal. *Cutters or pulpers* are of various types and may be operated by hand or power. The simplest hand machine is the stamp or lever cutter which slices the roots by means of a receptacle with knives set in echelon at the sides and a hinged handle with a block of wood for pressing the roots onto the knives. The commonest types work on the rotary principle and have a hollow barrel or drum carrying cutting



FROM "GRASS DRYING" (LONDON AND COUNTIES COKE ASSOCIATION)

FIG. 3.—TRAY DRIER



COURTESY OF VIRGINIA POLYTECHNIC INSTITUTE

FIG. 4.—MOW DRIER

devices of various shapes on the periphery. The roots are fed from a hopper, and the barrel, which is mounted on a frame, can rotate in either direction so that the roots can be sliced by one set of knives and cut into fingers by the other. It is usual to slice roots for cattle and cut them into fingers for sheep. For pulping roots, rotating disks with cutting projections are used, but these machines appear to be going out of use. Power root cutters may have an elevator for feeding the roots or for disposing of the roots after cutting.

Peanut Pickers.—The old and primitive way of gathering peanuts was to pick them from the vine by hand. With the scarcity of labour and the improvement of peanut picking machinery, hand methods have been replaced by machines of which there are two types—the thresher and the picker. The *thresher* is a cylinder type machine similar to the grain thresher, but with the cylinder usually fitted with spring teeth working above a spring-tooth concave. It frequently also has stemmer saws similar to cotton gin saws, but for removing the stems from the peanuts, and a flexible tooth stripper in place of the usual beater. The *picker type* differs considerably in principle from the thresher type. The picking is done by dragging the vines by means of a studded slat conveyor over a wire mesh screen in such a way that the nuts fall through and are brushed off from the underside.

Drying of Agricultural Products.—By reducing the moisture content of various commodities to between 10% and 25%—depending upon the commodity—it has been found that the deteriorating action of such agencies as bacteria, yeasts, moulds, insects, enzymes and probably certain purely chemical reactions could be arrested. For accomplishing this purpose there are four systems in use. One utilizes heat by indirect radiation, one by direct radiation, one uses direct heat, and the fourth dries without heat—the cold air duct method.

In the *indirect radiation* method heat is transferred to the product or to the drying air through the intermediate agency of a steam boiler and steam heating coils. An example of this type is the vertical cotton drier. This consists essentially of a tower about 15 ft. high with an approximately 4x4-ft. cross section, lined with sheet metal and fitted with sheet-metal partway floors at about 12-in. intervals and staggered so that alternate ends are open a distance of a few inches. The seed cotton is sucked from the transport truck and fed into the hot blast created by the drier fan which blows air over heated coils. This air which has a temperature of about 150° F. travels through the drying tower at approximately 800 to 1,200 lin.ft. per minute. The locks of cotton impinge violently upon the warm sheet-metal walls of the tower at each reversal of direction from floor to floor. From the bottom floor of the tower, the dried cotton is thrown against the cleaning screen where some of the foreign matter is cast out, after which the cotton is carried in a stream of hot air to the gins.

In the *direct radiation* method radiant heat from metal walls or from flues connected with the combustion chamber of a furnace is employed, as in one type of grain drier. Here the air at a maximum temperature of 180° F. is forced through vertical layers of grain usually from 4 to 6 in. thick and separated alternately by a vertical series of intake and exhaust flues. The grain to be dried is fed by gravity into the hopper at the top of the drier from a storage bin above. The grain passes down through the drier and cooler bins by gravity and then is conveyed to a pit by means of a screw. The discharge rate measured by the length of time the grain remains in the drier is regulated by dampers at the bottom of the hopper under the cooler bin.

In the *direct heat* method use is made of the products of combustion from a coal, coke or oil burning furnace and is used in the apron-conveyor, revolving-drum or batch type driers often for drying green products such as hay. In the *apron-conveyor type* the green forage is loaded on an endless screen-wire apron and conveyed through the drying chamber where hot air or furnace gases are circulated through the layer of forage on the apron by means of one or more fans. Driers of this type may have a single endless conveyor, or several conveyors one above the other. The forage may be fed into the drier whole, crushed or chopped and is exposed to a temperature of from 250° to 350° F. for a period of from 15 to 45 minutes, depending in part upon the initial moisture content of the forage. The *revolving-drum type* (fig. 2) is a high-temperature machine, necessitating a short period of exposure to prevent charring or burning the hay. The temperature of the furnace gases entering the machine is usually held at from 1,000° to 1,500° F. and the material remains in the drier from 1 to 3 minutes. The hay, chopped into short pieces, is fed into the blast of the hot gases drawn through by blowers. Flights or wings attached to the drier shell cause the chopped material to fall from the top side through the blast and assist in the drying. The *tray drier* (fig. 3) is of various designs one of which is quite popular in England for drying hay. Coke is used for fuel and the hot gases from the furnace are blown under two sections containing mats of hay. The section with green hay is arranged so the hot gases pass up through the mat and into the open until the hay is half dry, when it is pitched by hand into a second compartment with a cover. Here the gas passes through the half-dry hay and back to the furnace to be reheated. There are two additional

compartments symmetrical with the first two which are being prepared while drying is taking place in the others. In the *cold air duct type* or mow drier (fig. 4), as it is often called, no heat is used. A series of wooden ducts, rectangular in section, open on the under side and raised an inch off the floor cause the air to pass through the surrounding hay under pressure produced by a blower. These ducts are about 6 ft. apart and green hay may be piled on them to a depth of about 5 ft. until dry, when an additional 5 ft. may be added and so on up to the height of the mow. Depending upon atmospheric conditions a 5 ft. depth is usually dried in from 10 to 12 days. In 1943 one United States firm specializing in grass dehydrating methods built a portable plant to produce dehydrated alfalfa and grass meal on a railroad flat car. Six additional plants were built during 1944, the fleet of seven mobile units to serve seven of the southwestern states.

Before sending one of these portable units into a farming community, advance agents contract for a sufficient acreage of alfalfa conveniently located to a railroad siding and a natural gas supply. About 800 ac. of green material will keep a unit in operation 24 hours per day during the growing season. A revolving-drum type drier is used and heat is supplied from natural gas which is abundant in these states. The alfalfa and grasses are fed into a cutter where they are shredded. The material passes into the drier drum—7 ft. in diameter and 35 ft. long—where it is subjected to temperatures as high as 1,500° F. When the dried material leaves the drier, losing some 25% of its weight, it is automatically carried to the hammer mills through a series of cyclones for cooling purposes before being ground. Completely processed, the meal is packed in 100 lb. bags then shipped to the company's refrigerated warehouses where a temperature of 5° F. is maintained throughout the year. This refrigeration process is said to preserve the carotene content as well as other vitamins. Each portable unit will process 20 to 30 100 lb. bags of meal per hour.

Elevators.—Where large quantities of hay or straw are to be stacked or placed in the mow, or grain in bins or cribs for storage much labour is saved by the use of elevators. A common type consists of a hopper, a long trough, usually rectangular in section and open on top, and an endless belt or chain fitted with forks for conveying hay, flights (cross pieces) for conveying ear corn and sometimes small grain and flights of special design for working inside a spout for small grain, shelled corn, etc. The whole is mounted on a frame carried on four wheels and for convenience in transport the machine is made in sections so that it can be folded. The material is fed into the hopper from which it is picked up by the forks or flights and conveyed up the trough to the top of the stack, grain bin, mow, or silo. Elevators may be operated by animal power, internal-combustion engine, electric motor, or when used for stacking straw, direct from the threshing machine.

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PROCESSION, in general, an organized body of people advancing in formal or ceremonial manner (M. Eng. *processioun*, Fr. *procession*, Lat. *processio*, from *procedere*, to go forth, advance, proceed). This definition covers a wide variety of such progresses: the mediaeval pageants, of which the Lord Mayor's show in London is the most conspicuous survival; the processions connected with court ceremonies; those organized to demonstrate political or other opinions; processions forming part of the ceremonies of public worship. In a narrower sense of "going forth, proceeding," the term is used in the technical language of theology in the phrase "Procession of the Holy Ghost," expressing the relation of the Third Person in the Triune Godhead to the Father and the Son.

Greek and Roman Processions.—Processions are included in the ritual of many religions, and in many countries, both in the east and west, they accompany such events as weddings and funerals.

Religious and triumphal processions are abundantly illustrated by ancient monuments, *e.g.*, the religious processions of Egypt, those illustrated by the rock carvings of Boghaz-Keui, the many representations of processions in Greek art, culminating in the great Panathenaic procession of the Parthenon frieze, and Roman triumphal reliefs, such as those of the arch of Titus.

Processions played a prominent part in the great festivals of Greece, where they were always religious in character. The games were either opened or accompanied by more or less elaborate processions and sacrifices, while processions from the earliest times formed part of the worship of the old nature gods (*e.g.*, those connected with the cult of Dionysus, etc.), and later formed an essential part of the celebration of the great religious festivals (*e.g.*, the processions of the Thesmophoria, and that of the Great Dionysia), and of the mysteries (*e.g.*, the great procession from Athens to Eleusis, in connection with the Eleusinia).

Of the Roman processions, the most prominent was that of the triumph, which had its origin in the return of the victorious army headed by the general, who proceeded in great pomp from the Campus to the Capitol to offer sacrifice, accompanied by the army, captives, spoils, the magistrate and priests bearing the images of the gods, amidst strewing of flowers, burning of incense and the like (Ovid, *Trist.* iv, 2, 3 and 6). Connected with the triumph was the *pompa circensis*, or solemn procession which preceded the games in the circus; it first came into use at the *ludi romani*, when the games were preceded by a great procession from the Capitol to the Circus. The praetor or consul who appeared in the *pompa circensis* wore the robes of a triumphing general (*see* Mommsen, *Staatsrecht I*, 397, for the connection of the triumph with the *ludi*). Thus, when it became customary for the consul to celebrate games at the opening of the consular year, he came, under the empire, to appear in triumphal robes in the *processus consularis*, or procession of the consul to the Capitol to sacrifice to Jupiter. After the establishment of Christianity, the consular processions in Constantinople retained their religious character, now proceeding to St. Sophia, where prayers and offerings were made; but in Rome, where Christianity was not so widely spread among the upper classes, the tendency was to convert the procession into a purely civil function, omitting the pagan rites and prayers, without substituting Christian ones (Dahremberg and Saglio, *s.v.* "Consul"). Besides these public processions, there were others connected with the primitive worship of the country people, which remained unchanged, and were later to influence the worship of the Christian Church. Such were those of the Ambarvalia, Robigalia, etc., which were essentially rustic festivals, lustrations of the fields, consisting in a procession round the spot to be purified, leading the sacrificial victims with prayers, hymns and ceremonies, in order to protect the young crops from evil influences. (*See* Preller, *Röm. Mythologie*, pp. 370–372).

Processions in the Christian Church.—As to the antiquity of processions as part of the ritual of the Christian Church, there is no absolute proof of their existence before the 4th century, but as we know that in the catacombs stations were held at the tombs of the martyrs on the anniversary of their death, for the celebration of the eucharist, it is quite probable that the faithful proceeded to the appointed spot in some kind of procession. There are, indeed, early instances of the use of the word *processio* by Christian writers, but it does not in any case appear to have the modern meaning "procession." Tertullian (2nd century) uses *processio* and *procedere* in the sense of "to go out, appear in public," and, as applied to a church function, *processio* was first used in the same way as *collecta*, as the equivalent of the Greek *συνάξις*, *i.e.*, for the assembly of the people in the church (Du Cange, *s.v.* "Processio").

For the processions that formed part of the ritual of the eucharist, those of the introit, the gospel and the oblation, the earliest records date from the 6th century and even later (*see* Duchesne, *Origines*, 2nd ed. pp. 77, 154, 181; 78, 194), but they evidently were established at a much earlier date. As to public processions, these seem to have come into rapid vogue after the recognition of Christianity as the religion of the empire. Those

at Jerusalem would seem to have been long established when described by the authoress of the *Peregrinatio Silviae* towards the end of the 4th century (*see* PALM SUNDAY, for the procession of palms).

Litanies or Rogations.—Very early were the processions accompanied by hymns and prayers, known as *litaniae* (Gr. λιταναῖα from λιτή, prayer), *rogationes* or *supplicationes* (*see* LITANY). It is to such a procession that reference appears to be made in a letter of St. Basil (*c.* 375), which would thus be the first recorded mention of a public Christian procession. The first mention for the Western Church occurs in St. Ambrose (*c.* 388, Ep. 40 § 16, *Ad Theodos.*: "monachos . . . qui . . . psalmos canentes ex consuetudine usuque veteri pergebant ad celebritatem Machabaeorum martyrum"). In both these cases the litanies are stated to have been long in use. There is also mention of a procession accompanied by hymns, organized at Constantinople by St. John Chrysostom (*c.* 390–400) in opposition to a procession of Arians, in Sozomen, *Hist. eccl.* viii. 8. In times of calamity litanies were held, in which the people walked in robes of penitence, fasting, barefooted, and, in later times, frequently dressed in black (*litaniae nigrae*). The cross was carried at the head of the procession and often the gospel and the relics of the saint were carried. Gregory of Tours gives numerous instances of such litanies in time of calamity; thus he describes (*Vita S. Remig.* I.) a procession of the clergy and people round the city, in which relics of St. Remigius were carried and litanies chanted in order to avert the plague. So, too, Gregory the Great (*Ep.* xi. 57) writes to the Sicilian bishops to hold processions in order to prevent a threatened invasion of Sicily. A famous instance of these penitential litanies is the *litania septiformis* ordered by Gregory the Great in the year 590, when Rome had been inundated and pestilence had followed. In this litany seven processions, of clergy, laymen, monks, nuns, matrons, the poor and children respectively, started from seven different churches, proceeded to hear mass at Sta. Maria Maggiore (*see* Greg. of Tours, *Hist. Fr.* x. 1, and Johann. Diac. *Vita Greg. Magn.* i. 42). This litany has often been confused with the *litania major*, introduced at Rome in 598 (*vide supra*), but is quite distinct from it.

Funeral processions, accompanied with singing and the carrying of lighted tapers, were from very early times customary and in some ways similar to these; also very early, were the processions connected with the translation of the relics of martyrs from their original burying place to the church where they were to be enshrined (see, *e.g.*, St. Ambrose, *Ep.* 29 and St. Augustine, *De civitate Dei*, xxii. 8 and *Conf.* viii. 7, for the finding and translation of the relics of Saints Gervasius and Protasius). From the time of the emperor Constantine I. these processions were of great magnificence.

Origin of Christian Processions.—Some liturgists maintain that the early Church in its processions followed Old Testament precedents, quoting such cases as the procession of the ark round the walls of Jericho (Josh. vi.), the procession of David with the ark (2 Sam. vi.), the processions of thanksgiving on the return from captivity, etc. The liturgy of the early Church as Duchesne shows (*Origines*, ch. i.) was influenced by that of the Jewish synagogue, but the theory that the Church adopted the Old Testament ritual is of quite late growth. What is certain is that certain festivals involving processions were adopted by the Christian Church from the pagan calendar of Rome. Here we need only mention the *litaniae majores et minores*, which are stated by Usener ("Alte Bittgänge," in Zeller, *Philosophische Aufsätze*, p. 278 *seq.*) to have been first instituted by Pope Liberius (352–366). It is generally acknowledged that they are the equivalent of the Christian Church of the Roman lustrations of the crops in spring, the *Ambarvalia*, etc. The *litania major*, or great procession on St. Mark's day (April 25) is shown to coincide both in date and ritual with the Roman *Robigalia*, which took place *a.d. vii. Kal. Mai.*, and consisted in a procession leaving Rome by the Flaminian gate, and proceeding by way of the Milvian bridge to a sanctuary at the 5th milestone of the Via Claudia, where the *flamen quirinalis* sacrificed a dog and a sheep to avert blight (*robigo*) from the crops (*Fasti praenestini*, C.T.L.T., p. 317). The *litania major* followed the same route as far as the Milvian bridge, when it turned off and returned to St. Peter's, where mass was celebrated. This was already established as an annual festival by 598, as is shown by a document of Gregory the Great (*Regist.* ii.) which inculcates the duty of celebrating *litaniam, quae major ab omnibus appellatur*. The *litaniae minores* or rogations, held on the three days preceding Ascension Day, were first introduced into Gaul by Bishop Mamertus of Vienne (*c.* 470), and made binding for all Gaul by the 1st Council of Orleans (511). The *litaniae minores* were also adopted for these three days in Rome by Leo III. (*c.* 800). A description of the institution and character of the Ascensiontide rogations is given by Sidonius Apollinaris (*Ep.* v. 14). "The solemnity of these," he says, "was first established by Mamertus. Hitherto they had been erratic, lukewarm and poorly attended (*vagae, tepentes, infrequentesque*); those which he instituted were characterized by fasting, prayers, psalms and tears." In the Ambrosian rite the rogations take place after Ascensiontide, and in the Spanish on the Thursday to Saturday after Whitsuntide, and in November (Synod of Girona, 517).

Processions in the Modern Roman Catholic Church.—It is impossible to describe in detail the vast development of processions during the middle ages. The most important and characteristic of these still have a place in the ritual of the Roman Catholic Church. The rules governing them are laid down in the *Rituale Romanum* (Tit. ix.), and they are classified in the following way:—

(1) *Processiones generales*, in which the whole body of the clergy takes part. (2) *Processiones ordinariae*, on yearly festivals, such as the feast of the Purification of the Virgin (Candlemas, *q.v.*), the procession on Palm Sunday (*q.v.*), the *Litaniae majores* and *minores*, the feast of Corpus Christi (*q.v.*), and on other days, according to the custom of the churches. (3) *Processiones extraordinariae*, or processions ordered on special occasions, *e.g.*, to pray for rain or fine weather, in time of storm, famine, plague, war, or, *in quacunque tribulatione*, processions of thanksgiving, translation of relics, the dedication of a church or cemetery. There are also processions of honour, for instance to meet a royal personage, or the bishop on his first entry into his diocese (*Pontif. rom.* iii.).

Reformed Churches.—The Reformation abolished in all Protestant countries those processions associated with the doctrine of transubstantiation (Corpus Christi); "the Sacrament of the Lord's Supper," according to the 28th Article of Religion of the Church of England, "was not by Christ's ordinance reserved, carried about, lifted up, or worshipped." It also abolished those associated with the cult of the Blessed Virgin and the saints. The stern simplicity of Calvinism, indeed, would not tolerate religious processions of any kind, and from the "Reformed" Churches they vanished altogether. The more conservative temper of the Anglican and Lutheran communions, however, suffered the retention of such processions as did not conflict with the reformed doctrines, though even in these churches they met with opposition and tended after a while to fall into disuse.

Lutheran Church.—The Lutheran practice has varied at different times and in different countries. Thus, according to the Württemberg *Kirchenordnung* of 1553, a funeral procession was prescribed, the bier being followed by the congregation singing hymns; the Brandenburg *Kirchenordnung* (1540) directed a cross-bearer to precede the procession and lighted candles to be carried, and this was prescribed also by the Waldeck *Kirchenordnung* of 1556. At present funeral processions survive in general only in the country districts; the processional cross or crucifix is still carried. In some provinces also the Lutheran Church has retained the ancient rogation processions in the week before Whitsuntide and, in some cases, in the month of May or on special occasions (*e.g.*, days of humiliation, *Busstage*), processions about the fields to ask a blessing on the crops. On these occasions the ancient litanies are still used.

Church of England.—In England "the perambulations of the circuits of the parishes . . . used heretofore in the days of rogations" were ordered to be observed by the *Injunctions* of Queen Elizabeth in 1559; and for these processions certain "psalms,

prayers and homilies" were prescribed. The Puritans, who aimed at setting up the Genevan model, objected; and the visitation articles of the bishops in Charles I.'s time make frequent inquisition into the neglect of the clergy to obey the law in this matter. With "the profane, ungodly, presumptuous multitude" (to quote Baxter's *Saint's Rest*, 1650, pp. 344, 345), however, these "processions and perambulations" appear to have been very popular, though "only the traditions of their fathers." However this may be, the Commonwealth formally put an end to them, and they only survived in some remote country parishes; Sparrow, in his *Rationale upon the Book of Common Prayer* (London, 1668), speaks of "the service *formerly* appointed in the Rogation days of Procession."

Among the processions that survived the Reformation in the English Church was that of the sovereign and the Knights of the Garter on St. George's day. This was until Charles II.'s time a regular rogation, the choristers in surplices, the gentlemen of the royal chapel in copes, and the canons and other clergy in copes preceding the knights and singing the litany. In 1661, after the Restoration, by order of the sovereign and knights companions in chapter "that supplicational procession" was "converted into a hymn of thanksgiving." Akin to this procession also are the others connected with royal functions; coronations, funerals. These retained, and retain, many pre-Reformation features elsewhere fallen obsolete.

The only procession formally prescribed in the Book of Common Prayer is that in the order of the burial of the dead, where the rubric directs that "the priest and clerks meeting the corpse at the entrance of the churchyard, and going before it, either into the church, or towards the grave, shall say, or sing" certain verses of Scripture. Tapers seem to have been carried in processions, not only at royal funerals, until well into the 18th century. Processions, with the singing of the litany or of hymns, appear also to have been always usual on such occasions as the consecration of churches and churchyards and the solemn reception of a visiting bishop. Examples of processions in use in the English Church are the processional litanies, and the solemn entry and exit of clergy and choir. The use of the processional cross, banners and lights has been largely revived.

BIBLIOGRAPHY.—*See* the article "Bittgänge," by M. Herold, in Herzog-Hauck, *Realencyklopädie*, iii. 248 (3rd ed., Leipzig, 1897); Wetzer und Welte, *Kirchenlexikon*, *s.v.* "Prozession, Bittgänge Litanei" and Smith's *Dictionary of Christian Antiquities*, *s.v.* "Procession." For the early ritual *see* Duchesne, *Origines du culte chrétien* (3rd ed., Paris, 1903). *See* also G. Catalani, *Rituale romanum perpetuis commentariis exornatum* (1760); N. Serarius, *Sacri peripatetici de sacris ecclesiae catholicae processionibus* (2 vols., 1607); Jac. Gretser, *De ecclesiae romanae processionibus* (2 vols., Ingolstadt, 1606); Jac. Eveillon, *De processionibus ecclesiae* (1641); Edw. Martène, *De antiquis ecclesiae ritibus* (3 vols., Antwerp, 1763), etc. For the past usage of the Church of England, *Hierurgia anglicana*, ed. Vernon Staley, p. ii. pp. 3–22 (1903).

PROCESSIONARY CATERPILLAR or **ARMY WORM,** the name given to larvae of moths which when moving to a new feeding place, proceed in line, the head of each touching the tail of the caterpillar in front. Most of the old world kinds are Thaumetopoeidae (e.g., the European *Thaumetopoea processionea* on pine); while in the new world they are young larvae of Hemileucine Saturniidae.

See J. H. Fabre, *The Life of the Caterpillar*.

PROCÈS-VERBAL, in French law, a detailed authenticated account drawn up by a magistrate, police officer, or other person having authority of acts or proceedings done in the exercise of his duty. In a criminal charge, a procès-verbal is a statement of the facts of the case. The term is also applied to the written minutes of a meeting or assembly.

PROCIDA, an island off the coast of Campania, Italy (Gr. Προχύτη, Lat. *Prochyta*), 2 mi. S.W. of Capo Miseno, 2 mi. N.E. of Ischia on the west side of the Gulf of Naples, 12 mi. S.W. of Naples. Pop. (1936) 9,452. It is about 2 mi. in length, and, reckoning in the adjacent island of Vivara, is made up of four extinct craters, parts of the margins of all of which have been destroyed by the sea. The highest point of it is only 250 ft. above sea-level. It is very fertile. Procida, the only town, lies on the east side; its castle is now a prison. It also contains a royal palace.

PROCLAMATION. In English law, a royal proclamation is a formal announcement, made under the great seal, of some matter which the king in council desires to make known to his subjects; *e.g.*, the declaration of war, the statement of neutrality, the conclusion of peace, the annexation of territory, the summoning or dissolution of parliament, or the bringing into operation of the provisions of some statute the enforcement of which the legislature has left to the discretion of the king in council. Royal proclamations of this character, made in furtherance of the *executive* power of the Crown, are binding on the subject "where they do not either contradict the old laws or tend to establish new ones" (Dicey, *Law of the Constitution*, 6th ed., 51). The Crown has often *legislated* by proclamation; and the Statute of Proclamations 1539 provided that proclamations made with the assent of the council should have the force of statute law, if they were not prejudicial to "any person's inheritance, offices, liberties, goods, chattels or life." But this enactment was repealed by an act of 1547; and it is well settled that the Crown cannot by proclamation make or remake any law unless the proclamation is issued under statutory authority. (*Ex parte Chavasse*, 1865, 1 De G. J. & S. 622; *Grieve* v. *Edinburgh*, *etc.*, 1918, S. C. [Scotland] 700; *see* also MARTIAL LAW.) The Crown has power to legislate by proclamation for a newly conquered country (Jenkyns, *British Rule and Jurisdiction beyond the Seas*, pp. 95); and this power was freely exercised in the Transvaal Colony during the Boer War of 1899–1902. In the British colonies, ordinances are frequently brought into force by proclamation; certain imperial Acts do not take effect in a colony until there proclaimed (*e.g.*, the Foreign Enlistment Act 1870); and proclamations are constantly issued in furtherance of executive acts. In many British protectorates the high commissioner or administrator is empowered to legislate by proclamation. Proclamations cannot be issued by private persons unless under customary or other valid authority, *e.g.*, a proclamation by members of the Privy Council of the accession of a new sovereign. (A. W. R.)

PROCLUS or **PROCULUS** (A.D. 410–485), the chief representative of the later Neoplatonists, was born at Constantinople, but brought up at Xanthus in Lycia. Having studied grammar under Orion and philosophy under Olympiodorus the Peripatetic, at Alexandria, he proceeded to Athens. There he attended the lectures of the Neoplatonists Plutarch and Syrianus, and about 450 succeeded the latter in the chair of philosophy (hence his surname Diadochus, which, however, is referred by others to his being the "successor" of Plato). As an ardent upholder of the old pagan religion Proclus incurred the hatred of the Christians, and was obliged to take refuge in Asia Minor. After a year's absence he returned to Athens, where he remained until his death. His epitaph, written by himself, is to be found in *Anthologia palatina*, vii. 451.

His great literary activity was chiefly devoted to the elucidation of the writings of Plato. There are still extant commentaries on the *First Alcibiades*, *Parmenides*, *Republic*, *Timaeus* and *Cratylus*. His views are more fully expounded in the Περὶ τῆς κατὰ Πλάτωνα θεολογίας (*In Platonis theologiam*). The Στοιχείωσις θεολογική (*Institutio theologica*) contains a compendious account of the principles of Neoplatonism and the modifications introduced in it by Proclus himself. The pseudo-Aristotelian *De causis* is an Arabic extract from this work, ascribed to Alfarabius (d. 950), circulated in the west by means of a Latin translation (ed. O. Bardenhewer, Freiburg, 1882). Other philosophical works by Proclus are Στοιχείωσις φυσική ἢ Περὶ κινήσεως (*Institutio physica sive De motu*, a compendium of the last five books of Aristotle's Περὶ φυσικῆς ἀκροάσεως, *De physica auscultatione*), and *De providentia et fato, Decem dubitationes circa providentiam, De malorum subsistentia*, known only by the Latin translation of William of Moerbeke (archbishop of Corinth, 1277–1281), who also translated the Στοιχείωσις θεολογική into Latin. In addition to the epitaph already mentioned, Proclus was the author of hymns, seven of which have been preserved (to Helios, Aphrodite, the Muses, the Gods, the Lycian Aphrodite, Hecate and Janus, and Athena), and of an epigram in the Greek Anthology (*Anthol. pal.* iii. 3, 166 in

Didot edition). His astronomical and mathematical writings include Ὑποτύπωσις τῶν ἀστρονομικῶν ὑποθέσεων (*Hypotyposis astronomicarum positionum*, ed. C. Manitius, Leipzig, 1909); Περὶ σφαίρας (*De sphaera*); Παράφρασις εἰς τὴν Πτολεμαίου τετράβιβλον, a paraphrase of the difficult passages in Ptolemy's astrological work *Tetrabiblus;* Εἰς τὸ πρῶτον τῶν Εὐκλείδου στοιχείων, a commentary on the first book of Euclid's *Elements;* a short treatise on the effect of eclipses (*De effectibus eclipsium*, only in a Latin translation).

His grammatical works are: a commentary on the *Works and Days* of Hesiod (incomplete); some scholia on Homer; an elementary treatise on the epistolary style, Περὶ ἐπιστολιμαίου χαρακτῆρος (*Characteres epistolici*), attributed in some mss. to Libanius. The Χρηστομαθία γραμματική by a Proclus, who is identified by Suïdas with the Neoplatonist, is probably the work of a grammarian of the 2nd or 3rd century, though Wilamowitz-Möllendorff (*Philolog. Untersuch.* vii.; supported by O. Immisch in *Festschrift Th. Gomperz*, pp. 237–274) agrees with Suïdas. According to Suïdas, he was also the author of Ἐπιχειρήματα ἢ κατὰ Χριστιανῶν (*Animadversiones duodeviginti in christianos*). This work, identified by W. Christ with the *Institutio theologica*, was answered by Joannes Philoponus (7th century) in his *De aeternitate mundi*. Some of his commentary on the Chaldaean oracles (Λόγια Χαλδαϊκά) has been discovered in modern times.

Bibliography.—There is no complete edition of the works of Proclus. The selection of V. Cousin (Paris, 1864) contains the treatises *De providentia et fato, Decem dubitationes* and *De malorum subsistentia*, the commentaries on the *Alcibiades* and *Parmenides*. The *Institutio theologica* has been edited by G. F. Creuzer in the Didot edition of Plotinus (Paris, 1855); the *In Platonis theologiam* has not been reprinted since 1618, when it was published by Acmilius Portus with Latin translation. Recent editions of individual works are: In the Teubner series, Leipzig, *Commentary on Euclid* (edit. G. Friedlein, 1878); *Republic* (edit. G. Kroll, 1899–1901); *Timaeus* (edit. E. Diehl, 3 vols., 1903–06); *Cratylus* (edit. G. Pasquali, 1908); *Hypotyposis* (edit. C. Manitius, with German trans., 1909); *Institutio Physica* (edit. A. Ritzenfeld, with German trans., 1912); also *Scholia to Hesiod* (edit. E. Vollbehr, 1844); *Characteres epistolici* (edit. A. Westermann, 1856); *Hymns* (edit. E. Abel, 1883); also A. Ludwich (1895); Λόγια Χαλδαϊκά (edit. A. Jahn, 1891); Commentaries on the *Parmenides* (edit. A. E. Chaignet, French trans. and notes, also trans. of Marinus' *Life*, 1900–03). Thomas Taylor, the "Platonist," translated the Commentaries on Euclid, with the *Life* by Marinus and the *Elements of Theology* (2 vols., 1788–89); the *Theology of Plato* (1816); *Timaeus* (1820); *Fragments of the Lost Works of Proclus* (1825), and the three Latin treatises (1833).

On Proclus generally and his works *see* the article in *Suïdas* (edit. G. Bernhardy, 1853); Marinus, *Vita Procli* (edit. with Diogenes Laertius, *Lives of the Philosophers*, by C. G. Cobet, Paris, 1850); H. F. Müller, *Dionysios, Proklos, Plotinos* (1918) in *Beiträge zur Geschichte der Philosophie des Mittelalters* (edit. C. Baeumker, Münster; vol. xx., 1922) and Neoplatonism.

Extracts from the Χρηστομαθία are preserved in *Photius* (Cod. 239), almost the only source of information regarding the epic cycle; on the question of authorship, *see* Christ, sec. 637 and Sandys, p. 379; also D. B. Monro's appendix to his ed. of Homer's *Odyssey*, xii.–xxiv. (1901).

PROCOPIUS, Byzantine historian, was born at Caesarea in Palestine towards the end of the 5th century A.D. He became a lawyer, probably at Constantinople, and was in 527 appointed private secretary to Belisarius, whom he accompanied on his Persian, African and Italian campaigns. After the capture of Ravenna in 540 Procopius seems to have returned to Constantinople, since he minutely describes the great plague of 542 (*op. cit.* ii. 22). It does not appear whether he was with the Roman armies in the later stages of the Gothic War, when Belisarius and afterwards Narses fought against Totila in Italy; his narrative of these years is much less full and minute than that of the earlier warfare. Of his subsequent fortunes we know nothing, except that he was living in 559. Whether he was the Procopius who was prefect of Constantinople in 562 (Theophanes, *Chronographia*, 201, 202), and was removed from office in the year following, cannot be determined, though it is not improbable.

Procopius's writings fall into three divisions: the *Histories* (Persian, Vandal and Gothic Wars), in eight books; the treatise on the *Buildings of Justinian* (*De aedificiis*), in six books; and the *Unpublished Memoirs* (Ἀνέκδοτα, *Historia arcana*), so called because they were not published during the lifetime of the author.

The *Histories* are called by the author himself the *Books about the Wars* (οἱ ὑπὲρ τῶν πολέμων λόγοι). They consist of: (1) the Persian Wars, in two books, giving a narrative of the long struggle of the emperors Justin and Justinian against the Persian kings Kavadh and Chosroes Anushirvan down to 550; (2) the Vandal War, in two books, describing the conquest of the Vandal kingdom in Africa and the subsequent events there from 532 down to 546 (with a few words on later occurrences); (3) the Gothic War, in three books, narrating the war against the Ostrogoths in Sicily and Italy from 536 till 552. The eighth book contains a further summary of events down to 554. These eight books contain notices of some of the more important domestic events, such as the Nika insurrection at Constantinople in 532, and the plague in 542. They tell us, however, comparatively little about the civil administration of the empire, and nothing about legislation.

The *De aedificiis* contains an account of the chief public works executed during the reign of Justinian down to 560 which are of course ascribed to the personal action of the monarch. If not written at the command of Justinian (as some have supposed), it is evidently grounded on official information, and is full of gross flattery of the emperor and of the (then deceased) empress. In point of style it is greatly inferior to the *Histories*—florid, pompous and affected, and at the same time tedious Its chief value lies in the geographical notices which it contains.

The *Anecdota* (date probably 550) purports to be a supplement to the *Histories*, containing explanations and additions which the author could not insert in the latter work for fear of Justinian and Theodora. It is a furious invective against these sovereigns, with attacks on Belisarius and his wife Antonina, and on other noted officials. Owing to the ferocity and brutality of the attacks upon Justinian, the authenticity of the *Anecdota* has often been called in question, but the claims of Procopius to the authorship are now generally recognized. In point of style, the *Anecdota* is inferior to the *Histories*, and has the air of being unfinished, or at least unrevised. The history of Philip of Macedon by Theopompus probably furnished the author with a model.

The best complete edition of Procopius is by J. Haury (Teubner Series, 1905–13). There are English translations of the *History of the Wars*, by H. Holcroft (1653), of the *Anecdota* (1674, anonymous), of the *Buildings*, by Aubrey Stewart (Palestine Pilgrims' Text Society, 1888) and by H. B. Dewing (Loeb Classical Library, 1914, etc.). Chief authorities: F. Dahn, *Procopius von Cäsarea* (1865); J. Haury, *Procopiana* (1891–93). On the genuineness of the *Anecdota*, *see* J. B. Bury (who agrees with Ranke in rejecting the authorship of Procopius), *A History of the Later Roman Empire* (1889), vol. i. and introd. to vol. ii. (p. 57) and appendix to vol. iv. of his edition of E. Gibbon, *Decline and Fall* (1925). *See* also C. Krumbacher, *Geschichte der byzantinischen Literatur* (2nd ed., 1897).

PROCOPIUS OF GAZA (*c.* A.D. 465–528), Christian sophist and rhetorician, was born at Gaza. What is known of him is to be found in his letters and the encomium by his pupil and successor Choricius. Of his rhetorical works only the panegyric on the emperor Anastasius alone is extant. His letters (162 in number) throw light upon the condition of the sophistical rhetoric of the period. The fragment of a polemical treatise against the Neoplatonist Proclus is now assigned to Nicolaus, archbishop of Methone in Peloponnesus (*fl.* 12th century). Procopius's theological writings consist of commentaries which are early examples of the *catena* (chain) form of commentary, consisting of a series of extracts from the fathers, arranged, with independent additions, to elucidate Scripture.

Complete editions of the works of Procopius in Migne, *Patrologia graeca*, lxxxvii.; the letters also in *Epistolographi graeci*, ed. R. Hercher (1873); *see* also K. Seitz, *Die Schule von Gaza* (1892); D. Russos, Τρεῖς Γαζαῖοι (Constantinople, 1893); L. Eisenhofer, *Procopius von Gaza* (1897); further bibliographical notices in C. Krumbacher, *Geschichte der byzantinischen Literatur* (1897), and article by G. Krüger in Herzog-Hauck's *Realencyklopädie für protestantische Theologie* (1905).

PROCRUSTES, also called Polypemon or Damastes, in Greek legend, a robber dwelling in the neighbourhood of Eleusis, who was slain by Theseus (*q.v.*). The "bed of Procrustes" has become proverbial.

Bibliography.—*See* Diod. Sic. iv. 59; Hyginus. *Fab.* 38; Plutarch, *Theseus*, 11; Pausanias i. 38, 5.

PROCTER, ADELAIDE ANNE (1825–1864), English poetess, daughter of Bryan Waller Procter (*q.v.*), was born on Oct. 30, 1825. She began to contribute to *Household Words* in 1853. Her principal work is *Legends and Lyrics,* of which a first series, published in 1858, ran through nine editions in seven years, while a second series issued in 1860 met with a similar success (new ed., 1914). She died on Feb. 2, 1864.

PROCTER, BRYAN WALLER (1787–1874), English poet, was born at Leeds on Nov. 21, 1787. By the death of his father in 1816 he became possessed of a small property, and soon after entered into partnership with a solicitor; but in 1820 the partnership was dissolved, and he began to write under the pseudonym of Barry Cornwall. He was metropolitan commissioner of lunacy from 1832 to 1861. He died on Oct. 5, 1874.

His principal poetical works were: *Dramatic Scenes and Other Poems* (1819); *A Sicilian Story* (1820); *Mirandola,* a tragedy performed at Covent Garden with William Macready, Charles Kemble and Maria Foote in the leading parts (1821); *The Flood of Thessaly* (1823) and *English Songs* (1832).

PROCTOR, ALEXANDER PHIMISTER (1862–1950), U.S. sculptor and painter, was born in Ontario, Canada, on Sept. 27, 1862. As a youth he lived at Denver, Colo., spending much of his time in the Rocky Mountains; and his familiarity with the ways and habits of wild animals was supplemented later by study in the Jardin des Plantes, Paris. He was a pupil at the National Academy of Design and later in the Art Students' league, in New York, and first attracted attention by his statues of wild animals at the Columbian exposition, Chicago. In 1896 he won the Rinehart scholarship, which enabled him to spend five years in Paris, where he studied under Denys Puech and J. A. Injalbert. Among his works of sculpture are: "Quadriga," for the U.S. pavilion, Paris exhibition (1900); the Princeton Tigers, for Princeton university; the equestrian statue of Col. Theodore Roosevelt as rough rider, Portland, Ore., and groups in the City park, Denver, Colo., and Zoological park, New York city. He died on Sept. 4, 1950, at Palo Alto, Calif.

PROCTOR, RICHARD ANTHONY (1837–1888), British astronomer, was born at Chelsea, on March 23, 1837. He was educated privately, at King's college, London, and at St. John's college, Cambridge. He read for the bar but turned to astronomy and authorship. His book *Saturn and His System* (1865), though favourably received by astronomers, was a financial failure; and other financial losses obliged him to cultivate a popular style. He was for a time mathematical coach for Woolwich and Sandhurst.

In 1881 he founded *Knowledge,* a popular magazine, in which he wrote on a great many subjects. He became a fellow of the Royal Astronomical society in 1866 and honorary secretary in 1872. He was an expert in map-drawing and published two star atlases. His most ambitious work, *Old and New Astronomy,* was completed after his death, by A. Cowper Ranyard, and published in 1892. Proctor settled in the U.S. in 1881 and died at New York city on Sept. 12, 1888.

His many publications include *Half-hours with the Telescope* (1868); *Other Worlds than Ours* (1870); *The Borderland of Science* (1873); *The Poetry of Astronomy* (1880); *Mysteries of Time and Space* (1883); *Half-hours with the Stars* (1887). He contributed numerous papers to the *Monthly Notices* of the Royal Astronomical society and articles on astronomy to the 9th edition of the *Encyclopædia Britannica.*

PROCTOR, a variant of the word procurator (*q.v.*), nearly equivalent in meaning to agent (*see* PRINCIPAL AND AGENT). The title is used in England in three principal senses.

1. A practitioner in the ecclesiastical and admiralty courts. A proctor in this sense was formerly a qualified person licensed by the archbishop of Canterbury to undertake duties such as are performed in other courts by solicitors. The king's proctor is the proctor or solicitor representing the crown in the courts of probate and divorce. His power of intervening is limited, by the Matrimonial Causes act, 1860, to cases of collusion only, but he may also, as one of the public, show cause against a decree nisi's being made absolute (*see* DIVORCE). In the admiralty court a proctor or procurator was an officer who, in conjunction with the king's proctor, acted as the attorney or solicitor in all causes concerning the lord high admiral's affairs in the high court of admiralty and other courts. The king's proctor so acted in all causes concerning the king.

In the United States the term proctor is applied to practitioners in the admiralty and probate courts.

2. A representative of the clergy in convocation. A proctor in this sense represents either the chapter of a cathedral or the beneficed clergy of a diocese. In the province of Canterbury two proctors represent the clergy of each diocese; in that of York there are two for each archdeaconry. In both alike each chapter is represented by one.

3. The name of certain important university officials. At Oxford the proctors, with the vice-chancellor, supervise university business and appoint delegates for any particular affairs not otherwise provided for by statute. They are ex-officio members of nearly all the important delegacies. They also act as the assessors of the chancellor or his commissary. They supervise the voting at public meetings of the university and announce the results. They have, jointly, power of veto in convocation and congregation; no proposal can be passed into a statute or decree if twice vetoed by them. They are ex-officio members of the hebdomadal council, the governing council of the university, and they are the assessors of the vice-chancellor when he confers degrees. They are empowered to punish undergraduates, or graduates under the degree of bachelor of civil law and master of arts, by fine or by confinement to their colleges or lodgings (familiarly known as "gating"). They have to see that all examinations are properly conducted. They are responsible for the good order of the streets at night, so far as members of the university are concerned, and perambulate the streets nightly, accompanied by the university marshal and two sworn constables, familiarly known as "bulldogs." The proctors are elected by the heads, fellows and resident members of convocation of each college in rotation.

At Cambridge the proctors are nominated annually by the colleges in rotation and elected (a formal proceeding) by the senate.

At present their functions are (1) taking part in all university ceremonials, (2) enforcing discipline in the case of members of the university who are *in statu pupillari* (*i.e.,* undergraduates and bachelors of arts and law). (1) The proctors are ex-officio members of boards or syndicates such as those with which their duties are specially connected. But their presence is essential at all congregations of the senate, at which the senior proctor reads all the "graces" (already approved by the council of the senate). If any grace is opposed by any member of the senate saying *non placet,* the proctors take the votes of those present and announce the result, and on important occasions many hundreds of nonresident members of the senate come up to record their votes. (2) The proctors have authority to impose certain fines for minor offences. In the case of more serious offences the proctor generally reports the matter to the authorities of the offender's college to be dealt with by them or brings the offender before the university court of discipline.

PROCURATION, the action of taking care of; hence, management, stewardship, agency. The word is applied to the authority or power delegated to a procurator, or agent, as well as to the exercise of such authority, expressed frequently "by procuration" (*per procurationem*), or shortly *per pro.,* or simply *p.p.* In ecclesiastical law, procuration is the providing necessaries for bishops and archdeacons during their visitations of parochial churches in their dioceses. Procuration is merely an ecclesiastical due and as a consequence is suable only in a spiritual court. Procuration is also used specifically for the negotiation of a loan by an agent for his client, whether by mortgage or otherwise; and the sum of money or commission paid for negotiating it is frequently termed procuration fee. (*See* also PROXY.)

In French law, procuration means an authority given to an agent or representative; *e.g.,* a power of attorney.

The English criminal law makes the provision or attempted provision of any girl or woman under 21 years of age for the purpose of illicit intercourse an offense, known as procuration.

PROCURATOR, generally one who acts for another. With the Romans it was applied to a person who maintained or defended an action on behalf of another, thus performing the functions of a modern attorney. Roman families of importance employed an official corresponding to the modern steward and frequently called the *procurator*. Later, the name was applied especially to certain imperial officials in the provinces of the Roman empire. With the establishment of the imperial power under Augustus, the emperor took under his direct government those of which the condition or situation rendered a large military force necessary. Here certain officials, known as the *procuratores Caesaris*, took the place occupied by the *quaestor* in the senatorial provinces. They were either equites or freedmen of the Caesar and their office was concerned with the interests of the fiscus (the public property of the Caesar). They looked after the taxes and paid the troops. There were also officials bearing this title of *procuratores Caesaris* in the senatorial provinces. They collected certain dues of the *fiscus* which were independent of those paid to the *aerarium* (the property of the senate). This organization lasted with some modifications until the 3rd century. The *procurator* was an important official in the reorganized empire of Diocletian.

The title remained all through the middle ages to describe very different officials. Thus it was sometimes applied to a regent acting for a king, during his minority or absence; sometimes it appears as an alternative title to *seneschal* or *dapifer*. It preserved its legal significance in the title of *procurator animarum*, who acted as solicitor or proxy in the ecclesiastical courts, and was so called because these courts dealt with matters affecting the spiritual interests of the persons concerned. The economical significance remained in such titles as *procurator anniversariorum*, the exactor of dues for the celebration of anniversaries; this office was assigned to laymen. The *procurator draperii* was entrusted with the administration of matters pertaining to the art of cloth-making. The *procurator duplarum* was the collector of fines in certain churches from absent canons, etc. The officials entrusted with the administration of the goods of a church were called variously *procurator ecclesiae, procurator parcitatis, procurator universitatis*. Bishops and bishops-elect frequently described themselves by the title of procuratores ecclesiarum. The prior of a dependent religious house was sometimes styled *procurator obedientiae*. The official who represented the public interests in the courts of the inquisition was known as the *procurator fidei*. The administrator of the affairs of a large community was sometimes called the *procurator syndicus;* the administrator of goods left to the poor, *procurator pauperum*. In monasteries the *economus* was, and is, sometimes described as *procurator*. Thus the procurator has still the administration of material affairs in every Dominican priory. *Procurator di San Marco* was a title of honour in Venice.

The term procurator (Fr. *procureur*) is used in those countries whose codes are based on the Roman civil law for certain officials, having a representative character, in the courts of law. In Scotland the term procurator is now almost a law agent who practises in an inferior court. A procurator in the inferior courts has been, since the Law Agents Act 1873, exactly in the same legal position as other law agents. The procurator-fiscal is a local officer attached to the sheriff's court and charged with the duty of precognoscing witnesses regarding crimes, and with the prosecution of persons charged with a crime or offence in the sheriff's court. He also performs the duty of making enquiries into the circumstances of suspicious deaths. He was formerly appointed by the sheriff, but since 1907 has been appointed by the lord advocate. The procurator of the Church of Scotland is a member of the bar appointed by the general assembly as its legal adviser. A common English form of procurator is proctor (*q.v.*).

PROCYON, the brightest star in the constellation Canis Minor (*see* CANIS MAJOR), hence its Bayer equivalent, α Canis Minoris. It and Sirius (*q.v.*) in Canis Major were called the two dog-stars, though "the dog-star" refers to Sirius, which is the brighter of the two. Procyon is a double star consisting of one bright and one very faint component. It is located at a distance of about 11 light-years from the sun and is therefore one of the nearest stars. (*See* STAR: *Double Stars.*)

PRODICUS OF CEOS (b. *c.* 465 or 450 B.C.), a Greek humanist of the first period of the Sophistical movement, was still living in 399 B.C. He came to Athens as ambassador from Ceos, and became known as a speaker and a teacher. Like Protagoras, he professed to train his pupils for domestic and civic affairs, and made ethics prominent in his curriculum. He advocated no hopeless resignation, but rather the remedy of work. The influence of his views may be recognized as late as the *Shepherd of Hermas*. As for the origin of the belief in the gods, he holds that first came those great powers which benefit mankind, and after these the deified men who have rendered services to humanity. Of his natural philosophy we know only the titles of his treatises *On Nature* and *On the Nature of Man*. Two of his discourses on words were specially famous; one, "On Propriety of Language," is repeatedly alluded to by Plato; the other, entitled Ὧραι, contained the celebrated apologue of the Choice of Heracles, summarized in Xenophon, *Mem.* ii. 1, 21 *seq.*

See Hummel, *De Prodico Sophista* (Leyden, 1846); Cougny, *De Prodico Ceio* (1858); and Überweg, *Grundriss der Gesch. der Philosophie*, Bd. I. (1926).

PRODIGY, an extraordinary or wonderful thing, person, event, etc.; something which excites amazement and astonishment. The term has been particularly applied to children who display a precocious genius, especially in music. The German expression *Wunderkind* has of late been often adopted by those who have found the name "infant prodigy" too reminiscent of the "infant phenomenon" familiar to readers of Dickens. Among the more notable of the almost countless number of musical prodigies who have excited wonder may be mentioned Mozart who composed minuets before he was four; Beethoven, who played in public at eight and composed works which were published at 10; Hummel, who gave concerts at nine; Schubert, who composed at 11; Chopin, who played a concerto in public before he was nine; Mendelssohn, who began to compose systematically at 12; Brahms, whose exceptional talents attracted attention from his earliest years; Dvořák to whom the like applied; Richard Strauss, who wrote a polka and a song at six; and last but not least the famous English composer and organist Samuel Wesley, who played the organ at three and composed an oratorio at eight.

In regard to prodigies of other kinds one of the most remarkable ever known was the boy William Henry West Betty (born at Shrewsbury in 1791, d. London 1874), who from his amazingly precocious talents as an actor was known as the Young Roscius (after the famous Roman actor Quintus Roscius). He appeared on the stage at 11 years of age in the heaviest Shakespearean parts, the vogue which he enjoyed being such that the House of Commons actually adjourned to witness his Hamlet.

PRODUCER GAS: *see* GAS MANUFACTURE.

PRODUCT INTEGRAPH: *see* MATHEMATICAL INSTRUMENTS.

PRODUCTION. For the meaning of this term *see* CAPITAL AND INTEREST; ECONOMICS; VALUE; WEALTH.

PRODUCTION, CENSUS OF. In many countries no general survey of production is available. In countries mainly devoted to agriculture, the ascertainment of the distribution of the cultivated area, and of the quantities of the leading crops and the numbers of livestock maintained, gives information of the greatest importance. Where the extraction of minerals is important, the quantities of such minerals produced are a necessary element in the survey of the country's industrial resources. In various countries in which manufacture has reached a considerable degree of importance, periodic returns of the output of various leading products of the manufacturing industries are added to the records of agricultural and mineral products obtained. These surveys are, however, not merely incomplete in that they fail to cover the productive activities of the country, but they also fail to furnish a satisfactory measure of the results of that activity. For that purpose a census not of products but of production is needed. For the extractive industries the record of products serves to measure production reasonably well, since the value of the products of other industries used up in the processes essential to the extraction of new products is, in general, comparatively small.

A census of production must be something more than an enumeration of the products of the various establishments and industries surveyed and a record of their values. The products of other establishments or industries which have been used up in the productive processes surveyed must be ascertained if a true measure of the production carried on is to be secured. In strictness the effects of wear and tear, so far as not made good by the staff maintained within the establishment for that purpose, and also the effects of obsolescence on the plant and buildings, should be evaluated and included in the deduction from the value of the gross output needed in order to arrive at the value of the contribution made to production. In practice allowances for depreciation cannot be estimated with a precision approximating that attainable with reference to cost of materials, and adjustments in respect of the consequent overestimate of the production have to be made by some means other than the simple aggregation of the depreciation suffered by each establishment. The result of deducting the value of materials used from the value of the products resulting from work on them is designated "net output" in the reports on the Census of Production in the United Kingdom and is dealt with under the title "value added in manufacture" in the reports on the Census of Manufactures in the United States.

In addition to an enumeration of the kinds and values of goods produced, there is needed, for a proper understanding of the significance of these data resulting from a census, a record of the numbers of persons employed in the production of those goods and of the mechanical aids to production at their disposal. Information as to the distribution of the value of the recorded production between wages, returns to capital, taxation, profits, etc., will also have much importance, in view of the reaction of distribution on productive efficiency; but inquiries regarding the distributive allocation of the values produced do not appear to be an essential part of the census of production itself.

Information on these matters, like information regarding the quantities and values of imports and exports of the various classes of goods with which the census is concerned, is of great importance in the application of the results secured by means of the census. The comparison of the imports and exports of any class of products with the amounts and values of similar products made within any country affords information of fundamental importance. For the aggregate of all industries it furnishes measures of the dependence of the material welfare of the country on its foreign trade. Further, since the material income of a country consists in the goods produced and in those which are obtained from abroad in exchange, a census of production furnishes a basis for measuring the amount of, and the changes in, the total income of the community. In so far, too, as capital goods and consumption goods are capable of distinction, the total of products applied to capital purposes, replacement and increase together, can be ascertained. The formation of a reasonable estimate of what is required for maintenance of the existing stock of capital enables an estimate to be made, of a corresponding degree of reliability, of the increase of capital. Thus results of uncertain estimates formed on other principles can be submitted to useful tests. (A. W. F.)

UNITED STATES

The first census in the United States, that for 1790, covered population only, and not until 1810 was any effort made to secure data on other subjects. Fragmentary data on minerals and manufactures were collected in the censuses of 1810 and 1820, and beginning in 1840 employment and production information for these activities was collected in every decennial census. Questions on agricultural production were included in the 1840 census, and additional inquiries on the acreage and value of farms and related matters were included in 1850. The year 1850 also witnessed the first decennial census of state and local government finances; this census was later placed on an annual basis for the larger governmental units.

During the 19th century the decennial censuses of population and production were conducted by temporary staffs recruited for that purpose. With the creation of a permanent census office in 1902, the quinquennial censuses of the electrical industries were added to the program, and the census of manufactures was converted to a five-year basis.

The country's need for production information became more generally recognized during World War I; after the war the census of manufactures was made biennial and the census of agriculture quinquennial. In addition, the bureau of the census to an increasing extent conducted monthly, quarterly or annual surveys on the production of important manufactured products.

Censuses of construction and distribution were included in the decennial censuses of 1930 and 1940 and a census of service establishments in 1940. Thus at the beginning of World War II the census bureau's program included in one census or another most of the country's economic activity with the major exception of the professions, domestic service, the activities of the federal government and of industries, such as rail and water transportation, reporting to regulatory agencies.

While the biennial census of manufactures was discontinued during World War II, the regular census of agriculture was taken in 1945, a census of manufactures in 1947 and a census of business (trade and service) in 1948. At mid-century, legislation authorized the bureau to conduct censuses of manufactures, minerals, the distributive trades and service establishments covering the year 1953 and every fifth year thereafter. In addition, the bureau was authorized to conduct surveys deemed necessary to supply annual and other interim current data on the subjects covered by these censuses. This authority was exercised to conduct a sample survey of manufactures covering the year 1949.

Census of Manufactures.—From its inception in 1810, the census of manufactures grew from a few simple questions to a comprehensive survey of the most important aspects of U.S. industry. Beginning in 1849, which may be considered the first scientific survey of manufactures, every subsequent census included questions on the number of wage earners and their wages, on total value of products and total cost of materials and the derived figure, value added by manufacture; from 1899, information on salaried employees and their earnings was also collected. In other respects there were considerable changes after 1849. The collection of data on capital invested, a feature of every census in the earlier years, was discontinued after 1919; on the other hand, inventory data for the beginning and end of each census year were introduced in 1937, and an inquiry on expenditures for new plant and equipment during the year in 1939. During the earlier years, it was customary to collect information on such costs as rent and taxes, but subsequently the only cost items, other than labour costs, requested were "cost of materials and supplies," "cost of contract work" and "expenditures for fuel and electric energy." Data on horsepower of installed motors were collected in all decennial and quinquennial censuses from 1899 and in several of the earlier biennial censuses; this inquiry was dropped in the 1947 census. From 1879, when establishments in a few selected industries were asked to supply data on the quantity and value of individual products made, these data increased steadily with the growing complexity of U.S. industry and the increasing demand on the part of manufacturers and trade associations for this type of information. In 1947, value or quantity data (or both) were published for about 6,000 individual manufactured products. All later censuses also included inquiries on the consumption of the more important types of industrial raw materials and, in some instances, semifinished manufactures.

Table I shows the growth in U.S. industry from 1849 as recorded by the principal census measures of manufacturing activity. So far as possible, the historical data were revised to exclude industries not covered in the later censuses. However, it was not possible to adjust the back figures for three major changes in the scope of the census of manufactures. The decennial censuses through that of 1899 attempted to include all manufactured products, wherever made, whereas from 1904 only factory production was included. Data on hand and neighbourhood industries for 1899 show that this change resulted in the exclusion for that year of about 300,000 establishments employing 600,000 production workers and accounting for about $800,000,000 in value added. The relative, if not the absolute, importance of such ac-

tivities certainly declined after the turn of the century. In 1919, the minimum size limit for reporting establishments was raised from $500 to $5,000 in terms of value of products. For 1914, approximately 100,000 establishments employing 120,000 production workers and accounting for $150,000,000 of value added reported value of products between these two limits. Many of these smaller establishments were, however, included in 1919 and subsequent years because of the sharp rise in the price level during World War I. Finally, in 1947, the $5,000 value of product cutoff was abandoned, but establishments with no employees were not covered in that census. This resulted in the addition of several thousand establishments, but the effect on employment and value added was only a small fraction of 1%.

TABLE I.—*General Statistics for Manufacturing Industries in the U.S., Selected Years, 1849–1947*

Year	Number of establishments (thousands)	Production workers		Value added by manufacture (millions)	Index of physical production* (1899=100)
		Number (average for the year) (thousands)	Wages, Total (millions)		
Factories only					
1947	241	11,916	$30,242	$74,426	†
1939	174	7,808	8,998	24,487	373
1929	207	8,370	10,885	30,591	364
1919	270	8,465	9,664	23,842	222
1909	265	6,262	3,205	8,160	158
1899	205	4,502	1,893	4,647	100
Factories and hand and neighbourhood industries					
1889	354	4,129	1,821	4,102	‡
1879	254	2,733	948	1,973	‡
1869	252	2,054	620	1,395	‡
1859	140	1,311	379	854	‡
1849	123	957	237	464	‡

*Prepared by National Bureau of Economic Research.
†In preparation.
‡Not available.

The addition of the cost of materials and value of products figures reported by individual manufacturers to derive aggregates for industries and groups of industries or for states and other geographic units resulted in a considerable amount of duplication because of the use of products of some industries as materials by others. With some important exceptions, such as the steel, refrigeration and motor-vehicle industries, this duplication is not significant within individual industries. It arises importantly, however, from the addition of industries representing successive stages in the production of a finished manufactured product. Because of the unknown and varying amounts of duplication contained in cost of materials and value of products, these two figures were not shown in the 1947 census publications for groups of industries or states or local areas, and United States totals are not shown in Table I for any year. Except for 12 of the 453 industries covered in the census, individual industry totals are shown in the census publications both for the United States and for each producing date for which publication would not disclose the operations of individual companies.

Even where no serious amount of duplication is involved, "value of products" is frequently a very defective measure of the relative economic importance of individual manufacturing industries—principally because of the wide variation in the ratio of materials costs to processing costs. For this reason the bureau of the census early urged the use of "value added by manufacture" as the most appropriate census measure of the economic importance of individual manufacturing industries. Value added by manufacture is computed by subtracting from the value of products, the cost of materials and contract work used in making those products. An illustration may serve to indicate the considerations involved. In 1947, both the petroleum refining and the men's and boys' suits industries employed about 146,000 persons and in this respect could be said to have been of about equal importance. On the other hand, the former shipped products valued at $6,600,000,000 as compared with only $1,400,000,000 for the men's and boys' suit industry. A comparison in these terms would, however, be misleading because of the high cost of the materials (principally crude petroleum) consumed in the petroleum refining industry. After subtracting cost of materials, value added by manufacture in this industry was only about twice that for the suit industry ($1,500,000,000 against $700,000,000). Thus, in terms of value added by manufacture, the petroleum refining industry was considerably more important than the men's and boys' suits industry, because the former, in addition to employing approximately the same amount of labour, also used a large volume of capital equipment entering into value added in the form of such costs as depreciation and interest; higher wage and profit rates may also be a factor, as they certainly were in 1947.

Value added by manufacture should not be confused with the net contribution of the manufacturing industry to the nation's income, as shown in various national income reports. The principal differences between these concepts are twofold: (1) value added by manufacture does not exclude depreciation, which in many respects should be considered as equivalent to a materials cost; and (2) value added also includes taxes (except excise taxes) and other costs such as insurance, rent and advertising which are properly the contribution of nonmanufacturing industries.

Value added does have the advantage that, since it eliminates the type of duplication referred to above, the totals for individual industries may properly be combined to arrive at aggregates for groups of industries and geographic regions.

Figures for either value added by manufacture or value of products are affected by changes in the price level. In order to measure changes other than those deriving from price influences, indexes of the physical volume of manufacturing production for all manufacturing as well as for individual industries and industry groups have been compiled from census data. For an individual industry, an index of physical production is usually obtained by weighting the changes in the output of individual commodities by their value in a selected base year. Indexes for groups of industries and for all manufacturing are ordinarily obtained by weighting the indexes for individual industries by the value added by each industry in the base year. Indexes of physical production are thus independent of changes in the general price level and so can be compared with physical measures of input such as employment or man-hours worked. The latter figure was collected on a comprehensive basis only in the 1947 census but is available on a historical basis in part from other sources. In 1928, the bureau of the census published a monograph of the physical volume of manufacturing output as disclosed by census figures covering the years 1899 to 1925—*The Growth of Manufactures, 1899–1923*, by Edmund E. Day and Woodlief Thomas. In 1940, the National Bureau of Economic Research published a new index of manufacturing output in *The Output of Manufacturing Industries, 1899–1937*, by S. Fabricant and J. Shiskin and 1939 figures were subsequently prepared by that organization. This latter index is shown for selected years in Table I. The bureau of the census later undertook to carry the National Bureau's index forward to 1947. Production indexes, of which the most widely used is that of the board of governors of the federal reserve system, are published by various other agencies.

The 1947 census of manufactures covered, with minor exceptions, all establishments primarily engaged in manufacturing as defined in the *Standard Industrial Classification Manual*, vol. i, *Manufacturing Industries*, prepared by the bureau of the budget. In accordance with this system of industry classification, each establishment reporting in the census was classified into one of 453 manufacturing industries, generally on the basis of the principal products made. For many purposes, individual industries were combined into 20 broad groups of industries, usually known as major industry groups.

Table II shows the distribution of manufacturing activity by major industry group for 1947 and, where comparable data are available, for 1939. The industry distribution of employment or value added by manufacture for these two years should not be considered typical or normal; this was particularly true of 1947 when the equipment industries were engaged in working off the backlog of demand built up by the limitations on civilian production during the war years. Nearly every census had seen marked

changes in the definition of a substantial number of individual industries. Census practice was to retabulate, insofar as possible, the reports submitted in the preceding census in terms of the revised industry classifications, but it was frequently impossible to go farther back than one census. Consequently, of the 453 industries tabulated in 1947, comparable data for at least a few census measures were available for 443 industries in 1939, but only 217 could be carried back to 1929 and only 135 back to 1899. Since most of the changes in industry classification, however, occurred within a major industry group, comparable data for 14 of the 20 major groups were available back to 1899. Later changes in the definition of metal products industries affected the industry groups as well as the individual industries with the result that for four of these major groups census data could not be carried farther back than 1937. Historical data for industries and industry groups were published in vol. ii, *Statistics by Industry,* of the 1947 census of manufactures. This volume also contains detailed 1947 statistics on employment, pay rolls, value of shipments, cost of materials, inventories and capital expenditures for each industry as well as the quantity or value of the principal products of the industry and, in some cases, the quantity and value of the principal materials consumed.

TABLE II.—*Selected Statistics for Major Industry Groups, 1947 and 1939*

Major industry group	Number of production workers (average for the year)		Value added by manufacture	
	1947 (thousands)	1939 (thousands)	1947 (millions)	1939 (millions)
All industries, total.	11,916	7,808	$74,426	$24,487
Food and kindred products	1,099	802	9,025	3,485
Tobacco manufactures	103	87	641	350
Textile mill products	1,147	1,082	5,341	1,818
Apparel and related products	973	753	4,443	1,386
Lumber and products (except furniture)	596	423	2,497	731
Furniture and fixtures	283	189	1,378	418
Paper and allied products	389	270	2,875	888
Printing and publishing	438	324	4,269	1,765
Chemicals and allied products	466	276	5,365	1,819
Petroleum and coal products	170	108	2,015	697
Rubber products	215	121	1,303	406
Leather and leather products	349	327	1,533	583
Stone, clay and glass	406	267	2,307	856
Primary metal industries	1,010	672	5,766	2,170
Fabricated metal products	822	451	4,922	1,401
Machinery (except electrical)	1,244	536	7,813	2,037
Electrical machinery	639	248	3,894	941
Transportation equipment	987	545	5,869	1,773
Instruments	182	85	1,080	333
Miscellaneous products	398	242	2,090	630

In addition to industry data for the United States as a whole, the census of manufactures also provides information for states and local areas. In vol. iii, *Statistics by States,* of the 1947 census, the more significant employment and pay roll data, value added by manufacture and expenditures for new plant and equipment were shown for all counties and for all urban places having a population of more than 10,000 in 1940. Industry data were shown for states and selected metropolitan areas and industrial counties.

In vol. i, *General Summary,* the more significant information presented in vol. ii and iii was arranged by subject matter and both industry and state comparisons were presented.

Mineral Industries.—Incomplete and fragmentary data on the production of certain minerals were obtained at the census of 1810, but it was not until 1840 that any effort was made to collect data covering completely the production and employees of mines and quarries. These data were called for on the same schedule as those for manufactures, agriculture and fisheries. The mineral industries were canvassed at each subsequent decennial census with the exception of the 12th (1900), and a mines and quarries census was taken separately for 1902. Production figures were secured for all the minerals produced in the United States, including fuels (coal, petroleum and natural gas), metalliferous ores (iron, copper, gold, etc.), stone and miscellaneous minerals. Information from the 1939 census, for example, included the number of mineral enterprises; types of products; quantity and value of products; persons engaged, subdivided into salaried employees, wage earners, proprietors and firm members; the salaries and wages paid; wage earners classified by type of activity (underground work, surface work, etc.); number of active and nonactive days; total man-hours worked during the year; cost of supplies and materials; quantity and cost of fuels and electric energy consumed; amount paid to contracting corporations for work done; cost of buildings, machinery and equipment erected or installed; types of power equipment; number of mechanical loading machines; and cost of drilling and equipping oil and gas wells. The collection of annual production data was delegated to the bureau of mines.

In many establishments both mining and manufacturing operations are combined, such as the mining and smelting of copper or the mining of coal and the production of coke. These processes were separated in the census returns as far as possible, the mining operations being covered by the census of mineral industries and the manufacturing operations by the census of manufactures.

Census of Agriculture.—A beginning was made in the collection of statistics of agriculture in the census of 1840, when data were presented for the output of the principal farm products and for the number of livestock and poultry on hand. At the census of 1850 the inquiries on agriculture were materially extended to include acreage of farms, value of farms and farm implements and value of animals slaughtered, the schedule containing 46 items in all. The census of agriculture was taken decennially from 1850 to 1920, and every five years beginning in 1920. The schedule was expanded until in 1950 it contained more than 300 questions concerning tenure, acreage and classification of farmland, value of farm property, mortgage debt, farm equipment, farm labour, crop acreage and production, the output of livestock products and a detailed livestock inventory. By far the most important production items obtained through the farm census are the figures representing the quantities of crops harvested. The returns in the livestock industry are so classified by age and other characteristics, however, that they afford some basis for estimating the year's production of livestock. There are also questions with regard to the value of livestock sold and livestock slaughtered on the farm, though without specific classification or numbers of animals involved. The United States department of agriculture publishes each year estimates of the production of livestock, based in part on census figures and in part on information collected from a large number of representatives scattered throughout the country. This department publishes also annual estimates of crop production, farm income and other items having some relation to agricultural production.

From the census returns can be obtained figures representing the gross value of farm production. A rather detailed classification of farms by type, in combination with the gross value of farm production, was prepared for the 1950 census of agriculture. It is difficult, however, to get a figure representing the net value of farm production because of the fact that a considerable proportion of the production of several important crops, especially corn and hay, is fed to livestock on the farms, so that any figure obtained by adding the value of crops harvested to the value of livestock and livestock products would contain a considerable element of duplication. The figures for gross sales contain far less duplication from this source than do the figures for gross value of production; but even these involve an appreciable amount of duplication from the point of view of the farming industry as a whole, growing out of the fact that farmers purchase large quantities of feedstuff for feeding to their livestock, particularly the dairy farmers in the northeast and of some stock feeders in the middle west.

The agriculture census figures are particularly useful to those selling articles used by farmers, in that the statistics on farm values, number of farms operated by tenants, kind of crops grown, etc., show the extent of the potential market by counties. Such figures enable manufacturers of corn planters, for instance, to direct their sales efforts into the territory where corn is the major crop and to avoid sections farmed mainly by small tenants. Manufacturers of general articles also find these data of particular

benefit in planning sales programs. Where the average value of farms is $30,000 to $40,000, for example, it will be possible to market a fairly expensive type of automobile, while in a section where the average value of farms is only $3,000 to $4,000 even the least expensive type of car may sell with difficulty. Bankers and mortgage companies use the census data to determine limits of territory or limits per acre for their loans. Location of the production of the various agricultural products, as shown by census returns, also plays a part in the location of manufacturing plants using these products, such as canners, manufacturers of condensed milk, etc.

Electrical Industries.—Closely allied to the data included in the census of manufactures are those formerly covered in the censuses of electrical industries. This census was conducted at five-year intervals from 1902 through 1937, and covered the electric light and power industry, telephones and telegraphs and electric street railways, including in later years the motorbuses operated by street railway companies. The inquiries covered employment and other operating statistics, as well as capacity measures and financial data of the type not collected in the census of manufactures. None of these censuses were conducted after 1937. Much of the data, however, is published on a current basis by the Federal Power commission, Federal Communications commission, the Edison Electric institute, the American Telephone and Telegraph company or the American Transit association. Current summary information, together with the latest census data, is found in an annual bureau of the census publication, *Statistical Abstract of the United States.*

Methods of Collection.—The agricultural censuses have been conducted by means of a field canvass. The report forms are delivered to the farm operator and collected by personal visit from enumerators charged with a complete canvass of all farms in preassigned districts. In the 1939 census of manufactures, the forms were similarly handled by field enumerators who were responsible for the collection and distribution of report forms for both manufactures and business. The 1939 minerals census was conducted largely by means of a mail canvass; however, in certain industries, where the establishments were typically small and widely scattered, a field canvass was used.

Unless the census of manufactures is taken in conjunction with that for business or population, the field canvass is an inordinately expensive method of collecting reports. Consequently, in 1947, as in the earlier biennial censuses, the canvass was conducted largely by mail. Report forms were mailed to firms known or believed to be engaged in manufacturing activity and field enumeration was resorted to only in those instances in which satisfactory reports could not be obtained by mail or by telephone calls from the nearest district office of the bureau. The names and addresses of manufacturing establishments were derived from lists maintained at the bureau or made available by other government agencies or private organizations. In 1947 an important new source of manufacturers' names became available—the files of the bureau of old-age and survivors insurance of the Federal Security agency, to which all employers in manufacturing, as in most other industries, were required to report.

Despite exhaustive culling of industry lists, and the most careful handling of report forms, no census is ever 100% complete. In order to test the coverage of the 1947 census, there was undertaken late in 1948 an intensive field canvass of selected areas throughout the country. Preliminary results of this coverage check showed that more than 98% of all employees properly classified as engaged in manufacturing activities were covered in that census. The bulk of the establishments not included in the census were small and engaged in marginal manufacturing activities closely related to construction, distribution or other nonmanufacturing activities. For this reason, these establishments either did not appear on the lists used or were classified as nonmanufacturing when their report forms were reviewed.

Tabulation.—When the returns are received in the Washington, D.C., office of the bureau, they are carefully edited to identify omissions and discrepancies. When such errors are significant, correspondence is undertaken with the manufacturer. In the 1947 census nearly half of all reporting firms were asked to complete or clarify their returns. In the case of very small establishments, missing data are frequently estimated and evident discrepancies are corrected by reference to fairly stable relationships between the figures reported on various sections of the form. After the report has been edited, the information is usually transcribed to punch cards. Each punch on a card by its particular location serves either to classify the establishment as to size, type of ownership, location or industry or to record the statistical information submitted. When all the cards are available they are run through a machine which sorts them according to any specified classification or cross classification such as industry or industry by state. They are then run through a tabulating machine which mechanically counts the number of cards, lists the data recorded in the cards and prints the totals and subtotals desired.

Publication.—When a significant part of the tabulations are completed for a particular county (agriculture and business) or industry (manufactures), a preliminary statement often restricted to the more significant types of information is issued. Later, one or more printed bulletins containing final detailed figures for each state or industry are published. Finally, these separate pamphlets are collected into bound volumes which constitute the official report on the census. These are, however, frequently supplemented by a general report presenting the more significant data for each state and industry. The final census volumes are generally published two to three years after the close of the census year, though much of the information will have been in print for some time. For example, in the biennial census of manufactures, preliminary industry releases usually begin to appear about six months after the close of the census year. In the 1947 census, however, the first industry report was not released until Dec. 1948 because of the fact that the long interval between censuses made it difficult to determine that the returns for any particular industry were complete until all reports had been received and classified by industry.

Current Production Statistics.—Much of the information collected in the production censuses was being published at mid-20th century on a monthly, quarterly or annual basis in part by the bureau of the census and in part by other government agencies and private organizations. In the agricultural and minerals fields current data were being provided by the department of agriculture and the bureau of mines, respectively. In the manufactures field, employment and pay roll data were published on a current basis by the bureau of labour statistics of the department of labour; information on shipments, inventories and capital expenditures by the office of business economics of the department of commerce; and information on production of individual commodities from a wide variety of sources, principally the regulatory agencies of the federal government and a large number of trade associations.

Formerly, it was only in respect to commodity production information that the bureau of the census attempted to keep any of its census of manufactures on a current basis. The bureau's program was designed to cover the more important types of products not covered by other organizations. Among the products included were: wheat flour, confectionery, shoes, textiles, selected items of apparel, lumber, paper and pulp, household furniture, the major inorganic chemicals, fats and oils, ferrous and nonferrous castings, containers, heating and cooking apparatus, plumbing fixtures, tractors, machine tools and agricultural machinery. Current data on the quantity and value of the output of these and other manufactured products were published in the bureau's "Facts for Industry" series. Many of these series were also incorporated in the monthly *Survey of Current Business* prepared by the office of business economics, a convenient source of production data also for other manufactured commodities as well as for general information on factory employment, pay rolls, shipments, inventories and expenditures for new plant and equipment. On an annual basis, the more important production statistics were conveniently summarized in the *Statistical Abstract of the United States,* a publication of the bureau of the census. Selected production series were carried back as far as available in a companion publication, *Historical Statistics of the United States, 1789–1945.*

The statistical data published before mid-century on a current basis were deficient on three important counts. First, much of the general information collected between censuses was on a company rather than on an establishment basis. Consequently, it was difficult to carry forward data on an industry basis and, in particular, impossible to relate employment with the volume of production associated with it. Second, information on cost of materials was not collected and value added by manufacture could not, therefore, be derived from any of these sources. Finally, there were important gaps in the current coverage of manufactured commodities. It was in order to remedy these inadequacies that a survey of manufactures was taken in 1949, and similar surveys were proposed for every intercensal year. These surveys were to canvass all large establishments in each industry but in general only a sample of the smaller establishments. The tabulation plan was identical with that followed in the census and data was to be presented for the more important of the country's industries, all industrial metropolitan areas, and nearly all states and industrial counties. Major group industry data were to be shown only for the largest states. (P. M. HA.)

UNITED KINGDOM

Legislative Authority and Scope.—Censuses of production in Great Britain are taken in accordance with the provisions of the Statistics of Trade act, 1947, which lays down that the board of trade shall, for purposes of providing general surveys of the state of trade and business, take a census of production in respect of the year 1948 and of every subsequent year. The first census was taken in the United Kingdom in respect of 1907 under the provisions of the Census of Production act, 1906 and from then onward (except for interruptions of World Wars I and II) at roughly five-year intervals.

The necessity of annual censuses was recommended by the white paper on employment policy (Cmd. 6527) presented to parliament by the coalition government in May 1944, and the 1947 act gave statutory effect to the recommendations of the *Report of the Census of Production Committee* (Cmd. 6687, 1945). This act gave compulsory powers to the government to ask questions on a wide range of subjects, among them the nature of the undertaking, including its association with other undertakings; the persons employed, the nature of their employment, their remuneration and the hours worked; the output, sales, deliveries and services provided; stocks and work in progress; the outgoings and costs and capital expenditure; the power used or generated; the fixed capital assets, the plant and the premises occupied. The scope of these questions is sufficient to permit an effective analysis of most of the important aspects of production. The original 1906 act limited the scope of the census broadly to a summary of employment and output. It permitted questions to be asked mainly about the value for any product, together with the aggregate estimated value of materials used, the amount paid for work given out and such related data as employment, number of days worked and power used and generated. The quantitative data that could be asked for about output was limited, and none could be obtained compulsorily about materials, but power used covered coal and coke. Just as the original Census act arose out of the tariff reform controversy at the beginning of the century, an extension of compulsory powers to collect more information was given by the Import Duties act, 1932, in respect of the production of goods covered by the new tariff. This act enabled detailed information to be obtained about both output and materials. These powers were extended by the Finance act, 1933, to goods covered by the silk and McKenna duties and to all products by the Census of Production act, 1939. No census was taken, however, under this latter act (repealed in 1947) owing to the outbreak of World War II. Wages were specifically excluded as a subject of inquiry by the original Census act. Voluntary sample inquiries by the ministry of labour, conducted at about the time of each census, made possible, however, an estimate of the wages bill in the various industries. By all these means, even the pre-World War II census reports became a rich source of data on British industry, covering a wide range of subjects in a systematic and consistent manner.

By mid-20th century censuses had been taken in respect of the years of 1907, 1912 (incomplete), 1924, 1930, 1935, 1946 (covering selected industries only), 1948 and 1949. Import Duties act inquiries, covering a selection of industries protected by the tariff, were held for 1933, 1934, 1935 and 1937. The 1948 census covered nearly the whole range of questions permitted by the 1947 act. Those of 1949 and 1950 were skeleton censuses, covering a smaller range of subjects: specifically no questions were asked relating to the quantity and the value of main products sold or of the principal materials used in their manufacture. The final reports of each census give comprehensive definitions as well as the final results. The results of the 1912 census, in so far as available, were published together with the results of the 1924 census. Final results of the 1937 inquiry were being published together with the results of the 1948 census.

The 1948 census, like previous censuses, covered undertakings in the field of manufacturing, mines and quarries, building and contracting, public utilities and industrial undertakings of government departments, accounting together for about half of the total labour force in civil employment. For other branches of the national economy no similarly comprehensive range of information was available. For the distribution and service industries, the first census of distribution, taken in 1950, would provide this information. On agriculture, transport, communications and public administration a certain amount of statistical information on output, employment, etc., is available both for the past and on current developments. Information is collected by government departments and the industries concerned, and statistics arising are usually published in the *Annual Abstract of Statistics* and in the *Monthly Digest of Statistics*.

Pre-1939 censuses and the 1946 partial census covered productive operations carried out in Great Britain, but censuses in Northern Ireland (and for 1907 and 1912 for the whole of Ireland) were conducted at the same time and the results incorporated in the reports, which thus covered the whole of the United Kingdom. The Northern Ireland government did not take a census of production for 1948; the figures for that year therefore relate to Great Britain.

Information for purposes of the census is collected on the basis of questionnaires sent out to each individual firm in the industries covered. For purposes of the 1948, 1935 and 1930 censuses, however, firms employing ten or fewer persons were required to furnish information (with some exceptions) only about the number of persons employed and the nature of their business, whereas the 1907 and 1924 censuses included production of all establishments irrespective of size. The final report of the 1935 census was based on data supplied by 53,654 firms with more than ten employees; in addition, information on employment was supplied by 204,151 small firms with ten or fewer employees. The data relating to the firms and their plants are classified to industries according to the nature of their major products, largely in accordance with the standard industrial classification which provided a common basis of classifying information received from the same firm by different data-collecting departments. The 1935 census distinguished 123 individual industries, such as cotton spinning and doubling, etc. These industries were grouped into 15 main industry groups, such as textiles, etc., for each of which there is a group report, summarizing the information obtained. The bulk of information relates to firms classified to the individual industries or to the principal products of those industries wherever manufactured; in addition, separate reports were made for certain sectors of large industries, such as mechanical engineering.

Industrial Progress.—Table III compares the aggregate results for the United Kingdom in 1907, 1924, 1930 and 1935 in terms of gross output, net output and employment. The gross output of a trade is the total value of goods made and other work done during the year. The net output of a trade represents the value added to materials by the process of production and constitutes the fund from which wages, salaries, rents, rates and taxes, advertising and other selling expenses and similar charges have to be met, and from which depreciation and profits are pro-

vided. It indicates thus broadly the contribution of industry to the total national output, whereas the aggregate of gross output includes duplication, as the end product of one industry; for example, steel is the material used by another industry; *e.g.*, engineering.

TABLE III.—*Summary Results of Censuses of Production in the United Kingdom (Firms employing more than ten persons)*

	1907*	1924	1930	1935
Production (£ million)				
(a) Value of gross output (selling value of goods made and value of work done)	1,765	3,747	3,371	3,565
(b) Cost of materials and fuel used and amount paid for work given out.	1,053	2,105	1,789	1,876
(c) Value of net output (excess of row (c) over row (b) after deducting excise taxes)	697	1,548	1,504	1,625
Average number of persons employed (excluding outworkers) (thousands)				
(d) Operative staff	6,493	6,665	6,416	6,474
(e) Males	4,831	5,026	4,828	4,783
(f) Females	1,662	1,639	1,588	1,691
(g) Administrative, technical and clerical staff	492	633	725	832
(h) Males	422	480	532	596
(i) Females	70	153	193	236
(j) Total employed	6,985	7,298	7,141	7,306
Power equipment available for industry (thousand h.p.)				
(k) Prime movers	10,710	16,674	21,210	†
(l) Electric motors driven by purchased electricity	†	4,351	6,308	†

*Not comparable with later years, owing to: (1) inclusion of firms in the territory which is now republic of Ireland, (2) inclusion of small firms, (3) inclusion of trades (*e.g.*, laundries) excluded in later years and (4) deficiency of returns. The over-all effect of (1)–(4) is that output has to be reduced by nearly 6% to make it comparable with later years.
†No information was collected.

Employment.—Between 1907 and 1924 the number of persons employed by all firms, including small firms, covered by the two inquiries, increased in Great Britain by about 14%. Later figures available for the whole United Kingdom indicated an increase of 2% between 1924 and 1935, both years of only moderately good employment. Ministry of labour statistics suggested an increase of the order of 12% between 1935 and 1937 and a further increase of 10% between June 1937 and June 1949. The number of those employed in the census industries as a proportion of the total working population hardly changed in the first half of the 20th century.

The census results indicate that the number of administrative, technical and clerical staff expanded throughout the period. Among them the number of females more than trebled, while the males increased by nearly 50% between 1907 and 1935. At the same time the number of operatives either expanded less (as between 1907 and 1924)or even declined(as between 1924 and 1935). Among the operative staff taken as a whole, the proportion of females had not increased appreciably. Although female workers were more evenly distributed over the whole industrial field in 1935 than in 1907, nearly three-fifths of them were employed in textiles and clothing. In these two trade groups about two-thirds of the operatives were females. Among the administrative and clerical staff the proportion of females doubled between 1907 and 1935. The total of the controlling and clerical staffs amounted in 1907 to 7% of the total employed, in 1924 to 8.7%, in 1930 to 10.2% and in 1935 to 11.4%. A further increase appears to have taken place between 1935 and 1949. One reason for this increase is the change in industrial structure. Industries growing in proportionate importance, like metals, employ more administrative and clerical staff than textiles, diminishing in importance. Some of the other reasons for increase are the greater attention given to production planning, design, research, cost accounting and other work of like nature, and an extension of the preparation for sale and control of sales, carried out by the manufacturers' staffs.

Production and Productivity.—Changes in the value of output between the several censuses are the result of both changes in prices as well as in quantity. A measure of the quantitative changes can be arrived at by eliminating the effect of price changes and thus estimating changes in the volume of production. The estimates given in Table IV were prepared on the basis of data contained in the censuses (except for 1937) and of data on hours worked. They relate to manufacturing, mining, building and public utilities in the United Kingdom, but owing to minor adjustments are not strictly comparable with the data in Table III. Between 1907 and 1937 the volume of production increased at the annual compound rate of 2.3%, output per operative increased by 1.4% and output per man-hour increased at the compound annual rate of 1.7%.

Estimates for further years are conjectural because of changes in the character of production and of the labour force as well as because of lack of comparable data. The interim index of industrial production of the central statistical office estimated an increase of 20% in industrial production between 1937 and 1949, while employment of operatives and administrative staff increased by perhaps 10%, giving as a crude indication an increase of about 9% in output per employee.

TABLE IV.—*Productivity in the United Kingdom*

Year	Volume of production	Estimates of employment (operatives)	Output per operative	Output per man-hour
1907	100	100	100	100
1924	124	115	108	127
1930	133	110	121	*
1935	159	111	143	161
1937	184	124	147	165

*Not available.
Source: L. Rostas, *Comparative Productivity in British and American Industry* (Cambridge, 1948).

Mechanical Power.—The censuses indicate a striking increase in mechanical power available to industry. The estimated horsepower equipment of prime movers and of electric motors driven by purchased electricity available per operative increased from about 1.46 h.p. in 1907 to 2.17 in 1924 and to 2.51 in 1930. This development runs parallel with the rate of increase in output per worker. Unfortunately no data on power equipment were collected by the censuses after 1930, but the striking increase in electricity consumed by industry both between 1930 and 1935 and later is an indication of the further expansion in the use of power equipment by industry.

Industrial Change.—Subsequent censuses revealed a considerable change in the distribution of the productive energies engaged and of the output in industry in the United Kingdom as shown in Table V. Table V indicates the increase in the importance of manufacturing trades relative to nonmanufacturing trades in industry, especially in respect of the 1924–35 period. This was caused by the decline of mining, notably coal mining. Among manufacturing industries the data for 1924–35 indicate the increasing relative importance of the metal and metal-using trades, chemicals, paper and paper products, timber trades, clay and building materials trades and the food, drink and tobacco trades, and the declining importance of textile industries. The importance of clothing remained the same. Among nonmanufacturing industries, public utilities and building and contracting

TABLE V.—*Industrial Distribution of Persons Employed and Net Output*

Trade group	Average numbers of persons employed in all firms (per cent)				Net output per person in 1935†
	1907*	1924	1930	1935	
					£
Iron and steel	7.15	6.76	6.73	7.02	216
Engineering, shipbuilding and vehicles	11.47	13.43	14.96	14.88	226
Nonferrous metals	1.68	1.62	1.58	1.65	245
Textiles	18.49	16.01	13.64	13.15	149
Leather	.78	.70	.68	.71	211
Clothing	9.13	7.80	7.96	7.92	151
Food, drink and tobacco	6.70	6.76	7.39	7.79	387
Chemicals, etc.	2.03	2.36	2.39	2.53	456
Paper, printing and stationery	4.72	4.67	5.22	5.44	273
Timber	2.81	2.38	3.03	3.24	191
Clay and building materials	2.98	2.75	3.05	3.28	217
Miscellaneous	1.38	2.23	2.38	2.41	239
Total, factory trades	69.31	67.48	69.02	70.02	229
Building and contracting	7.53	6.96	7.78	9.50	199
Mines and quarries	13.90	16.14	13.02	10.51	162
Public utility services	8.30	8.21	9.01	8.71	264
Government departments	.97	1.21	1.16	1.26	213
Total, nonfactory trades	30.69	32.52	30.98	29.98	206
	100	100	100	100	
Total, all trades	6,830.4‡	7,980‡	7,922‡	8,132‡	222

*Includes the territory which is now the Republic of Ireland, but excludes trades not covered by later censuses. †In firms employing more than 10 persons. ‡Thousands.

increased their relative importance, but that of mining declined. It can be seen that the shift in productive energies and output took place from industries with a low net output per person employed, such as mining or textiles, towards industries with a high net output per person employed, such as public utilities or metals. This continuing process of shifting resources towards industries with higher net output per employee has been a significant factor in British industrial progress.

Concentration of Production.—The census throws light on the relative importance of different sized firms operating in British industry. In 1935 there were in the census industries 204,151 small firms employing not more than 10 persons which together employed about 826,700 persons or just over 10% of the total. Another 53,217 firms with more than 10 employees employed 7,203,100 persons or 90% of the total. These figures exclude the industrial activities of government departments; *e.g.*, naval shipyards. As the small firms are to a large extent engaged in such activities as repair work, it is more relevant to consider the degree of concentration among firms with more than 10 employees. In 1935 77% of these firms had less than 100 employees and they accounted together for 19% of the value of net output and 20% of the employment; 21% of the firms employing between 100 and 999, accounted for 39% of the net output and 40% of the employment; there were 1,010 big firms with 1,000 employees or more accounting for 1.9% of all firms, but producing 42% of the net output and employing 40% of all employees. (*See* Table VI.)

TABLE VI.—*Relative Importance of Different Sized British Firms in 1935**

Size of firms (average no. employed)	No. of firms	No. of firms per cent	Net output per cent	No. of persons employed per cent
11– 99	41,215	77.45	18.71	20.16
100– 499	9,722	18.27	26.34	27.67
500– 999	1,270	2.39	12.33	12.20
1,000–9,999	979	1.84	34.32	31.09
10,000 and over	31	0.06	8.30	8.88
Total	53,217	100.00	100.00	100.00

*Excludes those employed in the industrial undertakings of government departments.
Source: H. Leak and A. Maizels, "The Structure of British Industry," *Journal of the Royal Statistical Society*, p. 144 (1945).

Several firms may be owned or controlled by a single company, and on this latter basis the degree of concentration would be even greater. This is illustrated by looking at the number of persons employed in the three largest companies as a proportion of total employment in the various industries. For industry as a whole this proportion was 26% of total employment in 1935. The degree of concentration was specially pronounced in the chemical and allied trades (48%), the miscellaneous group (47%), public utilities, mainly through railway companies (44%), engineering and vehicles (43%), iron and steel (39%) and food, drink and tobacco (32%). It was just below the average in textiles, paper, printing, clay and building materials. It was low in such industries as clothing (13%), mines and quarries (10%), timber (10%) and building and contracting (4%).

Regional Distribution of Industry.—The following data indicates the relative importance of the various component parts of the United Kingdom in 1935:

TABLE VII.—*Regional Distribution of Industry, United Kingdom, 1935*

	Net output	Average no. of persons employed
England and Wales	1,462,000,000	6,495,000
Scotland	143,000,000	671,000
Northern Ireland	20,000,000	140,000
Total	1,625,000,000	7,306,000

The most important industrial regions, as classified in the census, were: the Greater London area giving employment to 1,467,000 persons; Lancashire and district (1,233,000); the midland area comprising Warwickshire, Worcestershire and Staffordshire (891,000), followed by the West Riding of Yorkshire, the east midland area and the northeast area of England. In Wales, industry is concentrated mainly in south Wales; in Scotland in the west central and east central districts; *i.e.*, round Glasgow and Dundee respectively. A comparison with earlier censuses indicates the geographical shifts in working population. The principal changes that had taken place by 1935 were the increased importance of Greater London and of the south of England in general, including London, also of the midland area, at the expense of the north of England, Wales and Scotland; but the changes were not due to a move of industry to the south but rather to the contraction or expansion of the industries sited mainly in the various regions, notably the decline in the cotton industry in Lancashire.

OTHER COUNTRIES

In addition to the United States and the United Kingdom a small but increasing number of countries at mid-20th century were making a practice of carrying out surveys yielding data relating to production and not merely to products. Canada early adopted the practice of the United States. Passing from a decennial to a quinquennial inquiry after 1900, the system of annual censuses of manufactures was established from 1917. Annual inquiries of a similar character have been carried out in the other countries of the Commonwealth of Nations: in Australia from 1903, in New Zealand from 1918–19, following quinquennial inquiries extending back to 1867, and in the Union of South Africa from 1915–16. There were two previous inquiries in South Africa in 1904 and 1911 and no inquiry in either 1930–31 or 1931–32. The republic of Ireland (Irish Free State, Eire) made the first such inquiries in 1926, then in 1929, 1931 and thereafter annually. These inquiries are very detailed in respect of subjects covered, comparable to the U.K. and U.S. inquiries; all of them give regional details. Of other British countries Southern Rhodesia has taken a voluntary annual census of industrial production since 1938, and Northern Rhodesia took one for the year 1947. India took a detailed census for 29 industries in 1946, which was extended to other industries in 1947.

All four Scandinavian countries conduct annual censuses of production, but the range of subjects covered is smaller than that of the British and U.S. censuses; additional information is available, however, from their censuses of establishments, held at less frequent intervals.

Several of the eastern European countries, among them Poland, Czechoslovakia, Hungary and Rumania, had taken annual censuses of manufactures of a limited scope before World War II, usually (except for Poland) not including data on the quantity of output. Of other major European countries Germany and Italy had very complete censuses of production relating to the years 1936 and 1937–39 respectively. In the Netherlands a census of production was found necessary in connection with the 1914–18 wartime organization and in 1918 an inquiry was made relating to 1916 and 1913. Later annual inquiries covered a small number of industries only, and referred to the bigger firms only.

Such important industrial countries as Belgium and Switzerland had never taken a census of production. France made an attempt in 1931. These countries, as well as many others, were taking before World War II censuses of industrial establishments, dealing with the numbers employed, the composition of the labour force, the mechanical power used, the number and size distribution of plants and other subjects. In many cases these were supplemented by annual inquiries of particulars or the principal goods produced.

Several of the South American countries had taken censuses of production at infrequent intervals. At mid-century the latest censuses were: in Argentina for 1946 (the results of the previous census for 1935 were published in 1938, and there were less detailed inquiries in 1939 and 1941); in Brazil for 1939 (published in 1948); in Chile for 1937 (published in 1945); in Colombia for 1944–45 (published in 1947); in Guatemala for 1946 (published in 1947); in Mexico for 1939 (published in 1947); in Uruguay for 1936 (published in 1939) and in Venezuela in 1936 (published in 1939–41).

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Other Countries: *Recensement économique et social du 27 février 1937,* Central Statistical Office (Brussels); *Statistique suisse des fabriques,* annual, Federal Bureau of Statistics (Berne); for Latin American censuses *see* N. B. Knox, *The Industrial Censuses of the American Nations,* U.S. Department of Commerce (1949). (L. Rs.)

PROFESSOR, a term now confined to a teacher of a special grade at a university or college (Lat. *profiteri,* declare publicly, profess). The educational use is found in post-Augustan Latin. In the universities of the middle ages the conferring of a degree in any faculty or branch of learning meant the right or qualification to teach in that faculty, whence the terms *magister,* "master," and *doctor* for those on whom the degree had been granted. To these names must be added that of "professor." The "three titles of Master, Doctor, Professor, were in the middle ages absolutely synonymous." (H. Rashdall, *The Universities of Europe in the Middle Ages,* 1895, i. 21.) The first endowed professorship at Oxford was that of divinity, founded by the mother of Henry VII. in 1502 and named after her the "lady Margaret Professorship." The foundation of the Regius Professorship by Henry VIII. in 1546 no doubt tended to the general modern use of the word. In England subordinate public teachers in faculties, or in subjects to which a professorial "chair" is attached, are known as "readers" or "lecturers," and these titles are also used for the principal public teachers in subjects which have not reached professorial rank. In colleges and universities of the United States, professor indicates a teacher of the highest rank, those next below being "associate professor" and "assistant professor" respectively. The title is often erroneously, if not fraudulently, used by magicians, "quack doctors" and faith healers generally.

PROFIT, a term used by business men to describe the result of their operations when that result is favourable. When the result is unfavourable the term loss is commonly used. Strictly speaking, the word profit means "result," whether favourable or unfavourable; but it is obviously more convenient to speak of an unfavourable result as a "loss" than as a "minus profit." As used by business men, the word profit must not be confounded with profits assessable to income tax or super tax. The rules for determining the liability of individuals or companies to these imposts are determined by statute, and are extremely artificial; similarly, profits in the business sense must not be confused with the economist's idea of profit.

If it were practicable for the business man to wait until his business was discontinued and wound up before attempting to arrive at any idea of what his profits were, it would be possible for him to accept the economic definition of profits as "the surplus remaining over from the employment of capital after defraying all the necessary expenses and outlay incurred in its employment, and after the capital has been replaced or provision made for its replacement." But the business man has to determine his profits as he goes along (1) because in no other way can he determine the most advantageous way in which to carry on his business; (2) because, in general, it would be impossible to obtain capital for business purposes, save upon the terms of distributing profits not less frequently than once a year, so that those contributing capital to enterprise may receive in return income by way of dividends. Hence the necessity of determining divisible profits from year to year.

It is absolutely impossible to determine the profits of a going concern from year to year with precision, because nothing more reliable than estimates can then be formed of the value of its outstanding obligations and unrealized possessions. But it would be unwise to distribute the whole of the profits year by year even if they were ascertainable, as were this to be done there would be no margin left to cover contingencies, and experience shows that unexpected losses are bound to occur from time to time. The problem that besets the business man year by year is not therefore how to ascertain the precise annual profits, but how to determine a figure of profit which can be divided without unduly jeopardizing the future prospects of the undertaking. Further, because distributions out of profits are made regularly at definite intervals and are treated by those who receive them as income, it is important that no kind of gain should be treated as divisible profits which by its very nature cannot be expected to recur.

Capital Profits and Revenue Profits.—The business man accordingly distinguishes between capital profits and revenue (recurring) profits, and pays dividends only out of the latter. Capital profits are increases of wealth arising from causes not directly connected with the carrying on of the business of the undertaking, *e.g.,* increases in the value of its fixed assets (*i.e.,* those assets held permanently as part of its equipment), a rise in the market value of which adds nothing to the fund out of which alone dividends can be paid. Indeed, a permanent rise in the value of fixed assets is a source of embarrassment rather than of congratulation, in that it increases the ultimate cost of replacements as and when such assets are worn out, and thus then at least tends to deplete the fund available for the payment of dividends. Conversely, capital losses arising from a fall in the value of fixed assets do not affect divisible profits so long as these assets continue to be equally effective as profit-earning equipment, while a fall in the cost of renewals is advantageous from a revenue point of view.

Of course, if and when a business is discontinued and wound up, capital losses and profits will materialize. If on balance there have been profits on capital, the fixed assets will realize more than they otherwise would have realized, and a correspondingly larger sum will be available out of which to make a return of capital or, rather, there will be a balance of capital profits to divide after capital itself has been returned in full. Conversely, if on balance there have been capital losses, the fixed assets will not realize a sum sufficient to enable the whole of the capital to be returned, and there will therefore be a realized loss on liquidation. Where the business is owned by a limited company, this means that the shareholders (or the holders of some class or classes of shares) will not receive the whole of their capital back; but if the business be owned by a concern not subject to limited liability, *e.g.,* a partnership, the members will have to contribute among them the ascertained loss *pro rata,* according to the shares in which they were entitled to participate in profits, and there will then be a sufficient fund to enable the whole of the capital to be returned to those who provided it.

In the case of a partnership, it is usual to divide the whole of the profits as shown by the annual accounts; but in the case of a company, it is not usual to pay away as dividend the whole of the profits shown by the annual accounts. A part of these profits is normally held back as a reserve against unforeseen contingencies, and another part is normally "carried forward" partly with a view to equalizing dividends in good and bad years, partly to avoid the inconvenience of paying away profits which have perhaps not entirely been received in cash.

PROFITEERING. This word came into colloquial use early in the World War, and, having been included in the title of an Act of Parliament in 1919, may be considered to have received official recognition as part of the English language. It signifies the making of an unreasonably large profit on the sale of goods or services, particularly those in common use. The practice has always been liable to arouse intense indignation among the public, and the word profiteer is a term of abuse deriving its sting partly from implied contrast with the word volunteer.

In normal times before the war, opportunities for making unreasonably large profits were to a great extent restricted by the play of competition, and in fact competitive prices were widely regarded as being *prima facie* reasonable. When competition was

excluded, the possibility of unreasonably large profits being made was obviously increased, and there was a widespread tendency on this ground to regard monopolies with suspicion. Some industries which could not ordinarily be run on competitive lines, or which tended to become monopolies, were consequently carried on as public undertakings, or were controlled by public authority as regards rates and conditions of trading.

Before World War I there had been a tendency for competition to be excluded to a greater or less extent in an increasing number of industries through the formation of trusts or combines. Though the selling prices fixed by such organizations were not in all cases higher than those which would have prevailed under competitive conditions, they were certainly higher in many cases; while even when they were not, a feeling was likely to arise where large profits were being made that the trust or combine in question was taking for itself an unduly large share in the economies effected by the elimination of the wastes of competition. The belief that unreasonably large profits were being made was undoubtedly the most powerful motive in the campaign for the control of trusts and combines in various countries.

Various measures were taken during World War I to restrict profiteering, especially in belligerent countries. These included the fixing of maximum prices, and in some cases of profit margins at each stage of production and distribution. Rationing of prime necessaries served to distribute supplies evenly and to prevent them from being sold to the highest bidder. The weapon of taxation was also employed in highly graduated income taxes, excess-profits taxes, etc., to secure for the public revenue a substantial part of the high wartime profits made by private interests.

As the result of inflation, profiteering was in some cases more rife after World War I than during its continuance. Under conditions of extreme inflation, such as occurred in Germany in 1923, profiteering became widespread. The rise of prices was so rapid that profits of hundreds or thousands per cent could be made by holding goods even for a few days. That, however, was a profit in paper marks, and it was obvious that paper marks, while circulating as currency, were entirely untrustworthy as a standard of value. The true postion did not become clear until after a stable currency had been reintroduced. It was then seen that while a comparatively small number of persons had made and retained fortunes, a vast mass of people had been reduced to penury.

British Government Measures.—In Great Britain, inflation reached comparatively small dimensions. After the Armistice, the general level of prices was for a time downwards, and during this period many wartime controls were withdrawn. Subsequently, prices began to rise and continued to advance until the spring of 1920, when a rapid fall began. Public apprehension led in the summer of 1919 to the passing of an act to check profiteering, commonly cited as the Profiteering act 1919. This act conferred upon the board of trade powers (*a*) to investigate prices, costs and profits at all stages; (*b*) to receive and investigate complaints regarding the making of excessive profits on the sale of any article to which the act was applied by the board of trade, and after giving the parties an opportunity of being heard either to discuss the complaint or to declare the reasonable price for such articles, and to order the seller to refund to the buyer any amount paid in excess of such reasonable price, the board also having power, where it appeared to them that the circumstances so required, to take proceedings against the seller in a court of summary jurisdiction; and (*c*) to obtain from all sources information as to the nature, extent and development of trusts and similar combinations. The act was to remain in force for six months only, but it was subsequently continued for a further three months, and later, by an amending act, for six months more until May 19, 1921.

To deal with retail trade, local committees, numbering in all over 1,800, were set up, and the board of trade delegated to them the bulk of their powers under the act relating to retail sale. There were also 108 appeal tribunals to which the seller had the right of appeal against the decision of a local committee. The task of dealing with larger transactions of wholesalers or manufacturers affecting whole trades or industries was entrusted by the board of trade to a central committee, which worked through three standing committees: the investigation of prices committee, the complaints committee and the standing committee on trusts. These standing committees in turn appointed subcommittees as required to deal with particular questions. The investigation of prices committee made investigations into the cost of production of various articles in all stages of their manufacture. Reports were published as parliamentary papers on agricultural implements and machinery, aspirin, biscuits, boot and shoe repairs, brushes and brooms, clogs, costings in government departments, furniture, gas apparatus, matches, metal bedsteads, motor fuel, pottery, standard boot and shoe schemes, tweed cloth, worsted yarns, wool and the wool topmaking trade. The complaints committee undertook the investigation of specific complaints and also investigated specific transactions brought to their notice.

The committee on trusts was responsible for obtaining information as to the nature, extent and development of trusts and combines. Numerous investigations were made. Mention may be made further of a provision contained in the Profiteering (Amendment) act, 1920, which authorized the Board of Trade to approve suitable schemes submitted by persons representing a substantial proportion of those engaged in the production or distribution of goods to which the original act was applied limiting the profit to be allowed on such manufacture or distribution. Only two such schemes were actually approved.

Since the lapsing of the Profiteering act in 1921, there has been no special legislation in Great Britain against profiteering except for the continuance of restrictions on the rent which may be charged for certain classes of houses. Public feeling, however, continued to be very susceptible on the question, especially when a rise of prices occurred. Various public inquiries have been conducted into costs of production and distribution of foodstuffs and other articles of common consumption, the most important of these being (*a*) the inquiry of a committee appointed in 1922 under the chairmanship of Lord Linlithgow to inquire into methods and costs of selling and distributing agricultural, horticultural and dairy produce in Great Britain and the diminution of the disparity between the price received by the producer and that paid by the consumer; (*b*) the inquiry of the royal commission on food prices appointed in 1925 and (*c*) the proceedings of the food council appointed in 1925 following the report of the royal commission on food prices to watch over food prices and supplies. It may be noted also that since 1923 an interdepartmental committee appointed by the Minister of Health and the president of the board of trade has been in being for the purpose of surveying the prices of building materials and receiving and considering complaints in respect thereof. (C. K. H.)

United States.—Figures gathered by the Federal Trade commission show the situation in the United States during the World War I period. In 1917 there was apparently no limit to the price purchasers were willing to pay, the condition being one of panic. In the next year profits were somewhat abated by government regulation.

During the war period oil companies circulated reports that the supply of gasoline was dangerously short, for the purpose of maintaining prices of that commodity while making enormous profits on fuel oil. Concerns bottling or canning vegetables, which had made future contracts, sometimes withheld portions of their output from delivery on such contracts and sold in the higher "spot" markets. In frequent cases licences were revoked by the Food Administration. The practice of such concerns in maintaining resale prices for jobbers contributed toward maintaining the general high level of prices and increased profits in some instances. The steel companies in 1917, prior to government price fixing, made abnormal profits, and a number continued to make unusually heavy profits thereafter. The United States Steel Corp., which made 5% before the war, received 25% on investment in 1917; and ten smaller concerns made from 30% to 319% on their investments. Certain sulphur companies took advantage of the war demand for sulphur to raise their prices to such an extent as to reap profits of approximately $15 a ton, which meant over 200% on investment in one case. The profits of tanners increased from two to five times, as they took advantage of the

enormous demand for leather and exacted very high prices. The price of hides was rapidly advanced, notwithstanding that at the same time "great supplies were withheld from the public."

High prices do not necessarily indicate excessive profits, but there is reason to believe that profiteering was common in cement, petroleum, lumber, farm implements, wool, clothing, sulphur, naval stores, rice, sugar, sand and gravel, raisins and other products, in addition to those already mentioned.

The U.S. Government attempted to deal with profiteering in three ways: (1) taxation; (2) price-fixing; (3) direct action under the Food Control Act. The first and the last methods proved largely ineffective.

By special taxes levied on profits, many thought that the spoils of the profiteers could be regained by the public. In 1916 a tax of 12½% was levied on the profits of munitions manufacturers; and a general "war profits tax" and an "excess profits tax" were imposed in 1917. In 1918 these taxes were combined. But, unfortunately, it proved so easy for most corporations to increase their investment accounts, and to pad their expenses, that the worst profiteers often showed small excess profits. Moreover, a considerable part of the tax was shifted to consumers in the shape of higher prices, as was possible during the inflation period.

Government price-fixing, while it did not prevent profiteering, did moderate the evil, notably through such substantial reductions as were made in the prices of wool, coal, sugar, flour and sulphuric acid. Unfortunately, this means was not used as vigorously and thoroughly as it would have been had there not been an ill-founded reliance upon profits taxes.

On Aug. 10, 1917 the Food Control Act became law. Section 4 of this act made it unlawful for any person to hoard or to make any unjust or unreasonable charge in transactions relating to "necessaries" (foods, feeds, fuel, fertilizers, farm implements and machinery), but imposed no penalty. Sections 6 and 7, however, provided for penalties and seizure, in case of hoarding. Section 5 authorized the licensing of dealers in necessaries and the fixing of fair storage charges, commissions, profits or practices. The fixing of prices for coal and coke was authorized in section 25. It was under this act that the Food Administration operated, and, as already indicated, its control over prices was partly effective. On June 30, 1919, however, the activities of the Food Administration were suspended; and as the agitation concerning the "high cost of living" grew in volume, the Department of Justice assumed the task of enforcing the law, which remained in force while a state of war was only technically in existence. But the attorney-general found his efforts limited by the absence of a penalty clause in section 4 and the restricted definition of "necessaries," and, at the president's request, Congress re-enacted the law in Oct. 1919, with amendments to cover these defects. In the year following the re-enactment of the law there were over 2,000 indictments, arrests and sentences, involving chiefly the commodities just mentioned, together with meats, potatoes and meals at restaurants. The great majority could not be sustained under the law. The act was declared unconstitutional by the U.S. Supreme Court in Feb. 1921. In the meantime prices had declined and the public lost interest in the subject of profiteering.

In a sense the U.S. Government was to blame for much wartime profiteering. In the first place it was lax in letting contracts and making purchases, either directly, or indirectly, by placing authority in the hands of interested persons. The "cost-plus system" invited profiteering as well as inefficiency. In the second place its combination of excess profits taxes and price regulation was unfortunate. Taxation proved at best to be an inadequate means of reaching profits, and early laxity in defining cost and investment made this means nugatory.

See the various *Reports* of the Federal Trade Commission; the *Report of the Massachusetts Commission on the Necessaries of Life* (1920); and *Senate Document No. 248* (65 Cong., 2 Session). (X.)

In European Countries.—Periods of inflation in different countries were marked by measures designed to check speculation and prevent further rises of price. Legislation to mitigate profiteering by combines was consequently passed in several countries, including notably Germany, Czechoslovakia and Norway.

The German experiment, represented by the "decree against the abuse of economic power," which came into force in Nov. 1923, is of particular interest. The decree provided amongst other things that the German minister of economic affairs may, when he considers a cartel agreement or the method of putting it into operation detrimental to the public interest, apply to the Cartel court set up in accordance with the decree to have the agreement declared void or the particular method of carrying it out forbidden. The public interest or the common good is to be considered as detrimentally affected, particularly when supply or demand is restricted in a manner not economically justifiable; when prices are raised or kept high; or when, in the event of prices being quoted in a stable currency, extras for risks are included; or when economic freedom is unreasonably restricted by boycott in buying or selling or by the fixing of discriminating prices or conditions. Until the summer of 1925, action by the government was confined to unofficial intervention, and it was claimed that this was successful in bringing about a large number of price reductions and in preventing price increases. In the latter part of that year the Government made a number of applications to the court with regard to business conditions or methods of price fixing adopted by particular cartels. These cases, however, were settled by arrangement, without the Cartel court giving a decision; and the Government made no further applications to the court. (C. K. H.)

PROFIT-SHARING, the term applied to an arrangement under which an employer, in accordance with an agreement freely entered into, hands over to his workpeople as supplementary remuneration a share, fixed in advance, of the profits of the concern in which they are engaged. This definition, it should be observed, excludes many forms of profit-distribution and bonus payment to workpeople. The condition "fixed in advance," for example, rules out of profit-sharing proper those cases in which an employer makes to his employees, at his absolute discretion, a present out of his profits, even though the payment is made regularly year after year; for such presents are gratuities lacking the elements of pre-agreement and rightful title. Again, the supplement distributed must be dependent on profits. Systems of payment by results, such as piecework, individual premium bonus, collective or fellowship bonus, and the like, are not profit-sharing. In such systems the payment, as a whole or in some supplementary part, is dependent upon the *output* of the individual or of the group, without reference to whether the production culminates in greater or less profit or loss to the undertaking.

The sponsors and guardians of profit-sharing as a system similarly rule out of their field such systems as that adopted in the remuneration of share fishermen or as the French *métayage* system (*q.v.*). These are methods of dividing, not the profits, but the *gross proceeds* of an undertaking.

Far more elusive is the distinction between profit-sharing and co-partnership, the essence of which is the issue on favourable terms of share capital to employees; indeed, it is hardly possible to make any clear-cut differentiation, the more so as the terms are constantly used as synonymous.

Early Examples.—The earliest known example of profit-sharing in any country seems to be a scheme introduced by the French National Fire Insurance company in 1820, the year of the company's foundation. The British Union Fire Insurance company followed in 1838, and the General Insurance company in 1850. These three schemes are still in active operation. One of the best known of all profit-sharing schemes is that of the Paris house decorator, Leclaire, which was introduced in 1842 and is still in operation. It was at first confined to the nucleus (*noyau*) of permanent employees belonging to the firm's Mutual Provident and Benefit society; but in 1870 it was extended to all employees. Some other French schemes are hardly less famous. Godin, of Guise, introduced profit-sharing in 1876; in 1880 the business was turned into a joint stock company, and became something in the nature of a co-operative society with domiciles, in a model village, for some classes of workers. The Bon Marché have a scheme dating from 1880, under which the whole of the shares in the company are to-day in the hands of actual or former employees. It

will be evident that the historical origins of profit-sharing are mainly to be found in France.

Great Britain.—The success of profit-sharing in France attracted much attention in Great Britain, particularly among the "Christian Socialists" (F. D. Maurice, Tom Hughes, Charles Kingsley, Vansittart Neale and others). From about 1850 onwards this group had exercised a very strong influence upon the nascent co-operative movement; hence profit-sharing was at this time widely adopted by co-operative societies, and the subject was constantly discussed at the annual co-operative congresses. At the present time (with one important exception: the workers' co-operative productive societies organised from the point of view not of the consumer but of the producer) profit-sharing is little practised in the co-operative movement.

Outside the co-operative movement the first important scheme in England was that of Henry Briggs, Ltd., a firm of coal owners in Yorkshire, which was introduced in 1865, and was at first very successful but later failed.

A scheme introduced by Messrs. Hazell, Watson and Viney, Ltd., in 1886 was discontinued in its original form in 1895; but a supplementary scheme, introduced in 1890, is still in force, and is of especial interest as the earliest instance in Great Britain of the co-partnership type of scheme enabling employees to share in profits by the purchase of shares on specially favourable terms.

In 1889 a scheme of profit-sharing was introduced by the South Metropolitan Gas company, providing for the payment of a cash bonus varying inversely with the price of gas. As the dividends payable to the shareholders under the company's acts also varied inversely with the price of gas, the workers' bonus was linked with the shareholders' dividends, and thus with the company's profits. The scheme was revised in 1894, in such a way that only half of the bonus was thenceforward payable in cash, the other half being invested in the purchase of the company's ordinary stock. By successive revisions, strong inducements were given to the co-partners to leave the withdrawable half of their bonus on deposit, with a view to eventual investment; and from July 1910 onwards it was provided that the withdrawable part of the bonus must be left in the company's hands to accumulate at interest, or invested in the company's stock with the trustees; or it might be withdrawn by giving a week's notice, but only under special circumstances. This capitalisation of the bonus is a feature upon which the advocates of this type of scheme—following the models specially approved in France—strongly insist. The name of the scheme was changed in 1903 from "profit-sharing" to "co-partnership," as being more descriptive of the nature and purpose of the new relationship that had been established between the company and its employees. In 1920 the scheme became for the first time statutory, under the company's act of that year; and the basis of the scheme was slightly changed. The surplus profits, after the payment of prescribed basic rates of dividend on the company's stocks, are now divided in the proportion of three-fourths to the consumers (in the form of a reduction in the price of gas) and the remaining fourth in equal parts to the ordinary stockholders, by way of increased dividends, and to the employee co-partners, by way of a bonus at a uniform percentage on their salaries and wages. As before, half of the bonus is capitalised, and the other half may only be withdrawn in special circumstances.

At the end of the year 1926, the employees of the company owned capital in the company to the extent of about £500,000 besides deposits at interest to the extent of nearly another £250,000. In another large gas company—in fact the largest gas company in the world, the Gas Light and Coke company—the employees at the end of 1927 owned £750,000 of the company's ordinary stock. Nearly all the leading, and many of the smaller, gas companies have adopted co-partnership schemes framed on the same general lines.

Other schemes deserving of special mention are those introduced by Messrs. Clarke, Nicholls and Coombs, Ltd., in 1890; by Messrs. J. T. and J. Taylor, Ltd., in 1896; by Messrs. Lever Bros., Ltd., in 1909; by the Bradford Dyers' Association, Ltd., in 1912; and by Messrs. Rowntree and Co., Ltd., in 1923; also the scheme foreshadowed by Imperial Chemical Industries, Ltd., in 1927. These six schemes contain two examples of each of the three principal types of profit-sharing and co-partnership: the cash bonus type, the bonus-capitalisation type and the share-issue type.

The following table shows the total numbers of schemes started in the various periods mentioned, the numbers of such schemes no longer in existence at the end of 1927, and the numbers and range of those still in existence at that date, as given in the *Ministry of Labour Gazette* for June 1928:—

TABLE I.

Period in which started	Total schemes started	Schemes discontinued (or suspended) by end of 1927	Schemes still in operation at end of 1927		
			Number of schemes	Total number of employees	Approx. number of employees entitled to participate
Before 1881	35	31	4	1,700	800
1881–1890	80	69	11	17,100	13,900
1891–1900	78	65	13	8,900	7,500
1901–1910	82	44	38	87,500	54,700
1911–1918	95	37	58	56,300	24,700
1919	57	18	39	35,000	22,400
1920	56	12	44	58,800	16,600
1921	14	1	13	27,900	11,800
1922	12	1	11	3,300	2,700
1923	18	1	17	29,000	22,800
1924	13	..	13	31,200	12,800
1925	12	1	11	31,100	5,400
1926	11	..	11	15,700	10,000
1927	14	..	14	5,900	2,400
Total	577	280	297	409,400	208,500

The following table, also taken from the *Ministry of Labour Gazette* for June 1928, shows how the schemes are distributed among the various industries:—

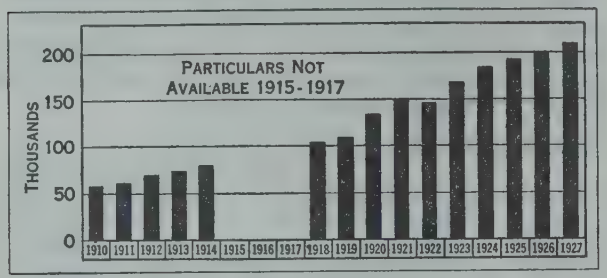
TABLE II.

Industry or business	Schemes in operation at end of 1927			
	Number of firms	Number of schemes	Total number of employees	Approx. number of employees entitled to participate
Agriculture	5	5	700	300
Glass, chemical, soap, oil, paint, etc.	15	15	52,000	29,700
Engineering, shipbuilding and other metal	42	44	67,700	23,900
Textile	29	29	46,800	19,900
Food and drink (manufacture)	31	33	43,400	28,500
Paper, printing, bookbinding, publishing, etc.	22	23	7,700	5,400
Gas, water, and electricity supply	53	53	49,500	41,900
Insurance, banking, and other financial businesses	9	9	37,200	33,000
Merchants, warehousemen and retail traders	44	45	40,400	11,200
Other businesses	40	41	64,000	14,700
Total	290	297	409,400	208,500

The growth of the movement, as will be seen, is irregular; indeed, the figures of new schemes started year by year show that the advance proceeds by spurts following periods of quiescence. The total of 208,500 employees entitled to participate in profit-sharing schemes is substantial, yet, considered relatively, it forms but a small proportion, less than 2%, of the total number of employees. Regarded industrially the proportion varies greatly and is insignificant, except in gas companies, in the banking, insurance and financial group, in the chemical trades and in food and drink manufacture; and in all these groups, with the one exception of gas companies, the profit-sharing statistics are

dominated by the figures for two or three very large companies.

The growth in the number of employees known to be working under profit-sharing arrangements is illustrated in the following diagram:—



Discontinued Schemes.—It has already been pointed out that about half the schemes started have come to an end. Of the 192 schemes started before the beginning of the present century, only 28 were still in operation at the end of 1927. An analysis of the causes of discontinuance is attempted, on the basis of such material as is available, in the official *Report* already mentioned; and another more detailed analysis, supplemented by special enquiries, is made in S. Rowntree's *The Human Factor in Business.* Rowntree's final conclusion is that, taking all schemes, existing and discontinued, together, about 63% may be regarded as successes and 37% as failures; and in many of the cases written down as failures the causes of failure were obvious and might have been avoided. The statistics of discontinued schemes, taken as a whole, are thus somewhat inconclusive, but it is possible to draw some conclusions from the figures analysed (*a*) by industries, and (*b*) by types of schemes.

(*a*) The figures for industrial groups are given in the table (p. 559). Attention may be directed to the extremely unfavourable results in agriculture. Other industrial groups with a high proportion of schemes discontinued are paper, printing, bookbinding and publishing, while merchants, warehousemen and retail traders, show heavy casualties. On the other hand, all the schemes in banking, insurance and other financial businesses that had been started were still in operation at the end of 1927; and gas companies' schemes also had a remarkably high proportion still in operation.

(*b*) More value, perhaps, attaches to the analysis by types of scheme. The figures in the following table are taken from the 19th *Abstract of Labour Statistics,* and relate to the position at the end of 1927.

TABLE III.

	Total	Discontinued	In operation at end of 1927
Schemes consisting in the issue to employees of share capital on specially favourable terms	77	18	59
"Deposit" schemes, under which interest, varying with the profits, is allowed on deposits made by employees	32	6	26
Other schemes, analysed by method of paying bonus:—			
(i) Bonus paid in cash, or credited to a savings or deposit account	300	181	119
(ii) Bonus retained in a provident, superannuation, or other similar fund	23	10	13
(iii) Bonuses paid in shares, or invested in capital of undertaking	50	16	34
(iv) Bonuses paid in other ways; combinations of above systems; and method of payment unknown	92	46	46
Total	574	277	297

It will be seen that the best result is shown by the "deposit" schemes, followed by the two "co-partnership" types of schemes —the share-issue type, and the bonus-capitalisation type. Much the worst result is shown by the cash bonus type (which, however, remains much the largest single class).

Rate of Profit-sharing Bonus.—There is a remarkable uniformity in the average rate of bonus paid by profit-sharing firms to their employees, which works out at a little over 5% addition in ordinary earnings over a long period of years.

Although the average rate, for all industries is remarkably uniform from year to year, there is no corresponding uniformity in the rate of bonus for the several industries. The following table shows the percentage addition to wages made by the profit-sharing bonus in the various groups of industries in each of the three years, 1925, 1926 and 1927: the figures are taken from the 18th and 19th *Abstracts of Labour Statistics.*

TABLE IV.

Industry or business	Percentage addition of bonus to wages			
	1924	1925	1926	1927
Agriculture	1·4	2·1	0·9	0·2
Glass, chemical, soap, oil, paint, etc.	6·1	7·3	3·8	3·5
Metal, engineering, and shipbuilding	1·4	2·1	2·6	1·6
Textile	3·4	2·9	2·2	2·3
Food or drink (manufacture)	7·1	6·3	5·6	3·9
Paper, printing, bookbinding, publishing, etc.	5·8	7·2	7·1	6·6
Gas, water and electricity*	4·6	5·1	4·1	4·1
Insurance, banking, finance†	..	..	..	..
Merchants, warehousemen, or retail traders	9·7	13·3	11·0	10·4
Other businesses	7·7	5·1	5·6	4·0
Total	4·9	5·3	4·4	3·9

*Almost entirely gas companies.
†Cannot be stated.

Views of Employers and of Trade Unions.—It is impossible to make any general statement about the views of employers. It must be taken as significant, however, that, in spite of three-quarters of a century of active propaganda, only some 500 or 600 firms are known to have introduced any form of profit-sharing or co-partnership; and that a large proportion of this small minority have been dissatisfied with the results.

As regards the attitude of the trade unions to profit-sharing, there appears to be little doubt that this has been almost uniformly hostile, or at best indifferent. Naturally, the whole effort of the trade unions, in regard to remuneration, is directed to keeping the *general* level of wages *in an industry as a whole* as high as possible. They are not greatly concerned to secure special advantages for the workpeople in a works here or there, where the employers are exceptionally prosperous.

But further—and this is a point to which many critics of the movement attach great importance—it is conceived to be positively injurious to the trade union movement, as a mass organisation, to have the workpeople in a factory here and there isolated from their fellows by special privileges, since the workpeople so placed may be expected to be wanting in zeal for the defence of their less fortunate comrades, and averse from risking their employment if a dispute should come to the final arbitrament of a strike.

The practical importance of the fundamental distinction, referred to above, between profit-sharing and payment by results is that while payment by results offers a bonus based on factors which are wholly or largely under the control of the workers, profit-sharing offers a bonus based on factors which are in great part outside their competence, and which depend in great part on the judgment, skill and enterprise of the directors and the management. For this reason profit-sharing compares unfavourably with systems of payment by results, *if regarded simply as a method of industrial remuneration;* and it may be said at once that the shortcomings of profit-sharing as a method of remuneration are freely admitted by many modern advocates of the system. The emphasis is nowadays laid rather upon the means profit-sharing affords of giving the workers an assurance that they are receiving "a square deal."

The weakness of profit-sharing as a stimulus to effort lies partly in the remoteness of the connection between the individual effort and the reward accruing to the individual making that effort, partly in the length of time that usually elapses between the additional exertion and the receipt of the reward, and partly in the customary smallness of the reward.

France.—Reference has already been made to some of the historic French profit-sharing schemes.

The French Profit-sharing society published in 1924 a revised (third) edition of their monograph on profit-sharing, containing the names of 140 firms practising profit-sharing in France. This total shows a slight advance on the 114 given in the second edition of the monograph 12 years earlier; but it is to be noted that the definition of profit-sharing is much wider than that adopted in Great Britain; while schemes introduced by firms domiciled in Alsace-Lorraine are now included, which would, of course, not have been included in the earlier edition. Two points of special interest in the *Report* may be noticed. In the first place the historic schemes of Leclaire, Godin, the Bon Marché and others still appear in the list. Secondly, the pre-eminence of insurance companies' schemes is still very marked, a fifth of all the schemes in the list—28 out of 140—being in insurance companies.

The 1924 *Report* of the French ministry of labour on profit-sharing mentions two acts which make profit-sharing compulsory in two special cases, and a third which introduces a kind of permissive co-partnership. An act of Dec. 18, 1915, makes profit-sharing compulsory in workers' productive co-operative societies formed under the act. Particulars are given in the *Report* of 328 such societies, employing 12,000 workers, about half of whom are non-members. An act of Sept. 9, 1919, makes profit-sharing compulsory under all mining concessions granted after that date, of which there were 51 at the date of the *Report*. An act of April 26, 1917, permits the formation of joint stock companies with labour co-partnership (*sociétés anonymes à participation ouvrière*) in the form of labour shares (*actions de travail*), which are the collective property of the employees organised in a co-operative society. Eleven companies had been formed under the act, at the date of the *Report*, of which six were actually working as joint stock companies with labour co-partnership; but it is stated to be too early to form any conclusion as to the success of the experiment.

So far as regards voluntary profit-sharing the inquiry covered 168 businesses; but 93 of these failed to satisfy even a very wide definition of profit-sharing. The remaining 75 undertakings employed 102,000 manual and non-manual workers, of whom 62,000 work for the Paris-Orleans Railway company. In more than one-third of the cases the adoption of profit-sharing was subsequent to the year 1919. The share in the profits varies from 5 to 70% and more; rates of 6 to 20% being commonest. Information regarding 62 establishments employing 99,550 workers indicates that, in 1921, nine of them, employing 63,050 workers, realised no profits, and there was consequently no distribution. Fifty-three establishments, employing 36,500 workers, distributed 25,743,000 francs among 20,415 workers, an average of 1,260 francs for each participant. The actual amounts varied between a minimum of 24 and a maximum of 4,169 francs. On the whole, profit-sharing appears to be on the decline.

Germany.—Profit-sharing had gained little ground in Germany prior to the War. The number of businesses known to be practising profit-sharing at that time was 21, with probably a little more than 15,000 workers. The most interesting of these schemes was that existing in the famous Zeiss works, at Jena.

The position after the War has been studied by the social attaché to the Swedish legation at Berlin; and the following observations are largely based on the report of his investigation (*Sociala Meddelanden*, No. 11, 1923).

There was a revival of interest in profit-sharing in Germany after the revolution; and some of the leading industrialists, including Krupp and Stinnes, were among its advocates.

According to a report by Werner Feilchenfeld, secretary of the Berlin chamber of commerce, published in 1922, in which he carried his investigations as far back as 1824, a system of profit-sharing had existed in 95 undertakings; but of these only 29 were in operation in 1921.

The great majority of profit-sharing schemes in Germany provide for the payment of a bonus in cash, or for payments into savings bank accounts or into provident or benefit funds. As a rule, the distribution is based on the annual earnings.

Only two instances are apparently on record in Germany of the "co-partnership" type of scheme, both of which have been discontinued. The first was almost contemporaneous with the Briggs scheme in England, and was apparently modelled upon it. The latter was introduced in the great Krupp business in 1922, and discontinued in 1925, on the ground, it is stated, that it would not be possible in future years to pay the dividend (6% preferential) on the workers' shares. (J. H.)

United States.—Profit-sharing is a method of additional remuneration of employees under which the employees receive a share, fixed in advance in relation to profits. In other words the basis of distribution of the profits between the stockholders and the employees is predetermined. The actual amount distributed depends upon the profits earned and varies from year to year according to the company's ability to earn profits. The conception of profit-sharing in the Senate report of 1939, pp. 2–5 (which makes profit-sharing include "all payments to employees, regardless of the form in which they are allocated or distributed, which are in addition to the market rate") is incorrect.

Early Examples.—Experience with profit-sharing in the United States dates from at least 1867. The pioneer experiments were, however, short-lived. The first enduring plan appears to be that established by the Peace Dale Manufacturing Company of Peace Dale, R.I., in 1878. This company, which was engaged in the manufacture of shawls, worsted goods and woollen fabrics, employed about 450 workers. Its profit-sharing plan was typical of those most frequently adopted in subsequent years. It provided for the allotment of a percentage of the profits, after making certain deductions for depreciation, reserve and dividends, to be distributed among those employees who had been with the company for a specified time on the basis of their individual earnings. It was also provided that, if the profits were not sufficient to allow a distribution of at least 1% of the earnings, the profit-sharing bonus would not be paid. This situation arose in the first year of the plan's creation. Thereafter, for the succeeding 11 years, a share of the profits varying between 3 and 5% of earnings, was paid to all eligible employees.

Another conspicuous example of the early systems in the United States, and one similar to the Leclaire plan in France, was that adopted in 1886 by the N. O. Nelson Manufacturing Company of St. Louis, Missouri, which continued 49 years. Under the terms of this plan capital received the usual commercial return and the remaining profits, after setting aside 2½% for educational purposes and 5% for a provident fund, were proportionately divided between capital and labour on the basis of the relationship between the total pay roll and the total capital investment. Profit-sharing dividends from 8 to 10% were paid for a number of years. Until 1890 the employees were permitted a choice between payment in cash or in the stock in the company. After that time all payments were made in the form of stock. In 1894 it was decided to allow profit-sharing dividends only to those employees who invested 10% of their wages in the company's stock. During the dull years which followed, no dividends were paid, but in 1906 a total of $108,778 was distributed in the form of company stock to employees, customers and the provident fund.

Extent of Profit-Sharing.—Profit-sharing has never reached considerable proportions in the United States. Of 50 plans set up before 1896 only 12 remained in operation in 1896. The United States Bureau of Labor Statistics found only 60 "true" profit-sharing plans in 1916; *i.e.* covering rank and file employees as contrasted with "limited" plans which apply only to "principal employees." There were probably not over 80 to 90 true profit-sharing plans in the United States in 1930 and some of those were discontinued during the depression years which followed. Seventy years' experience yielded a net growth of hardly more than one plan per year. The National Industrial Conference Board report

on *Practical Experience with Profit-Sharing* (1920), which covered 41 true profit-sharing plans indicated two general conclusions: That profit-sharing is still in the experimental stage and may have more merit than its history indicates and that it has been successful thus far only in the hands of a minority of employers, men with social vision and unusual interest in policies of such a kind, and with workers of considerable intelligence and who have confidence in their employer.

The latest figures on the extent of profit-sharing in the United States are given in C. C. Balderston's *Profit-Sharing for Wage Earners, 1937*, which showed that 193 plans were known to have been initiated in the United States and Canada and 679 in Great Britain and Northern Ireland. Sixty-seven of these American and 266 of the British plans were in active operation in 1937. In a National Industrial Conference Board study published in 1928, which reported results of inquiries of 4,655 establishments in many industries, the percentages of profit-sharing establishments varied from 1·9% in the rubber industry to 12·7% in the case of mercantile establishments. Public utilities and the chemical industry ranked second and third, with 9·4% and 7·3%, respectively, of the companies investigated participating in plans of profit-sharing. Only six of the plans included in the survey began before 1916. The National Industrial Conference Board reached three conclusions in its report on profit-sharing:

(1) From experience with profit-sharing in the past and the plans now in operation, profit-sharing has been successful for limited periods.

(2) Judging from the long list of abandoned plans and the comparatively small number that have endured more than a few years, the effectiveness of profit-sharing in surviving the many vicissitudes of an industrial enterprise is decidedly uncertain.

(3) In the light of the high percentage of abandonment due to dissatisfaction among the workers, it is reasonable to conclude that wise and efficient management plays a very important part in the success of profit-sharing plans.

Analysis of Profit-Sharing Plans.—Profit-sharing plans introduced as an incentive for the employee to remain in the service of the company and to increase the loyalty and efficiency of the wage-earner almost always require a minimum period of employment as a pre-requisite for participation in the sharing of profits. In only 7 of the 41 cases included in the conference board's 1920 report were the workers permitted to share in the profits immediately after employment. The period of service specified ranged from three months to four years, with one year as the usual eligibility requirement.

Sharing of profits has been found to be most successful where a large proportion of workers are allowed to participate. In most cases after a certain period of employment no discrimination is made between employees on the basis of their efficiency or satisfactory service. The Barnett National Bank and the Oneida Community, Ltd., include all of their employees in the distribution of profits, although the share is increased in proportion to years of service.

The Hammermill Paper Company and the Charles Warner Company share their profits only with a limited number of their employees.

In a few instances employees share the losses of lean years, the most noteworthy example of this policy being the plan of the A. W. Burritt Company of Bridgeport, Conn., which was adopted in 1900 and abandoned in 1922. Under that plan 10% of the weekly wage of each employee electing to participate was held until the close of the current fiscal year. If no profits were earned, this fund was divided between the company and the participating employees on the basis of the ratio between capital stock and the annual pay roll of participants in the same way that the profits were distributed.

The payment of the profit-sharing bonus may be made in cash, stock or certificates which bear interest, or a combination of any two of these. Except where the payment is in cash the profit-sharing system is in effect a thrift or savings plan.

Some companies make a partial cash payment with a deferred share later in order to hold the employee after the period of distribution. Most plants make awards once a year, near the Christmas season.

Limited Profit-Sharing Plans.—In addition to profit-sharing plans of the general type, a number of establishments have plans limited to their principal employees and intended primarily to increase administrative efficiency. This policy has been adopted by the Dennison Manufacturing Company which also maintains a modified profit-sharing system for the wage-earners. The limited plan provides for the issue of industrial partnership stock solely to the principal employees in amounts based on total yearly profits after a guaranteed return to capital. This stock carries voting power provided that the dividends on first preferred stock have been paid, but the stock can be held only as long as its owner remains with the company.

When an employee leaves the company he is obliged to exchange his industrial partnership shares for second preferred non-voting stock.

Practical Difficulties.—Organized labour has been hostile to profit-sharing for a variety of reasons. Testifying before the Senate Committee, William Green said labour "is not opposed to principles involved in profit-sharing but . . . to the way in which it has developed and operated. . . . Labor cannot be asked to accept blindly management's decision on what constitutes profits." He insisted that all records ought to be equally available to both sides, that the company's sales policies, executive salary scale, financial policies, and wage structure should be mutually discussed as a basis for profit-sharing and that "collective bargaining should be extended to the field of profit-sharing." Under such conditions labour's attitude would be favourable. John Lewis maintained that labour could not accept as part of its just compensation a share in profits so long as the conditions which control the profits "are completely beyond its control or influence." Employers, too, have serious questions. They have established the plans for any one of several reasons: To promote social justice, reduce labour turnover, increase the interest and loyalty of their employees, encourage thrift, increase efficiency and decrease restriction of output. Often they cannot see that the end sought is achieved.

Many plans have failed to produce economies or increases in efficiency equal to their cost, others have been discontinued because of labour troubles.

A smaller percentage have been ended by the employees asking for higher wages in lieu of profit-sharing.

Uncertainty of profits is, perhaps, the most disturbing factor—uncertainty as to whether there will be any profits, how large they will be, and whether the distribution of them will be on a mutually satisfactory basis.

Present Status of Profit-Sharing.—Although profit-sharing has been successful in a number of instances, it is doubtful whether it is gaining ground at the present time. The underlying purpose of profit-sharing, which was to create a bond of mutual interest between management and workers and to promote greater co-operation and efficiency, has found expression in other forms, such as co-operative thrift and savings schemes, stock purchase plans, benefits for sickness and accident, group life insurance and pension or retirement plans. The profit-sharing systems of some companies have continued to exist through the years, although the details of the plans have been modified from time to time. The N. O. Nelson Manufacturing Company of St. Louis operated on a profit-sharing basis from 1886 to 1935. The Bourne Mills of Fall River, Mass., has continued to share profits with its employees each year, with the exception of 1904, since 1899. Although the plan of the Baker Manufacturing Company has been in existence since 1894, it was not until 1899 that profit-sharing actually became effective.

The most significant development in profit-sharing has been its application in unionized plants. At least seven companies now have profit-sharing in union plants. In all cases the control of profit-sharing is entirely in the hands of the companies but in three of them the unions have insisted upon discussion of the plan at bargaining time. A few unions have asked for profits-shares in addition to the wages provided by the agreement.

Other Countries.—The Dutch schemes, though mostly very small, present many interesting and original features; and Switzerland has the unique experiment of a scheme in the Federal postal

service, which was, however, abandoned after four years, in 1873.

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(D. D. L.)

PRO FORMA INVOICE. When a consignment of goods is made for sale on commission, or when goods are forwarded on approval, it is usual to invoice them in a form identical with that of an ordinary invoice but bearing the endorsement "Pro forma." The consignee is thus fully advised of the contents, descriptions, qualities and prices of the goods consigned.

PROGNATHISM, the term applied with its opposite *Orthognathism*, to describe the degree of projection of the upper jaw, which is determined by the angle made by the face with the brain-cap. (*See* CRANIOMETRY.)

PROGNOSIS, a term used in modern medicine, as it was in Greek, for an opinion, forecast or decision as to the probable course, duration and termination of a case of disease. It is to be distinguished from "diagnosis," the determination or identification of a disease in a particular case from an investigation of its history and symptoms.

PROGRAMME MUSIC, a nickname which is the only current term for instrumental music without words but descriptive of non-musical ideas. Musical sounds lend themselves to descriptive purposes with fatal ease. A chromatic scale may suggest the whistling of the wind or the serenades of cats. Reiterated staccato notes may suggest raindrops or the cackling of hens. Again, music is powerfully suggestive of emotion; and the emotions it calls up may fit some particular story, or may resemble those inspired by a sunset or a storm. But chromatic scales, reiterated notes, emotional contrasts and climaxes, are also normal musical resources; and nothing infuriates a musician more than the non-musical explanation of such things where the composer's aim was purely musical. Sound as it occurs in nature is too inorganic to form the raw material for art, and so there is no natural tendency in music to include, as a "subject," any item not inherent in the art-form. Explicit programme music has thus never been a thing of cardinal importance, though it has often been prominent and always popular. But the conditions of artistic creation are not to be confounded with any correct theory of art. The doctrine of art for art's sake is correct: but it concerns results, not processes; and many of the purest works of art have been produced for ulterior purposes.

Until recent times no composer has written for the voice without words; for speech is a privilege which the human voice will not willingly renounce. No doctrine of absolute music will prevent a good composer from shaping his vocal music to the words which he sets. Good literature will inspire him to explore and express its inner meaning. Bad literature may suggest to him the truths it misrepresents; and the great composers are quicker to seize the truth than to criticize its verbal presentation or to suspect insincerity. The earliest mature musical art was, then, inevitably descriptive, since it was vocal. While programme music derives many of its characteristics from ancient times, it cannot properly be said to have existed until the rise of modern instrumental music, based upon external ideas and independent of the use of words.

A complete code of musical symbolism came to maturity in the 16th century. Part of it was profoundly true and characteristic of moods; part was harmlessly mechanical; and a few details were manifestly false, as when "atra nox" is represented by a curiously jaunty rhythm because that rhythm is indicated by black notes. When symbolism, true or false, has thus arisen in vocal music it may be expected to retain its intention in music without words. But we must not expect too much descriptive power in early instrumental music; and when a scholar tells us that a funeral piece for organ by Froberger depicts in its final rising melisma the ascent of the soul to heaven, he unwittingly accuses Froberger of sinister intentions in a precisely similar funeral piece which ends with a descent to the lowest bass.

The resources of the modern orchestra can attain a realism which at first seems less ridiculous than that of earlier descriptive music. But the expensive realism of the dozen muted brass instruments that in Strauss's *Don Quixote* accomplish in ten rehearsals what a flock of sheep achieve extempore, is not less, but more childish than the thunderstorm in the Fitzwillian Virginal Book.

Beethoven's Theory of Expression.—On the other hand when superior persons object to the childishness of the birds and the thunderstorm in Beethoven's *Pastoral Symphony* it is they who are childish in supposing that realism is in question at all. The real cuckoo, nightingale and quail happen to be musical birds whose themes are exactly what Beethoven wants for a break in the rhythm at a point of *repose* in the coda of his slow movement. Similar final digressions can be seen in slow movements with no programme at all, *e.g.*, in the violin sonata of 24, the pianoforte sonata in D minor (op. 31 No. 2), and the string-quintet in C major, op. 29. Not a bar of the *Pastoral Symphony* would be otherwise if its "programme" had never been thought of. The "merry meeting of country folk" is a subject that lends itself admirably to Beethoven's form of *scherzo* (*q.v.*); and the thunderstorm, which interrupts the last repetition of this scherzo and forms a tremendous introduction to the peaceful finale, is as musical as other unique features in Beethoven's pure art-forms.

Beethoven is recorded to have said that he always composed according to a "picture" he had in his mind; and he sometimes gave his friends an explanation, jocular or evasive, of some particular composition. But the word *Bild* is much more indefinite than "picture"; and Beethoven's dull Boswell, Schindler, often exasperated him into defending himself by saying the first nonsense that would serve to stop foolish questions. Composers who have much to express cannot spare time for translating it into other terms than those of their own art. The *Eroica Symphony*, though inspired by Beethoven's short-lived belief in Napoleon as the liberator of mankind, is not programme music at all. The funeral march represents heroic death and a mourning world, but not the obsequies of a biographical subject; and when critics tell us that the finale is "an inappropriate concession to sonata form" they merely show themselves unmusical without thereby becoming literary. The profound and subtle sonata *Les Adieux, l'Absence et le Retour* is true programme music. It represents Beethoven's feelings on parting from the Archduke Rudolph when the royal family left Vienna shortly before its bombardment. It deals only with the parting, the absence and rejoining of the two men. Nothing is heard of war, and the sentiment is as deep as it is manly. Beethoven's private sketch-books record that the work is "written from the heart": no courtly formula, even if this was shown to the Archduke. Ingenuity is misplaced in tracing external details. (The end of the first movement of *Les Adieux* has been compared to the departure of a coach.) The real emotional basis is universal and musical.

Beethoven summed up the whole theory of great programme

music in his note to the Pastoral Symphony; "rather the expression of feelings than sound-painting." Overtures to plays or operas cannot so easily dispense with story-telling; but Beethoven refuses to be drawn into a chronological series of illustrations. His overtures to *Coriolan, Egmont* and *Leonora* deal with salient emotions roused by their subjects. Wagner was able to place the substance of the *Coriolan* overture in Shakespeare's scene between Coriolanus and his mother and wife before the gates of Rome; but Thayer found that the forgotten poet Collin's play, which was Beethoven's subject, sheds far more light on the music. The music, however, once it took shape, could do without Collin or Shakespeare. The *Leonora* overture was at first (in the form known as No. 2) a huge prelude to the opera, with a gigantic exposition and development, and the shortest wind-up compatible with adequacy, after the trumpet-call behind the scene has relieved the tension. In the later version (*Leonora No. 3.*) Beethoven ruthlessly compresses the exposition until the trumpet-call becomes the middle point of the design, which afterwards expands in a further development, full recapitulation and a climax which makes this overture the first and greatest of all "symphonic poems" (*q.v.*). Critics who cavil at the trumpet-call as a weakness from the point of view of absolute music only show that they cannot tell absolute music from absolute nonsense. Distance is surely too elementary a phase of sound to be excluded from absolute music, nor can the fanfares of a trumpet be separated either from the instrument or from its associations. As a piece of absolute music *Leonora No. 3.* is a huge movement in sonata form rising steadily to a point at which the tension is relieved by the new incident of a distant trumpet-call, after which the music expands from sheer joy. Beethoven's maxim *mehr Ausdruck der Empfindung als Malerei* therefore holds here, and bridges the gulf between absolute and illustrative music.

Portrayal of Characters and Moods.—This is equally true with archaic and modern programme music; it is always characters and moods that are successfully portrayed, while chronology is useless and the illustration of incidents is apt to be ridiculous unless it contrives to be witty. Thus, the *Bible Sonatas* of J. Kuhnau (published in 1700) and their clever imitation in Bach's early *Capriccio on the Departure of a Beloved Brother* rely mainly on moods, and are successful with incidents only when these would be accompanied by music in real life or drama. If Kuhnau's music were half as vivid or inventive as his prose introductions it would be immortal. But much may be learnt from noting how his unconsciously humorous prose describes other things than the music attempts to portray and omits the very things in which the music is at its best. While Kuhnau strains himself, like a bad nurse telling bogey-stories, in his prefatory description of the size and appearance of Goliath, in the music it is the boasts (*le bravate*) of Goliath that are portrayed. The best movement in the Goliath sonata is a figured chorale (*Aus tiefer Noth schrei' ich zu Dir*) representing the terror and prayers of the Israelites. On the other hand the cast of David's sling, with the fall of Goliath, is not nearly so sublime as the fall of a tea-tray. Kuhnau's other subjects (*Saul cured by David's music; The Marriage of Jacob; The Healing of Hezekiah; Gideon,* and *The Funeral of Jacob*) are all thoroughly musical; more so than he succeeds in making them. Bach's *Capriccio* describes the anxiety and sorrow of the friends of the departing brother; and his utmost realism takes the form of a lively fugue on the themes of the postilion's coachhorn and cracking whip. Buxtehud illustrated the "nature and characters of the planets." This is an astrological, not an astronomical subject: the planets signify temperaments and their motions are the music of the spheres. No wonder, then, that this musical subject has been adopted in one of the outstanding masterpieces of modern orchestral music, *The Planets,* by Holst.

Adaptability of Lyrical Music.—Instrumental music on the lyric scale lends itself to illustrative purposes more readily than larger forms. Nearly all the harpsichord pieces of Couperin have fantastic titles, and a few of them are descriptive music. His greater contemporary and survivor, Rameau, wrote important operas and much extremely graphic harpsichord music. *La Poule,* with its theme inscribed "co-co-co-co-co-co-cocodai," is an excellent movement in spacious form, and is also one of the most minutely realistic compositions ever written. French composers have always contributed *con amore* to music that takes advantage of external stimulus; and already in 1801 descriptive music was considered so specially French that Haydn apologized for his imitation of frogs in *The Seasons,* saying that this "französische Quark" (rubbish), had been forced on him by a friend. But throughout the growth of the sonata style, not excepting Haydn's own early work, the tendency towards gratuitously descriptive music often appears; partly because there was no definite distinction between early symphonic music and overtures or incidental music to plays (*e.g.,* Haydn's *Il Distratto*). Dittersdorf's symphonies on the metamorphoses of Ovid are excellent music in which the descriptive elements do not disturb the symphonic form until the metamorphosis which is then illustrated in almost Wagnerian breadth. For instance, the first three movements of the *Change of the Lycian peasants into Frogs* show the rusticity of the peasants, the gracefulness of the goddess, and the rudeness of the peasants to the goddess; and then the finale indicates an altercation ended, after a pause, in a low mysterious quivering sound as of frogs in a marsh.

Dittersdorf is not a great composer; but many more learned and resourceful artists have shown less than his common-sense in distributing the descriptive and the formal elements of their music. It seems incredible that any composer could be so foolish as to commit himself to describing a chronological sequence in a sonata-form which compels him to go through a full restatement of events which only happened once; yet many composers refused to abandon either the sonata form or the chronological sequence. Lyric forms presented no such difficulties.

Schumann and Spohr.—Schumann sometimes invented his titles after his pianoforte lyrics were finished, and sometimes wrote on the inspiration of literature. In either case, as with Beethoven, the music throws far more light on the programme than the programme throws on the music. Musical people may profitably study E. T. A. Hoffman and Jean Paul Richter in the light of Schumann's *Novelletten* and *Kreisleriana;* but if they do not already understand Schumann's music, Jean Paul and Hoffman will help them only to talk about it. In revising his early works Schumann sometimes made them more musical and sometimes destroyed grotesque touches that are musically as well as psychologically true. For instance, in the *Davidsbündler-tanze* (op. 6.) the hot-headed Florestan, having finished an impassioned tirade, feels that he has been making a fool of himself. His last note pauses unharmonized and he sits down awkwardly. In a later edition, with unnecessary scruple Schumann suppressed this detail together with the prose titles and signatures. The fashion of fantastic titles affected even the most formal composers during the romantic period.

No one wrote more programme music than Spohr; and, while Spohr's programme constantly conflicted with the externals of his form and ruined the latter part of his symphony *Die Weihe der Tone,* it did not broaden his style. Mendelssohn's Scotch and Italian symphonies, and his Hebrides overture, are cases of generalized local colour. His Reformation symphony, which he himself regarded as a failure, and which was not published until after his death, is a descriptive work less attractive but more coherent than Spohr's *Weihe der Ton.* The overture to the *Midsummer Night's Dream* is a marvellous musical epitome of Shakespeare's play; and the comparative slightness and conventionality of its second theme closely correspond with Shakespeare's two pairs of lovers, though it does not illustrate their quarrels under the fairy spells.

Influence of Berlioz.—Berlioz made programme-music a vital issue in the 19th century. With an inextinguishable gift for voluminous composition he is utterly incapable of focussing his attention on either his music or his programme. The most trivial external detail may distract him at the height of his rhetoric. The moonshine and sentiment of the *Scène d'amour,* in his *Romeo and Juliet* symphony is charming; and the agitated sighing episodes which interrupt its flow, can be understood in the light of

Shakespeare's balcony scene, if not by their musical sense. But when Berlioz thinks of the nurse knocking or calling at the door, he makes a realistic noise without either musical or dramatic purpose. It does not interrupt the duet, nor increase the emotional tension, nor illustrate Juliet's artifices for gaining time, nor her agitation at the interruptions of the nurse. Perhaps this was the passage on which a lady once congratulated Berlioz for his vivid representation of *Romeo arrivant dans son cabriolet*. This piece of purely orchestral music has an introduction in which real voices are heard from convivial persons returning home from the ball. Berlioz complains that the public has no imagination and that therefore certain sections which presuppose an intimate knowledge of Shakespeare's play *avec le dénouement de Garrick* should be omitted. But what the public lacks for these sections is neither imagination nor familiarity with Garrick-Shakespeare, but a capacity to take the butterfly vagaries of Berlioz's mind as their basis of reference.

With all his absurdities, Berlioz's genius for composition carried him further towards a new music than Liszt was able to advance in his symphonic poems. These, as has been said in other articles (*see* MUSIC, sections 8–10, and SYMPHONIC POEM) are the beginnings of an instrumental music that achieves the same continuity as Wagner achieved in music-drama. But Liszt hardly even began to achieve the right sort of movement; and his conscientious plan of deriving the whole piece from transformations of a single figure was quite irrelevant even when it was effective. As a musical illustrator he is clever; but he ties himself down to chronological sequence, which, though it does not conflict with his forms, is always open to Weingartner's objection that it cannot control the pace of the listener's thoughts. The composer's first view-halloo may make one listener fancy himself in at the death of the Blatant Beast, while the mind of another will plod to the end, to learn that that event never takes place.

Strauss.—The symphonic poems of Strauss are invulnerable by this objection, even though it is often true of their details. Most listeners will probably identify Don Quixote's tilting at windmills with the passage in which Strauss uses a stage wind-machine; but this represents a later adventure in which Don Quixote and Sancho are seated blindfold on wooden horses and are persuaded that they are flying on winged steeds through the air. Strauss's music, however, does not really depend on this sort of thing at all. His earliest symphonic poems are masterpieces of new form and movement: *Don Quixote* is sectional only because its subject lends itself to an episodic treatment which Strauss has as much right as Humpty Dumpty to call variations, and in it, no less than in *Also sprach Zarathustra, Ein Heldenleben,* the *Sinfonia Domestica* and their aftermath the *Alpensinfonie,* single designs are triumphantly accomplished in music of Wagnerian continuity. It is not necessary that the designs should be perfect. Uncles and aunts may interrupt it to say that the baby is the image of its dada or mamma; and the wickedness of critics may devastate pages of the music of the hero who gave them their opportunity when he paused on a dominant chord to look round for applause; but local defects do not annihilate fundamental qualities.

Caricature.—One thread remains to be gathered into this account. Caricature is a rare and dangerous element in music, but it is as old as Orlando di Lasso. Mozart, besides the subtleties of *Cosi fan tutte* and the comic parts of *Die Zauberflöte,* produced in his *Musikalischer Spass,* a burlesque of village players and bad composers. On paper the work is a delicious study in the psychology of "howlers," and in its finale Mozart idealises all the nightmare stagnation of the composer whose *tempo* gets faster and faster while his phrasing gets slower and slower. In performance the effect is even more surprising than analysis would lead the reader to expect. But the Leipzig editors of the parts have crowned Mozart's farce by correcting the mistakes!

Caricature enters prominently into Strauss's *Till Eulenspiegel, Don Quixote* and *Ein Heldenleben;* and also into many passages in Mahler's symphonies. Its danger is that it often opens these composers to suspicion when they intend to be touchingly simple.

But nothing is more vexatious than the laying down of *a priori* limits to what is legitimate for artists. If sermons in the mind of the painter help him to paint, and pictures in the mind of the composer help him to compose, by all means let them get on with the work. (D. F. T.)

PROGRESSIVE EDUCATION MOVEMENT, THE (in Europe called New Education) is the 20th century expression of new ideas inherited from Comenius, Rousseau, Pestalozzi and Froebel. Progressive leaders sprang up in both America and Europe simultaneously but independently at the end of the 19th century. In Chicago, Ill., Col. Francis W. Parker and Prof. John Dewey, each for himself, began teaching and practising the philosophy of education which forms the intellectual basis of the movement. In Europe three men inaugurated the movement in their respective countries: Cecil Reddie in England, 1889, Herman Lietz in Germany, 1898, Edmond Demolins in France, 1898. In the United States the Progressive Education Association and in Europe the New Education Fellowship led the movement and promulgated its underlying ideals. Progressivism with its new spiritual element, its discontent with traditional practices, and its vision of a finer procedure, notably affected American education, both private and public, from nursery school to university. The leaders of the movement advocated and put into practice the following beliefs: (1) education at any age should be a natural growth involving experiences—physical, mental, moral, social and spiritual—adapted to the age, health, interests and abilities of each pupil; (2) genuine education develops, not through imposed formal learning from books and lectures, but only through self-directed, spontaneous activities, preferably pursued in group situations; (3) interest aroused in an atmosphere of freedom is the proper incentive to effort, not the external compulsions of authority, penalties and rewards; (4) the finest education is that which through inspiration and opportunity stimulates and releases native power, resulting in original thinking, action or creation; and (5) educational processes, like processes of growth, involve continuing change and are subject to improvement through experimentation.

Four influences contributed vigour to the movement: (1) the needs created by recent social-economic developments; (2) the rise of the human sciences—biology, physiology, psychology and psychiatry; (3) the challenge of democracy and individualism to the authoritarian traditions of mass education; and (4) the extension of altruistic idealism to include childhood and youth.

(M. S.)

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PROGRESSIVE PARTY, U.S. Three so-called Progressive parties have in the U.S. represented third-party movements in the presidential campaigns of 1912, 1924 and 1948.

The Progressive party movement of 1912 began as an insurgent outbreak among Republican members of congress in 1910 against the speaker of the house of representatives. Opposition to the administration of Pres. William Howard Taft crystallized in 1911 when the National Progressive Republican league was organized by Sen. R. M. La Follette of Wisconsin.

Theodore Roosevelt soon placed himself at the head of that Progressive movement. Alleging unfair tactics on the part of the "Old Guard," his followers left the Republican national convention in Chicago, Ill. (June 1912), and Roosevelt was nominated for the presidency by a Progressive national convention, also held in Chicago, early in August.

As a result the Republican party was hopelessly split, Roosevelt receiving a popular vote exceeding that of Taft by more than 600,000.

Woodrow Wilson, the Democratic candidate, carried all but eight states. The electoral vote was 435 for Wilson, 88 for Roosevelt, 8 for Taft. The popular talley was 6,285,214, 4,126,020

and 3,483,922 for Wilson, Roosevelt and Taft respectively.

In 1916 harmony was restored in the Republican party. Roosevelt declined a second Progressive nomination and supported the Republican ticket. During World War I partisanship was in abeyance, but upon its termination the old rift soon reappeared. The administration of Harding encountered dissatisfaction among farmers, as did the Coolidge administration.

In 1924 Wisconsin and other farm states, after sitting in the Republican convention at Cleveland, O., held a conference for progressive political action. Sen. Robert M. La Follette was nominated for president and Sen. Burton K. Wheeler of Montana for vice-president.

The platform promised a "house cleaning" of executive departments, public control of national resources, public ownership of railways, tariff and tax reduction.

Republican strategy in 1924 consisted largely in denouncing the alleged radicalism of the La Follette platform, while ignoring Democratic attacks. Coolidge won easily, and La Follette carried only Wisconsin.

Unlike its predecessors, the Progressive party founded by Henry A. Wallace in 1947–48 stressed foreign issues in its platform—principally abandonment of the Marshall plan and the Truman doctrine.

This party was formally organized in Philadelphia, Pa., July 22–25, 1948, naming Wallace as its candidate for president and Sen. Glen H. Taylor of Idaho for vice-president. In the presidential election of 1948, the party polled only 1,156,103 popular votes and no electoral votes.

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PROHIBITION is a method for the legal regulation of the manufacture, sale and transportation of alcoholic beverages. It has such extensive and varied applications as to make its other uses in legal terminology of minor importance. National prohibition was adopted in the U.S.A. by the ratification of the 18th amendment to the constitution, Jan. 16, 1919, effective one year thereafter, and repealed by the ratification of the 21st amendment, Dec. 5, 1933. Both amendments were adopted by large majorities only after full and free discussion, with determined and well-directed opposition, and neither can truthfully be said to have been "put over" by a fanatical minority or selfish economic interest.

National prohibition was the logical result of nearly 100 years' experience with state and local prohibition. It was not adopted without due appreciation of the difficulties it would encounter, nor until other expedients were tried to avoid the necessity of this experiment. Some of these expedients and the legislative background of national prohibition and its repeal are more fully discussed in the article LIQUOR LAWS AND LIQUOR CONTROL (*q.v.*). Well-considered public opinion, pro and con, with respect to prohibition, cut deeper across the lines of political parties, rural and urban life, churches and families than any other question of the generation in which the 14 years 1920–33 fell. Its application on a national scale over an area so large as the U.S.A., and to a population living under such diverse racial and climatic conditions, made it by common consent the greatest social experiment of modern times.

Local Option and State Prohibition.—Local option started in Maine (P.A. 1829, c. 133), Indiana (L. 1832, c. 170) and Georgia (A. 1833, 125) in the first third of the 19th century, and state prohibition in Maine in 1851. Most local option statutes permitted the electorate in local political units, usually counties, but sometimes cities, villages, towns and even districts of a city, to vote "yes" or "no" on licences to sell "on" or "off" the premises for a limited period, usually one or two years. Some statutes embodied the local option principle by requiring a licence applicant to get the approval of a majority or two-thirds of the voters in the area to which the licence applies; or providing that no licence be issued, if a majority petitioned for its refusal. Other variations of local option were tried. Thus Arkansas (Digest Stat., 1884, par. 4515) had prohibition with a "licence" local option, and Iowa had prohibition for a time with selling permitted under the mulct law, Code (1897) par. 2448. (*Cf.* Clark Byse, "Alcoholic Beverage Control Before Repeal" [in "Alcoholic Beverage Control" (1940)], *Law and Contemporary Problems*, vol. vii, No. 4, Duke University Law School.)

Licensing systems date back to colonial times. Combined with local option they furnish for the U.S.A., in the light of its experience with both state and national prohibition, the best hope for the possible effective application of the principle of prohibition. A properly drafted high licence statute with local option for prohibition in well-defined areas, or a prohibition statute with local option for licence in carefully planned areas, would go far to remove the majority of the social evils of the liquor traffic without resort to absolute prohibition. State licence systems in the absence of similar legislation by congress have been upheld by the U.S. supreme court as a constitutional exercise of the state police power. (*Cf. The License Cases*, 46 U.S., 5 How., 504, 1847).

State prohibition stems from the development of the temperance movement of the second quarter of the 19th century. In the first quarter that movement was primarily individualistic. The thousands of temperance societies in the northern states, most of them in New England, resulted from a great religious revival and their efforts centred in personal regeneration and what the individual could do for himself. Its progress though encouraging was too slow to stem the rising tide of liquor consumption and its disastrous social consequences. The next logical step was to federate the temperance societies in strong state and national associations and exert political power to regulate or prohibit the production and sale of intoxicating beverages. The greater and more influential national organizations like the Woman's Christian Temperance Union (W.C.T.U.), the National Temperance society, the Total Abstinence brotherhood (T.A.B.), the National Prohibition party and others took up the cudgels after the Civil War; and the Anti-Saloon league with its powerful state and national organization, in the closing years of the century.

The continuous agitation of the temperance societies resulted in "limited" state-wide prohibition by an Indiana statute (1816) making sale of liquor on Sunday illegal, and the "15 gallon" law in Massachusetts (L. 1838 c. 157) prohibiting sale of "less than 15 gallons of spiritous liquor or mixed liquor part of which is spiritous (except for medicinal and mechanical uses) to be delivered and carried away at one time." This apparently accomplished little and was repealed in 1840. The first absolute state prohibition law, due to Neal Dow, organizer of the Maine Temperance Union, was an act "to restrict the sale of intoxicating drinks," approved Aug. 7, 1846. It was too weak in many of its provisions to be effective but was strengthened by the act "for the suppression of drinking houses and tippling shops" approved June 2, 1851. This act repealed all but 13 sections, those containing certain enforcement provisions, of the 1846 statute. The Maine law of 1851 remained substantially unchanged for 70 years and became the model in the next decade for no less than 13 state-wide prohibition laws. But by 1863 in all but five of these states the statutes were repealed or invalidated by state supreme court decisions.

(*Cf.* Ernest A. Grant, "The Liquor Traffic before the Eighteenth Amendment," in *Annals*, vol. 163, Sept. 1932.)

The second stage of organized effort for state prohibition was an outgrowth of reconstruction following the Civil War. It began with the organization of the National Prohibition party in 1869 at Chicago, and the Woman's Christian Temperance Union (1874); marked the return of some states that had tried prohibition in the first period and had given it up; and reached its zenith in the decade 1880–90. Eight states enlisted but only three remained by 1904.

The third and last stage of state prohibition before national prohibition was tried covers the first two decades of the 20th century, was largely due to southern and western rather than New

England forces, and was led by the Anti-Saloon League of America (1895) and the state anti-saloon leagues. Thus when national prohibition went into effect (Jan. 1920) state-wide prohibition under state laws was already in effect in 33 states (more than two-thirds of all the states), and in 18 of them by constitutional amendment adopted or ratified by referendum election. In addition Alaska, Puerto Rico, the District of Columbia and Hawaii were included in 1917–19 in the prohibition area. Ninety per cent of the townships and rural precincts, 85% of the counties and more than 75% of the villages of the United States were under prohibition by state legislation. Two-thirds of the members of the senate and house of representatives came from states or districts having state prohibition which together with local option had put 63.3% of the population and 95.4% of the land area under prohibition. These statistics and similar ones for local option alone may be misleading unless cautiously interpreted as to their real significance, as later experience with national prohibition amply demonstrated. They are not an exact measure of the dryness of a community because often they do not mean a desire to be rid of liquor altogether but only the ugly aspects of the saloon and the liquor traffic in a residential neighbourhood so long as ample supplies may be had from near-by wet areas. Many communities find the ubiquitous bootlegger the lesser evil, and "near-by" has been greatly extended by improved transportation facilities, roads and automobiles. (Cf. *The Local Option Fallacy,* Distilled Spirits Inst., Washington, D.C., rev. ed., Oct. 1942, p. 32; Raymond B. Fosdick and Scott, *Toward Liquor Control,* pp. 22–27.)

Federal Aid to State and Local Prohibition.—It has been said that "liquor consumption did not decrease during the period when the state-wide prohibition movement was strongest" (C. Byse, *op. cit.,* p. 561). The statistical support for such a statement is far from conclusive. Such evidence as does exist, like that regarding local option and state prohibition, must be examined with caution, and deductions and implications made with reserve. If per capita consumption of spirits, wine and beer be combined and some allowance be made for mounting illegal consumption in the years when state prohibition was strongest, possibly a fairly tenable case can be made for the assertion just quoted, but the implied charge that this is the measure of the so-called breakdown of state prohibition is far from true. The cost and difficulties of enforcement, and the protection of dry areas from the inroads alike of the liquor traffic and bootleggers from bases in near-by wet areas were objects of greater concern to the supporters of prohibition.

The states first sought in various ways to protect their dry areas by their own powers. For example, Texas in 1910 made the sale of liquors in no-licence territory a felony. All tried to check the flow of liquor having the constitutional protection of interstate commerce over which the federal government had exclusive jurisdiction. For 43 years the U.S. supreme court followed the rule laid down in the celebrated License Cases (46 U.S., 5 How., 504, 590, 1847) that state legislation could prohibit the sale of liquor without a licence even if imported in the original barrel brought in by interstate commerce. This reversed a ruling in 1827 that held a state law unconstitutional which imposed a licence tax on an importer of liquor. But the still more celebrated Original Package case in 1890 practically reversed the 1847 rule by holding that a state could not prohibit a liquor dealer from importing liquor in interstate commerce for resale in original packages (135 U.S. 100, *Leisy* v. *Hardin*). This nullified state prohibition and congress at once sought by the Wilson act (26 Stat. 313, 1890) "to divest intoxicating liquors of their interstate character" by providing that "liquors transported into a state . . . shall . . . upon arrival in such state . . . be subject to the operation and effect of the laws of such state enacted in the exercise of its police powers, to the same extent . . . as though such . . . liquors had been produced in such state." While this act presented grave constitutional difficulties, the supreme court upheld it in *In re Raher* in 1891 (140 U.S. 545), but in a later case (*Rhodes* v. *Iowa,* 170 U.S. 412, 1898) the court construed the word "arrival" to mean delivery to the consignee and not merely arrival in the state. So the mail-order business, skilful advertising and travelling salesmen still made the evasion of prohibition easy. The U.S. supreme court did try to help the states to find their own remedy, by upholding (1) a Missouri statute which imposed an inspection fee on all liquors shipped from other states into Missouri and offered for sale (190 U.S. 17, 1905), and (2) a South Dakota statute putting an annual licence charge on the business of soliciting orders to be filled from liquors at the time outside the state (*Delameter* v. *South Dakota,* 205 U.S. 93, 1907). In some other cases, however, the Wilson act was further emasculated, by refusing the state the right to prohibit C.O.D. shipments of liquor (*Adams Express Co.* v. *Kentucky,* 206 U.S. 129, 1907), and by not permitting a state to compel a resident-consignee to certify to a state official the quantity and kind of liquor to be imported, or a nonresident-consignor to attach a certificate to the package (*Vance* v. *Vandercock,* 170 U.S. 438, 1898).

The Webb-Kenyon Act.—Passed March 1913, over President William Howard Taft's veto, "An Act divesting intoxicating liquors of their interstate character in certain cases" (37 Stat. 699) was the most aggressive step that congress and the federal government had taken to aid state prohibition. Broader than the Wilson act which merely sought to remove the bar of the original package decision, it was intended to remove the federal protection which liquor enjoyed as an article of interstate commerce. It forbade the transportation of intoxicating liquors into a state by any persons interested therein "to be received, possessed, sold or in any manner used either in the original package or otherwise, in violation of any law of such state." Notwithstanding President Taft's own opinion, and that of his attorney-general, and able lawyers in the senate who advised him, to the effect that the act was unconstitutional, the supreme court sustained it in the Clark Distilling Co. cases, decided Jan. 8, 1917 (242 U.S. 311). This was further strengthened by the adoption of the Reed "bone-dry" amendment to the P.O. Appropriation act of March 3, 1917 (39 Stat. 1069, c. 162) which sought to eliminate completely the illegal mail-order liquor traffic.

The Webb-Kenyon law at first stimulated state prohibition. In 1914 state constitutional amendments were adopted by popular vote and substantial majorities in Arizona, Colorado and Oregon, but rejected by substantial majorities in California and Ohio. Statutory prohibition was adopted in Washington on an initiative measure by 18,632 majority, and in Virginia by a majority of 30,365 in 150,000 votes cast. Congress for the first time adopted in this year a resolution in one house by a majority vote (193–189), but it did not obtain the requisite two-thirds required for the submission of a prohibition amendment to the federal constitution. Considerable extension of dry territory under local option votes was secured in many other states. In 1915 Alabama re-enacted a prohibition law adopted in 1907 but repealed in 1911; and Idaho, Iowa, Arkansas and South Carolina adopted state prohibition statutes. Idaho also submitted to the people a constitutional amendment to the state constitution which was adopted the following year. The year 1916 also recorded the adoption of constitutional state prohibition in Michigan, Montana, Nebraska and South Dakota.

In 1917 the resolution for the submission of the prohibition amendment to the federal constitution received the necessary two-thirds vote in congress which also enacted prohibition for the District of Columbia and the territory of Alaska. A referendum on prohibition was voted on in Puerto Rico in July and adopted by 99,774 votes for prohibition to 61,295 against. Indiana, New Hampshire and Utah adopted state-wide prohibition statutes, and New Mexico, a state constitutional amendment. Minnesota voted also for a constitutional amendment by a majority of 15,932 of all the votes cast, but this was 756 short of the majority the state constitution required for its adoption. Missouri and California defeated constitutional amendments by substantial majorities. By the end of this year before the federal amendment was submitted for ratification, statutory or constitutional prohibition was the law in 25 of the 48 states, and in the District of Columbia, Alaska and Puerto Rico. In nearly every state in one way or another dry territory had been greatly extended.

In 1918, while ratification was proceeding, Florida, Nevada, Ohio, Texas and Wyoming adopted state-wide prohibition statutes, and Utah a prohibition amendment to its state constitution. Congress enacted a prohibition statute for Hawaii, and passed the War Prohibition act as an amendment to the agricultural appropriation bill. Several states adopted constitutional prohibition amendments in 1919.

The 18th Amendment.—The text of the amendment ratified Jan. 16, 1919, by the 36th state making the necessary three-fourths of all the states required for its adoption is as follows:

"Section 1. After one year from the ratification of this article the manufacture, sale, or transportation of intoxicating liquors within, the importation thereof into, or the exportation thereof from the United States and all territory subject to the jurisdiction thereof for beverage purposes is hereby prohibited.

"Section 2. The Congress and the several States shall have concurrent power to enforce this article by appropriate legislation.

"Section 3. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by the Legislatures of the several States, as provided in the Constitution, within seven years from the date of the submission hereof to the States by the Congress."

The amendment as ratified and proclaimed in effect on Jan. 16, 1920, was subsequently ratified by ten additional states, and in six of these (South Dakota, Idaho, Washington, Kansas, Utah and Wyoming) by unanimous vote in both houses of the legislature. Only two states (Connecticut and Rhode Island) did not ratify it. Dr. Ernest H. Cherrington in an article entitled "World Wide Progress Toward Prohibition Legislation" (*Annals*, vol. 109, p. 223, Sept. 1923) says: "No amendment to the Federal Constitution ever received as strong official sanction by the States as the 18th amendment. The original Constitution was adopted in the thirteen original States by a majority of about two to one. The aggregate vote in the State senates and State houses of representatives for the ratification of the 18th amendment shows a majority of more than four to one."

Forty-seven states enacted laws to help carry into effect the provisions of the 18th amendment, though one such law in Nevada was held unconstitutional because of a defect in title. New York, Montana and Wisconsin repealed their enforcement statutes by the end of 1929, but until then the great mass of state legislation tended to strengthen state efforts to enforce prohibition. In the next five years, however, by the end of 1934, all but nine states had voted to repeal their statutory or constitutional prohibition measures, or both, or they had enacted liquor control of the state monopoly or licence type, sometimes with local option for limited prohibition. After the repeal of the 18th amendment by the ratification of the 21st amendment, effective as of Dec. 5, 1933, and the repeal of the prohibition provisions of the Volstead act in Aug. 1935, there were only three states left (Kansas, Mississippi and Oklahoma) in 1942 with state-wide statutory prohibition.

THE ERA OF NATIONAL PROHIBITION

These 14 Years.—From Jan. 16, 1920, to Dec. 5, 1933, is 14 years lacking a few weeks, a short period in the life of a nation, but a momentous one in the social history of the American people. Not since the slavery issue of the middle years of the 19th century has any question been so widely debated, so bitterly contested or pursued with so much determination and idealism as national prohibition by the people of the United States. It came with surprising suddenness, yet the way had been prepared for over 100 years. The new techniques and devices of a greater variety of governmental agencies employed today in the work of liquor control, rather than prohibition, and a new reliance on scientific research for guidance on the complex problems of alcohol, as exemplified by the Research Council on Problems of Alcohol, of the American Association for the Advancement of Science, and as now carried on by temperance and educational organizations everywhere, and even by agencies of the liquor traffic itself, such as Distilled Spirits Institute, Inc.—these and other similar forces give some assurance that the "experiment noble in motive" of national prohibition may not have been in vain.

The Background Influences.—A sufficient indication of the long-time trends in prohibition legislation in state and nation has already been given to account in part for the tidal wave of demand for action on a national scale. Social and economic factors played perhaps as great if not a more important role than the more noticeable moral, religious and political influences organized with increasing effectiveness. New scientific knowledge in the early years of the 20th century caused a mounting public interest in health and efficiency, and the new industrial economics of expanding large-scale production brought increasing support, both moral and financial, to every effort to curb the liquor traffic and reduce the ravages of alcohol. New educational forces at work viewed with growing disfavour the saloon as the so-called poor man's club, and finally there was manifest everywhere increasing irritation with the saloon as a political menace.

World War I was not the cause of the demand for national prohibition though it probably did accelerate it. The absent soldier vote if cast at the time would not have made any substantial change in the decisions reached at the polls. As soon as the United States entered the war, two economic factors—the fear of the loss of manpower on account of intemperance, and the loss of food used in the manufacture of alcohol but needed to supply the army of the United States and that of its allies—served to crystallize an overwhelming sentiment in favour of permanent constitutional prohibition as well as war prohibition. The War Prohibition act of Nov. 1918, an amendment to the Agricultural Appropriation bill, enacted ten days after the Armistice was signed, did not go into effect until June 30, 1919, six months after the ratification of the 18th amendment, but it set a standard until the end of demobilization. It forbade the use of grain, cereals, fruit or other food products in the manufacture or production of beer, wine or other intoxicating malt or vinous liquor for beverage purposes, and made it unlawful to sell for any beverage purposes any such product or any distilled spirits from bond except for export. Such acts, together with earlier congressional enactments such as the Food Control act of Aug. 1917 and the act restricting or prohibiting the sale of liquor at military stations or to members of the military forces in uniform, or in or near military camps, all had a marked effect in support of national prohibition.

The Volstead Act.—The National Prohibition act (41 Stat. 305), popularly known as the Volstead act, and sometimes referred to as the Prohibition Enforcement law, passed the house of representatives, July 22, 1919, by a vote of 287 to 100, three members voting "present." It passed the senate with slight amendments and without a roll call on Sept. 4, 1919. The conference report was adopted in the senate, Oct. 8, without roll call or record vote, and in the house by a vote of 321 to 70 on Oct. 10. It then went to President Woodrow Wilson who vetoed it, and returned it Oct. 27. The house on the same day, by a vote of 176 to 55, passed it over the president's veto, and the senate did likewise the next day by a vote of 65 to 20. Therefore on Oct. 28, 1919, this measure became law applicable by its terms immediately for the enforcement of the War Prohibition act, and "when the 18th amendment to the Constitution goes into effect," intended to carry out the purposes of that amendment. The act is notable for its definitions, including the fixing of ½ of 1% of alcohol by volume as the test of intoxicating liquor, and the delegation of power to the commissioner of internal revenue to make regulations, with the approval of the secretary of the treasury, having the force of law, for carrying out the provisions of the act. The ½ of 1% definition was not new. It was in use in many state prohibition laws and had been the standard since 1902 for internal revenue taxation.

The constitutional validity of the adoption of the 18th amendment, and the constitutionality of the Volstead act with its definition of intoxicating liquor were tested in the U.S. supreme court and promptly sustained in the leading cases of *Hawke* v. *Smith*, decided June 1, 1920 (253 U.S. 221), and *Rhode Island* v. *Palmer*, decided June 7, 1920 (253 U.S. 350), in which the court disposed of several cases pending. Prohibition as embodied in the 18th amendment was held within the amending power, a part of the constitution, and "must be respected and given effect the same as other provisions of that instrument," and was "operative throughout the entire territorial limits of the United States . . . [and] of its own force invalidates every legislative act, whether by Congress, by a state legislature, or by a territorial assembly, which authorizes or sanctions what the [first] section forbids." The court had previously sustained the War Prohibition act and the ½ of 1% limit which it specified. The liquor interests hoped for greater latitude by construction of the first section of the 18th amendment which did not specify the content or define intoxicating liquor. The court, however, without stating or discussing this contention, cited the war prohibition cases in support of the conclusion that while "recognizing that there are limits beyond which Congress cannot go in treating beverages as within its power of enforcement, we think those limits are not transcended by the provisions of the Volstead Act."

THE WORKING OF THE NATIONAL PROHIBITION ACTS

Enforcement.—The Volstead act provided for drastic enforcement, and was intended to give the government ample powers, through the commissioner of internal revenue of the treasury department, to detect and suppress all manner of violations. Congress was at liberty to amend these administrative features and set up any agency of enforcement it chose. It did in fact put the prohibition unit of the treasury under a new assistant secretary, and by the act of March 3, 1927, created a bureau of prohibition in the treasury department with a commissioner of prohibition responsible directly to the secretary of the treasury.

The Supplemental Prohibition Enforcement act of Nov. 23, 1921, (42 Stat. 222) made the already drastic regulations for physicians' prescriptions, and for sacramental wine, more so. It provided that only spirituous or vinous liquor, the latter containing not more than 24% of alcohol by volume, could be prescribed, and that not more than ¼ gal. of vinous liquor nor any quantity of liquor containing more than ½ pt. of alcohol could be prescribed for the use of any one person within 10 days, and that no physician might have more than 100 permits within 90 days unless to meet emergency needs, to be demonstrated to the satisfaction of the commissioner who issues such permits. These restrictions on physicians' prescriptions were upheld as constitutional by the supreme court in *Lambert* v. *Yellowley* (272 U.S. 581). Other provisions of the Supplemental act gave the enforcing authorities control over importations for non-beverage purposes; provided that both the Supplemental and the National Prohibition acts applied not only to the United States but to all territory subject to its jurisdiction; that liquor laws in force when the National Prohibition act was adopted, and not in conflict therewith, should continue in force; and also made it unlawful for any U.S. officer to search any private dwelling without a search warrant. The court, however, in 1925 in *Carroll* v. *U.S.* (267 U.S. 132) upheld the search of an automobile or vehicle of transportation without a warrant where the search was not malicious or without probable cause. A Georgia statute which prohibited the possession of liquor which had been legally acquired before national prohibition went into effect was upheld as within the police power of the state, in another supreme court decision, *Samuels* v. *McCurdy* (69 L. ed. 371). The department of justice approved the wider use of the padlock and abatement of nuisance provisions of sec. 22 and other sections of the National Prohibition act. The methods employed in the enforcement of prohibition, as in the case of tariff and revenue laws generally, and in other laws where there is a strong motive to defeat their purpose, raise many nice questions of constitutional guarantees of liberty and the protection of innocent persons, but the supreme court decisions throughout the prohibition era went far to sustain the gov-

ernment and congress in the exercise of the fullest constitutional powers to enforce prohibition.

The Concurrent Power.—The second section of the 18th amendment clearly indicates by the grant of concurrent power "to congress and the several states" the joint duty and responsibility of the national and state governments to enforce prohibition through co-operation and each government performing that part of the task for which it was peculiarly fitted. In *Rhode Island* v. *Palmer* (253 U.S. 350) the court defined and interpreted "concurrent power" as the power to enforce prohibition by appropriate legislation, but not to enable congress or the several states to defeat or thwart it; that it is not joint power requiring that the legislation thereunder by congress to be effective should be approved or sanctioned by the several states or any of them; neither does it mean that the power to enforce is divided between congress and the several states along the lines which separate or distinguish foreign and interstate commerce from intrastate affairs. The court also added that concurrent power, "while not exclusive, is territorially co-extensive with the prohibition of the first section of the amendment, embraces manufacture and other intrastate transactions as well as importation, exportation and interstate traffic, and is in no wise dependent on or affected by action or inaction on the part of the several states or any of them."

As thus construed the concurrent power section of the amendment reserved to the states their police power over intoxicating liquors, with the single limitation that they could not exercise it to permit what the amendment prohibits. The former policy of strengthening the police power of the state by removing constitutional barriers was now changed to one of co-operation in which the states and the federal government had equal responsibility and power. It was not a grant of any new police power to the states, but an enlargement of the police power they possessed, by extending concurrent power to interstate commerce and to importation and exportation of intoxicating liquors. Neither did concurrent power impose any new obligation on the states, but merely emphasized an old one, as Governor Alfred E. Smith noted as follows: "After repeal there will still rest upon the peace officers of this State the sacred responsibility of sustaining the Volstead Act with as much force and as much vigor as they would enforce any State law or local ordinance" (memo accompanying his approval in 1923 of the repeal of the N.Y. Prohibition law).

If the plain intent and ideal of sec. 2, as interpreted by the U.S. supreme court, had been realized more fully, enforcement would not have broken down so soon nor would have come the demand for repeal with overwhelming force in 1935. The states, however, with few exceptions, refused to co-operate whole-heartedly; and partly on account of old conflicts under the federal-state system, but chiefly because of practical politics and partisan advantage, by so doing sealed the doom of the 18th amendment.

Administrative Difficulties.—The chief obstacles to efficient enforcement did not come from the courts, but rather from administrative difficulties arising from untrained and incompetent personnel, and the lack of enforcement machinery, or its location in several departments of the government. The failure at the outset to put all enforcement officers under civil service caused increasing trouble. Some conflict and overlapping in the efforts of the treasury and the department of justice led the judicial conference of the senior circuit judges, with the concurrence of Chief Justice William Howard Taft, to recommend in Nov. 1924 that the prohibition unit of the treasury be transferred bodily to the department of justice, and that all appropriations for enforcement be expended under the attorney-general. It was thought that a closer co-ordination of the experience and technique of the treasury department with prosecutions by the department of justice would avoid the prosecution of trivial, futile and unimportant cases which crowded the dockets, and would enable district attorneys better to prepare those cases which would really deter the principal offenders. Partly because of the nature of the proceedings in federal courts requiring jury trial, and partly due to the absence of federal police courts to dispose of petty cases, "the resources of the federal government in administration and judicial machinery were sufficient to cope successfully only with what might be called the 'wholesale' aspects of the enforcement problem—smuggling, including report of arrests, seizures, etc., made by federal prohibition officers, the withdrawals of bonded liquors, the diversion and conversion of industrial alcohol to beverage uses, interstate transportation of liquors and the major conspiracies to violate the law, some of which are of giant proportions" (*see* BOOTLEGGING AND SMUGGLING). For the rest, state and local machinery would have to be relied upon to enforce the law.

In response to these and many other suggestions, and to bring the problems of prohibition enforcement more directly under the eye of the secretary of the treasury and the president, congress reorganized the prohibition unit, and created by act of March 3, 1927, a bureau of customs and a bureau of prohibition in the department of the treasury. This was recommended by the secretary of the treasury and centralized responsibility for enforcement of prohibition in a commissioner directly responsible to the secretary of the treasury. It provided for the appointment of a staff under the commissioner, subject to the provisions of the civil service law. In the opinion of the commissioner the civil service requirement did bring about a marked improvement in personnel, and enabled the new bureau to continue more effectively the policy previously followed, namely, decentralization of the prohibition service, and concentration upon the things that federal enforcement could do best, whether the state and local authorities did their part or not.

Treaties to check liquor smuggling were negotiated with Great Britain in Jan. 1924 (ratified and proclaimed, May 22, 1924) and the principal countries of Europe, and Canada, Cuba, Panama and Mexico. These treaties embodied the so-called 12-mile limit, or one-hour run, for boarding and examination of private vessels under foreign flags. They were liberally construed by the U.S. supreme court. (*See* SMUGGLING.)

The major effort in the reorganization of prohibition enforcement was the Prohibition Reorganization act of May 27, 1930 (Pub. No. 273, 71st Cong.). This act, effective from July 1, 1930, established the bureau of prohibition in the department of justice, and the bureau of industrial alcohol in the treasury department. They were previously a single bureau in the treasury department. It was a functional change which greatly accelerated improved enforcement of the prohibition laws, but it came too late to repair the public's shattered confidence in the enforcement agencies, either federal, state or local. Albert E. Sawyer, technical expert of the National Commission on Law Observance and Enforcement, thought that there were losses as well as gains in the reorganization, and that "the undeniable improvement in the effectiveness of prohibition work since the transfer may be the direct result of the aggressiveness which has characterized the attorney-general and his assistants." (For chart and excellent discussion, *see* "The Enforcement of National Prohibition," *Annals*, vol. 163, Sept. 1932, pp. 10–29.)

National Commission on Law Observance and Enforcement.—President Herbert Hoover appointed May 20, 1929, a commission of 11 eminent citizens including one woman, the president of Radcliffe college, to make "a thorough inquiry into the problem of the enforcement of prohibition under the provisions of the 18th amendment of the constitution and laws enacted in pursuance thereof, together with the enforcement of other laws." Eight days later the commission with George W. Wickersham as chairman met at the White House and President Hoover emphasized that he wanted a broad inquiry dealing not only with one law or the laws of the federal and state governments separately, but with the enforcement of, obedience to, and attitude toward all law.

The commission performed its task ably, thoroughly and with commendable speed. Through public hearings in various parts of the country, by special studies of experts engaged by the commission, it assembled from both official and unofficial sources much valuable data not previously available in consolidated form. A preliminary report was submitted in Nov. 1929, and a supplementary report in Jan. 1930. Both dealt chiefly with legal and constitutional questions of procedure in law enforcement. The president sent both reports to congress on Jan. 13, 1930, with a message, accompanied by memoranda from the attorney-general and the secretary of the treasury, endorsing recommendations for more centralization of administrative responsibility for enforcement, more courts and better judicial and prosecuting procedure (H.R.Doc. No. 252, 71st Cong., 2nd Sess.). Congress and the public alike, however, awaited the appearance of the major report on the larger issues involved. This appeared a year later with the title: "A Report on the Enforcement of the Prohibition Laws of the United States," and was sent to congress with a message from the president on Jan. 7, 1931 (H.R.Doc. No. 722, 71st Cong., 3rd Sess.). After a time several volumes of documents and evidence followed.

Thus the commission under pressure for too great speed in making a full report had not quite achieved the larger purposes for which it was organized. It was courageous in its exposé of the weakness of the first seven years of what it called "imperfect enforcement," and sparing in its praise of the improvement of the three years of reorganization. The lack of a master plan, of skilful leadership, of proper co-operation and a united front between such important key agencies as the customs, coast guard, and prohibition bureau, and even the activities of the pressure groups and political forces, pro and con enforcement, are dealt with frankly and fearlessly, and if the report could have been issued five years earlier might have built up normal support of public opinion for normal observance of the prohibition laws. But in 1930 it was too late to expect that, and the commission seemed to think that some modification of the prohibition policy was necessary to restore public confidence in the enforcement agencies of government, either federal, state or local. Yet five of the nine major recommendations and conclusions of the report were squarely opposed to repeal of the 18th amendment; the restoration in any manner of the legalized saloon; the modification of the N.P. act to permit light wines and beers; authorizing federal or state governments to go into the liquor business; inadequate co-operation of the states. Condensed and authoritative statements and interpretation of the commission's report by its chairman, and chief technician, will be found: (1) *Amer. Bar Ass'n Jour.*, vol. 16, Oct. 1930, pp. 654, 660–61 (Wickersham, "Program of the Commission on Law Observance and Enforcement"); (2) two articles by A. E. Sawyer, *Michigan Law Review*, vol. XXX, Nov. 1931, and *Annals*, American Academy of Political and Social Science, vol. 163, pp. 10–29, Sept. 1932.

The Economic and Social Results of Prohibition.—Here

is the nub of the controversy that raged so violently in the decade preceding repeal of the 18th amendment. That much more heat than light emanated from the millions of spoken and written words on this theme was to be expected. Scientific standards of measurement and scientific data on which to base sound judgment were, for the most part, lacking, even for such items as uniform records of arrests for drunkenness, of law violations, prosecutions, sentences, alcoholic morbidity and mortality, etc., on which the government should have been able to disseminate accurate information. Looking back it is clear that the prohibition "authority" of the federal government, wherever located, did a poor educational job, because in the last analysis it was the social and economic aspects of national prohibition, rather than the moral or legal, that decided the fate of the 18th amendment. In every state of the union there was a middle-of-the-road contingent, which cast perhaps 75% of the vote. It could have been lined up for or against national prohibition on clear-cut statements of fact concerning social and economic consequences of one policy or another.

The report of the Federal Council of Churches (*Research Bulletin No. 5*, p. 83, 1925) is one of the best of the unofficial inquiries and furnishes some significant conclusions based on good scientific handling and sampling of questionnaire testimony of social workers. This shows a preponderant opinion at that time that prohibition had helped secure better furnished homes for working people; better mental health of the home as shown by better family co-operation, respect of children for parents, and of parents for children, and by better educational ideals; also larger proportion of the husband's income going to wife and family, and improved marital relations. Favourable community effects were recorded in this special poll: less children's delinquency; less malnutrition; liquor for minors less accessible. But in contrast the inquiry also showed more drinking by young people, and a worse attitude toward law enforcement and respect for laws in general. The Federal Council report, however, does not support the theory that prohibition had caused a moral breakdown among young people. The report's most conclusive finding is that social legislation is no substitute for social education, and that "the illicit liquor traffic will be finally overcome only when and where education in temperate living strongly reinforces the arm of the law."

Similar reports, not all of them so well documented, appeared from many social agencies, business men's organizations, and civic groups, and some dealt more definitely with the wage-earner's stake in prohibition. Still other reports emanated from organizations and groups opposing prohibition: the Association Against the Prohibition Amendment, Repeal Associates, Women's Organization for National Prohibition Reform, the Moderation League, the Crusaders, etc., presented studies of the new evils, and their social and economic consequences, attendant on the failure to enforce, or as some contended, the unenforceability of national prohibition. Matters emphasized in these reports are: the speakeasy as a substitute for the saloon; the public disregard for all laws; public corruption for protection of illegal traffic; the effect on the administration of justice of overflowing prisons and courts cluttered with prohibition cases; the threat, to social and economic security, of huge revenues from the illegal liquor traffic in the hands of well-organized criminals.

Among the many individual studies of the social and economic consequences of prohibition, typical and well-balanced, are: (1) Prof. Irving Fisher's *Prohibition at Its Worst* (1926) and *Prohibition Still at Its Worst* (1928), and his report to the American Economic Association (1927, *A. E. Review*, xvii, No. 1, suppl. March) which claimed that the country was at least $6,000,000,000 better off as a result of prohibition. (2) Prof. Herman Feldman's *Prohibition: Its Industrial and Economic Aspects* (1927) based on a nine months' personal study of industrial plants, documentary material, and questionnaires sent to 1,200 concerns with over 1,250,000 employees. Feldman finds that "the economic benefits of legal prohibition are based upon substantial prohibition in fact; on the actual abolition of the saloons, or their reduction to a negligible quantity, not on the mere change in name; on a greatly lessened consumption of alcoholic beverages; on a general influence in promoting temperance and discouraging overindulgence." (3) Dr. Clark Warburton's *Economic Results of Prohibition* (1932), and in briefer form, *Prohibition and Economic Welfare* (*Annals*, American Academy of Political and Social Science, vol. 163, pp. 89–97, Sept. 1932). This is an able study, but largely negative in its conclusions and results because of the lack of positive statistical evidence and unwillingness to weigh or consider any other kind of evidence. In general, Dr. Warburton concludes that "prohibition had little to do with the prosperity of the Nation from 1923 to 1929 and the increased purchases during those years of many types of luxury and semi-luxury goods."

To this brief statement of very general conclusions from many sources, and in rather sharp contrast to that of Dr. Warburton, just cited, should be added the statement of Secretary of Commerce Herbert Hoover in an address before the U.S. chamber of commerce, as quoted in the *Christian Science Monitor*, March 11, 1925, as follows:

"There can be no doubt of the economic benefits of prohibition. Viewing the temperance question only from this angle, prohibition has proved its case. I think increased temperance over the land is responsible for a good share of the enormously increased efficiency in production, which statistics gathered by the Department of Commerce show to have followed the passage of the dry law. Exhaustive study from many angles of production . . . indicates that while our productivity should have increased about 15% due to increase in population, the actual increase has been from 25% to 30%, indicating an increase of efficiency of somewhere from 10% to 15%. . . . There is no question in my opinion that prohibition is making America more productive."

REPEAL OF THE 18TH AMENDMENT AND THE POST-REPEAL ERA

The revolt against the 18th amendment, and the agitation for its repeal, did not assume serious proportions until the presidential campaign of 1932 when it became a national issue. Conscientious objectors, like Dr. Nicholas Murray Butler, had voiced their protest even before the amendment was ratified. In the Borah-Butler debate in Boston, April 8, 1927, Dr. Butler said:

"The 18th amendment must come out of the Constitution because it does not belong there. It affronts and disfigures it. It contradicts every principle upon which the Constitution rests, and the difficulties, the embarrassments, the shocking scenes reported daily from every part of the land are the natural and necessary result of the inner contradiction that has been set up between the Constitution as it was and the 18th amendment added to it in 1919. . . .

"We talk of law enforcement. You cannot enforce conflicting laws—something must give way; and, when it is the 18th amendment and the legislation based upon it on the one hand and the whole body of the Constitution, the Bill of Rights, the whole of political English and American History on the other, which do you suppose will have to give way? It must be this new and invading element in our public law."

Such was the moral objection which was intelligently and forcibly presented by a sincere small minority. It might have won more sustainers if it had shown greater recognition of the economic facts that underlie public morals, and of the effectiveness of the constitution and the government it set up, to deal with the social problems of modern democracy.

The Modificationists.—They were a second and more numerous group of less conscientious objectors. They wanted more alcohol, "light wines and beer" (or by any other name the people might prefer), than the 18th amendment allowed under the implementing Volstead act, or than the supreme court would sanction if that act were amended to increase the ½ of 1% standard of intoxicating liquor. Hence they advocated repeal of the Volstead act, leaving to the states the enactment of such prohibitory laws as their citizens might desire the implement the 18th amendment within their boundaries and provide varying degrees of dryness or wetness to suit local tastes. Prof. Howard Lee McBain (*Prohibition: Legal and Illegal* [1928]) considered this suggestion and others like it to circumvent the 18th amendment, but his conclusions gave scant encouragement to those who did not want to conform to the dictates and spirit of national prohibition while the 18th amendment remained a part of the constitution.

The political demand for repeal lagged behind the changes taking place in public opinion. In 1928 the national party platforms of both major parties pledged vigorous (Republican) and honest (Democratic) enforcement, but by 1930 the state party platforms in 21 states (14 Democratic and 7 Republican) demanded repeal of the 18th amendment, and in 1932, both national party platforms favoured repeal with safeguards to protect state prohibition territory, or the submission of a proposal to revise in a way to furnish such safeguards.

Supporters of the Experiment.—Opposed to repeal or modification were two groups: (1) the extreme and uncompromising upholders of constitutional prohibition as the only practical method of dealing with the organized liquor traffic and bringing it under social control. In the main the officials of the Anti-Saloon leagues and most of the temperance societies, and such political leaders as Senator Morris Sheppard and Congressman Volstead were spokesmen for this group; (2) a large group of no less sincere but more moderate prohibitionists who were more keenly alive to the economic foundations and implications of national prohibition. This included such national leaders as Senator William E. Borah, Herbert Hoover and many captains of industry, like Henry Ford, Thomas A. Edison and others. This group favoured a longer trial and a greater effort to secure co-operation of both state and national governments, and enlist the active support of the great mass of law-abiding citizens, before saying that the 18th amendment and its supporting legislation could not be enforced. Many excellent suggestions offered in the W. C. Durant prize contest, Aug. 27–Nov. 30, 1928, "for the best and most practical plan to make the 18th amendment effective," showed conclusively that it was not lack of brains or technical skill on the part of the leaders who would and could have enforced the 18th amendment if they had had the strong support of a favourable public opinion such as caused its adoption. Countersuggestions showing the trend towards and the character of the demand for repeal, will be found in the W. R. Hearst temperance prize contest, Jan.–Apr. 1929, "for the best plan to repeal the 18th amendment and substitute in place of prohibition a more liberal and more American measure," later changed to "the best plan to achieve temperance." For a full account of these contests and the winning plans *see* W. C. Durant, ed., *Law Observance*, p. 573 (1929); and Francis J. Tietsort, ed., *Temperance or Prohibition*, p. 397 (1929).

The presidential campaign of 1932 settled the issue overwhelmingly for repeal. The plank in the Democratic platform was unequivocally for repeal, and the Republican plank, as recommended by the majority of the resolutions committee, apparently favoured the submission of a proposal to revise the 18th amendment with some safeguards attached. Dr. Butler, Senator Borah and other leaders claimed, however, that the minority recommendation of the resolutions committee favouring outright repeal more nearly represented the majority sentiment of the convention, but had been defeated by controlled votes. The *N.Y. Times* of June 7 and 9, before the Republican convention had acted, quoted two of the most influential supporters of the 18th amendment, John D. Rockefeller, Jr., and John R. Mott, as respectively in favour of repeal and resubmission.

Submission and Ratification of the 21st Amendment, Repealing the 18th.—The second session of the 72nd congress meeting within a month of the November elections lost no time in preparing a joint resolution which was adopted by two-thirds majority in both houses; in the senate, where the joint resolution originated, by a vote of 63 for, to 23 against, on Feb. 16, 1933, and in the house on Feb. 20 by a vote of 289 for, to 121 against. It was deposited in the department of state, Feb. 20, and the following day was sent by the secretary of state to the respective governors of the 48 states.

The proposed amendment, as subsequently ratified, becoming the 21st amendment to the constitution, reads as follows:

"Section 1. The eighteenth article of amendment to the Constitution of the United States is hereby repealed.

"Section 2. The transportation or importation into any State, Territory, or possession of the United States for delivery or use therein of intoxicating liquors, in violation of the laws thereof, is hereby prohibited.

"Section 3. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by conventions in the several States, as provided in the Constitution, within seven years from the date of the submission hereof to the States by the Congress."

This was the first use to be made of the method of ratification by conventions instead of by legislatures, but in less than 10 months conventions did meet in 36 states which ratified and two (North Carolina and South Carolina) which rejected the amendment. On Dec. 5, 1933, the secretary of state certified the ratification. The president followed this certification on the same day with a proclamation, pursuant to sec. 217a of the National Industrial Recovery act, in which he declared the 18th amendment repealed. While the president did call on all citizens to co-operate with the government in getting rid of the illicit liquor traffic, and to note the new prohibition against wet states invading the territory of those who wished to remain dry, not even the president seemed to realize the full significance of the second section of the 21st amendment. That was left for Justice Louis D. Brandeis and the supreme court to reveal in two little-noticed but remarkable decisions: (1) *State Board of Equalization of California* v. *Young's Market Co., et al.* (299 U.S. 59) decided in 1936; and (2) *Finch & Co.* v. *McKittrick* (305 U.S. 395) decided Jan. 3, 1939. The gist of these two decisions of Justice Brandeis may be seen in two sentences. One taken from the first, speaking of the 21st amendment, says that the words of the amendment "are apt to confer upon the States the power to forbid all importations which do not comply with the conditions which it prescribes"; and the other, from the second decision, to the effect that: "Since that amendment (the 21st), the right of a State to prohibit or regulate the importation of intoxicating liquor is not limited by the commerce clause." Prof. Noel T. Dowling of the Columbia university law school noted within a month after the first decision was handed down, its revolutionary character in constitutional law and history. He raises the question whether it was the intent of the 21st amendment to go so far, and whether the court would go the whole way to permit the states to put themselves in a position of economic isolationism with respect to intoxicating liquors. The second decision gives an affirmative answer to both questions. (*See* Noel T. Dowling, "Liquor and the Constitution," *Independent Journal,* Dec. 18, 1936, Col. Univ.) The second section of the 21st amendment not only put the Webb-Kenyon law substantially in the constitution, and thereby placed it beyond the power of congress to change, but by the interpretation given to it in the Brandeis decisions "the states," as Prof. Dowling says, "seem to have been lifted to a new, surprising, extraordinary position of power in the American federal system."

After Repeal.—At the end of nearly a decade after repeal (1943) it was still impossible to predict how far the states would succeed with the new powers in doing what they failed to do before national prohibition, and what the federal government without their full co-operation failed to do during the era of national prohibition. The president's proclamation of repeal also promised federal aid, and among other things said: "The objective we seek through a national policy is the education of every citizen toward a greater temperance throughout the Nation."

Steady progress toward legal tax control has been made by the Federal Alcohol administration, and in the states through the "licensing" and "monopoly" control in all except the three "prohibition states" (Kansas, Mississippi and Oklahoma). (*See* LIQUOR LAWS AND LIQUOR CONTROL.) During 1942, local option elections in nearly 1,500 geographical areas showed more pronounced dry gains than in any one of the previous nine years, all of which showed some dry gain. It was reported that in that period in over 12,000 local option elections the drys won nearly two-thirds of them. Both the liquor interests and the temperance forces were suspicious of each other fearing that advantage would be taken of the war situation to renew old controversies. Polls indicated a rising tide of dry sentiment even to a reported 36% in one poll favourable to national prohibition. Although there was something in the pattern of World War II events to suggest the antecedents of prohibition in the years 1917–19, the background of legislative demands and action was radically different. The temperate statement of the executive committee of the Federal Council of Churches on Nov. 27, 1942 (*Information Service,* Dec. 5, 1942), presented positive measures to control and reduce the evil effects of beverage alcohol, with particular reference to the wartime situation. These probably fairly represented the attitude of the Protestant Churches, and indicated the trend of thought in most of the temperance societies, Protestant and Catholic.

Too great or sole reliance on legal compulsion defeated national prohibition. The better course that combines education and restraint, both legal and voluntary, in the suppression of the evils of the liquor traffic, was well illustrated in a broadcast of Prime Minister Mackenzie King of Canada, on Dec. 16, 1942, from Ottawa, on "Temperance and a Total War Effort." He asked the provinces to further restrict the hours of sale to eight per day; he lamented the increased consumption of alcoholic beverages as unseemly in wartime when so many are sacrificing so much; and he announced the decision of his government under its war powers to prohibit after Feb. 1, 1943, all liquor advertisements throughout Canada for the duration.

Whatever may be said of prohibition, law, enforcement or repeal, these facts remain: During the prohibition era, a vast, illicit and vicious business of bootlegging was active. It could not have existed without enormous purchases, *in toto,* of bootleg stuff by otherwise reputable citizens who not only resisted the law but defied it and disobeyed it, thus lowering the standards of civic honour.

When repeal came in, it proved to be no immediate remedy for the appalling disintegration of social, intellectual and moral ideals, caused in large part by the illegal practices connected with bootleg liquor. In 1942, war brought additional questionings and difficulties. Many were inclined to believe that certain strict governmental protective and prohibitory measures might still be necessary for social welfare, but that the real progressive solution of the liquor problem might lie in the acceptance of individual responsibility; in voluntary commitment to the temperance cause; in scientific study; in home training and parental example; in the teaching and nurture of the church; and in better social customs.

In a word, the solution might lie more in the educational and spiritual realm, than in the legislative and political.

A new pragmatic emphasis on social and economic results and less controversy about ideologies may characterize the post-repeal era.

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See also: Liquor Laws and Liquor Control; Drink Bill; Bootlegging; Smuggling; Temperance; "Gothenburg" Licensing System; Disinterested Management; Local Option. (S. McC. L.)

PROHIBITION IN LAW, a term meaning the action of forbidding or preventing by an order, a decree, etc. As defined by Blackstone, prohibition is "a writ directed to the judge and parties of a suit in any inferior court, commanding them to cease from the prosecution thereof, upon a surmise either that the cause originally or some collateral matter arising therein does not belong to that jurisdiction, but to the cognizance of some other court." A writ of prohibition is a prerogative writ—that is to say, it does not issue as of course, but is granted only on proper grounds being shown. Before the Judicature acts prohibition was granted by one of the superior courts at Westminster; it also issued in certain cases from the court of chancery. It is now granted by the high court of justice. By the Judicature act, 1873, s. 24, it is provided that no proceeding in the high court of justice or the court of appeal is to be restrained by prohibition, a stay of proceedings taking its place where necessary. In the case of courts of quarter sessions, the same result is generally obtained by *certiorari* (*see* Writ).

In Scots law prohibition is not used in the English sense. The same result is obtained by suspension or reduction. In the United States the supreme court has power to issue a prohibition to the district courts when proceeding as courts of admiralty and maritime jurisdiction.

Most of the states have also their own law upon the subject, generally giving power to the supreme judicial authority in the state to prohibit courts of inferior jurisdiction. (*See* Liquor Laws and Liquor Control; Temperance.)

Prohibition is a writ which lies to restrain the unlawful exercise of judicial functions on the part of a lower court, issuing from a court of higher jurisdiction. Again, it may be used to restrain an official from doing an administrative, ministerial or legislative act not falling within his province.

PROHIBITION PARTY, THE NATIONAL, a minor political party of the United States which set as its primary objective the legislative prohibition of the manufacture and sale of intoxicating liquors. From time to time it also proclaimed its interest in other reforms. The party was organized in 1869 and in 1872 placed its first candidate for president in the field. It offered candidates for president and vice-president in every succeeding presidential election. Though one of the most persistent of the third parties, it polled fewer votes in most elections than some others of more radical character. Its highest figure, 271,058 votes out of a total of 12,043,603 cast, was in 1892. In 1948 it polled only 103,216 out of 48,833,680 cast. While the 18th amendment was in effect, the party agitated for its enforcement, but growing hostility to prohibition and the amendment's final repeal in 1933 forced the party to resume the political struggle within individual states.

PROJECTION, IN MATHEMATICS. Let A, B, C, D, etc., represent points of a straight line l and A′, B′, C′, D′, etc., points of another straight line l′ in the same plane with l. If the straight lines, AA′, BB′, CC′, DD′, etc., are all perpendicular to the line l′, the set of points A′, B′, C′, D′, etc., is said to be an orthogonal projection of the set, A, B, C, D, etc., (fig. 1). The correspondence between the two sets of points, by which A corresponds to A′, B to B′, etc., is called an orthogonal projection. In case the straight lines AA′, BB′, etc., are all parallel, without being necessarily perpendicular to l′, we use the term parallel projection instead of orthogonal projection (fig. 2). In case the lines AA′, BB′, CC′, etc., all meet in a point O we speak similarly of central projection. In all three cases we say that the two sets of points A, B, C, D, etc., and A′, B′, C′, D′, etc., are in perspective and that the points of one set are projected into the points of the other set. The point O is called the centre of perspectivity or the centre of projection of the two sets of points as indicated in the accompanying diagram (fig. 3).

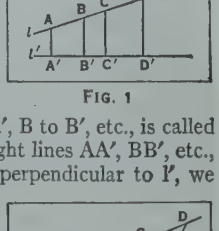

Fig. 1

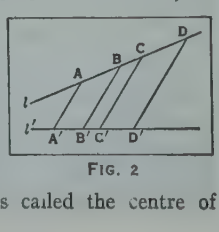

Fig. 2

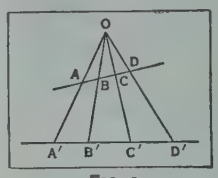

Fig. 3

These conceptions have been generalized in various ways. For example, let A, B, C, D, etc., be the points of any figure F in space and A′, B′, C′, D′, etc., be corresponding points of a figure in a plane π. If the straight lines AA′, BB′, CC′, etc., are all parallel or all meet in a point O the figure in the plane π is called a projection of the other figure. If the lines AA′, BB′, etc., are all perpendicular to the plane π, the figure in π is called an orthogonal projection of the other figure. (*See* also Descriptive Geometry; Perspective; Projective Geometry.) (O. V.)

PROJECTIVE GEOMETRY. Projective geometry is a branch of mathematics which originated in the study of projections as applied to problems of perspective in the drawing of pictures and in optical instruments. These practical applications are now studied under the captions of descriptive geometry (*see* Descriptive Geometry) and geometrical optics (*q.v.*), while projective geometry itself is cultivated for its intrinsic interest. It is a well co-ordinated and symmetrical theory of considerable aesthetic merit, which on the one hand enables us to view elementary geometry as a completed whole, and on the other hand serves as the starting point of the higher algebraic geometry. For a more detailed study the reader is referred to one or more of the text books listed at the end of this article. The article itself attempts merely to state some of the general ideas, definitions and theorems in an introductory way and without proof.

One-dimensional Projectivities.—The notion of projection is defined in the article on that subject (*see* Projection). Suppose that the points of a line *a* are projected into the points of a line *b*, and the points of *b* into the points of a line *c*, the points of *c* into the points of a line *d*, and so on, ending up with the points of the line *k*. Every point *A* of the line *a* then corresponds to a definite point *K* of the line *k*. This correspondence is called a *projective transformation* or *projectivity*, and is sometimes indicated symbolically by

$$\{A\} \overline{\wedge} \{K\}$$

The set of all points of a line *l* is called a *range* (or a *pencil* or *row*) of *points*, so that in the books on projective geometry there is often talk of projective ranges. In case we wish to discuss the correspondence, not of all the points of *a*, but only of certain ones, say A_1, A_2, A_3, A_4, we may write

$$A_1A_2A_3A_4 \overline{\wedge} K_1K_2K_3K_4.$$

The first theorem about projectivities is that any three points of a straight line can be projected into any three points of a straight line. In other words the statement

$$A_1A_2A_3 \overline{\wedge} K_1K_2K_3,$$

is true whenever it is true, (1) that A_1,A_2,A_3 are distinct and collinear, and (2) that K_1,K_2,K_3 are distinct and collinear. It is also true that if the points A_1,A_2,A_3 and K_1,K_2,K_3 are on different lines the projectivity can be brought about by the intervention of not more than two intermediate projections. That is, if the points A_1,A_2,A_3 and K_1,K_2,K_3 are given on different lines it is possible to find a line *b* such that A_1,A_2,A_3 can be projected respectively into the points B_1,B_2,B_3 of *b*, and these points into K_1,K_2,K_3, respectively. If A_1,A_2,A_3 and K_1,K_2,K_3 are on the same line, three intermediate projections may be needed.

A second theorem is that any projective transformation of a line is fully determined by the fate of three of the points of the line. In other words, if it is specified that A_1 goes to K_1, A_2 to K_2, A_3 to K_3, then for any point A_4 of the line A_1A_2 there is a uniquely determined point K_4 of the line K_1K_2 to which A_4 goes. This theorem is often referred to as the *fundamental theorem of projective geometry*.

Points at Infinity.—From the point of view of elementary geometry, there are certain exceptions to these theorems, due to the existence of parallel lines. For example in fig. 1, the point A_0 is not projected into any point of the line *b* because the line from

A_0 to the centre of projection is parallel to b. This circumstance complicates the statement of the theorems about projections if we adhere to the point of view of elementary geometry. In projective geometry it is avoided by introducing the conception of *points at infinity*, or *ideal points*. To every straight line a there is attributed one point at infinity and every line parallel to a is said to meet a in the point at infinity of a. In fig. 1 the point A_0 is therefore said to be projected into the point at infinity of the line b. The points at infinity of the straight lines of a plane are said to constitute a straight line, the *line at infinity* of this plane. All the points at infinity of a three-dimensional space are said to constitute a plane which is called the *plane at infinity*.

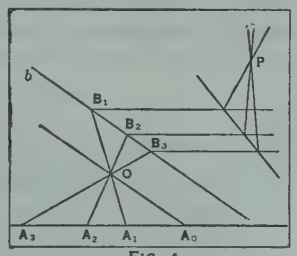

FIG. 1

We shall not attempt here to justify the conception of points at infinity. The question is discussed at length in the books on projective geometry. It may be remarked however that the ordinary points are just as much idealized as are the points at infinity. No one has ever seen an actual point or realized it by an experiment of any sort. Like the point at infinity it is an ideal creation which is useful for some of the purposes of science. With the aid of these conceptions we obtain great simplicity and symmetry in the statements of geometry. For example we have: (a) any two points have one and only one straight line in common; (b) any two straight lines in a plane have one and only one point in common; (c) any two planes have one and only one line in common; (d) a straight line and a plane have one and only one point in common, unless the line lies in the plane; (e) a straight line and a point are on one and only one plane, unless the point is on the line. Each of these statements would have to be split up into at least two propositions in order to state its full content in the language of elementary geometry; and each of the propositions would be more complicated to state than the more general projective proposition in which it is contained.

Principle of Duality.—If we restrict attention to the points and lines of a single plane there is a duality between the two propositions (a) and (b) in the list above. They can be written:

(a) Two points are on one and only one line.

(b) Two lines are on one and only one point.

Either proposition remains true if the words point and line are interchanged. The same thing is true of every theorem of the projective geometry of the plane. If it is properly formulated it remains valid when the words point and line are interchanged. This statement is called the principle of duality in the plane. (*See* DUALITY.) Its exact meaning depends, of course, on what we mean by a theorem of projective geometry. This is explained below with the aid of the notion of the projective group.

After the principle of duality in the plane has been comprehended it is necessary only to state one of each pair of dual theorems. The other one goes without saying. Indeed, after we have arrived at a number of propositions from which we are going to deduce all the rest by logical processes without appeal to other knowledge, and after we have verified the duals of these fundamental propositions, we know in advance that the principle of duality will hold for all the theorems which we are going to derive. This way of dealing with the principle of duality requires that the material of projective geometry shall be organized as a distinct body of knowledge (*see* the remarks on axioms, etc., below).

The principle can also be established by showing the existence of "duality transformations" which carry every plane figure into a dual figure in which the points and lines of the first are replaced by the lines and points of the second.

There is also a principle of duality in space, according to which the propositions of three-dimensional projective geometry when properly stated remain valid when the words point and plane are interchanged. In the list above, the propositions (a) and (c) are dual, (d) and (e) are dual, and (b) is dual to the proposition that any two straight lines with a point in common are in a common plane. In like manner there are principles of duality in spaces of any number of dimensions.

Pencils of Lines.—We must now understand that the statements which we have made about one-dimensional projectivities hold without exception, and therefore include all the special cases which arise when one or more of the points in question is a point at infinity. Glancing again at fig. 1, it is evident that there is a one-to-one correspondence between the points of the line a and the lines through the point O which are in the same plane with a, namely, each point corresponds to the line joining it to O. Such a system of lines is called a *pencil of lines* and the point O in which all lines of the pencil meet is called the *centre of the pencil*.

The notions of projectivity and perspectivity are now extended so as to apply to pencils of lines as follows: The correspondence between a range of points and a pencil of lines in which each point lies on its corresponding line is called a *perspectivity;* and any correspondence between two pencils of lines, or between a pencil of lines and a range of points, or between two ranges of points which is the resultant of any number of perspectivities is called a *projectivity*. This definition includes the definition previously given of a projectivity between two ranges of points as a special case. Under this definition, in fig. 1, the range of points on a is projective with the pencils of lines at O and P as well as with the pencil of parallel lines; and each of these pencils of lines is projective with the others; each of the projectivities being a one-to-one correspondence determined by the figure. Just as in the analogous case of ranges of points, if a_1,a_2,a_3 are lines of one pencil and b_1,b_2,b_3 are lines of another pencil, there is one and only one projectivity in which a_1,a_2,a_3 correspond to b_1,b_2,b_3 respectively.

Conic Sections.—The corresponding lines of two distinct projective pencils of lines in the same plane intersect in the points of a conic section (*q.v.*), provided the line joining the centres of the two pencils does not correspond to itself. For example, in fig. 2, the two pencils of lines at A and B are projective in such a way that corresponding lines are perpendicular, and they intersect in points of a circle. If the corresponding lines had not been perpendicular the corresponding lines would have intersected in an ellipse, or in a parabola, or in a hyperbola.

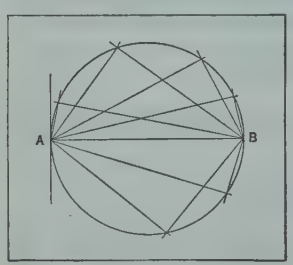

FIG. 2

This theorem of the generation of a conic by means of projective pencils makes it possible to deduce all the properties of conic sections from the theory of one-dimensional projectivities. For example, the fact that there is one and only one conic through five coplanar points, no three of which are collinear, is an immediate consequence of the fact that a projectivity between two pencils of lines is fully determined by the correspondence of three lines of the one pencil with three lines of the other. The theorem is a good example of the unifying power of projective geometry, for it includes as special cases a host of theorems about the construction of conic sections when the given five points are in special position from the point of view of elementary geometry. An equal number of additional theorems is obtained by applying the principle of duality in the plane; and a corresponding group of theorems about cones is obtained by space duality.

The Ruled Quadric.—Let A_1,A_2,A_3,A_4 be four points of a line a and B_1,B_2,B_3,B_4 four points of a line b which is not in the same plane with a. In case

$$A_1A_2A_3A_4 \overline{\wedge} B_1B_2B_3B_4,$$

then any straight line c which meets the three lines A_1B_1, A_2B_2, A_3B_3, will also meet A_4B_4. Hence there is a whole family of straight lines which meet the lines A_1B_1, A_2B_2, A_3B_3, A_4B_4. The lines of this family fill up a surface which is called a *quadric surface* because its equation is of the second degree. It is called a

ruled quadric because of the straight lines which lie upon it. Indeed, the surface may be described as follows: let a, b and c be the three lines already described under these names. There is a family of lines each of which meets a, b and c and there is just one line of this family through each point of a, b or c. This family may be called the *first ruling* or *regulus* of the quadric. Any line which meets three lines of the first ruling meets all lines of this ruling, and the family of all such lines is a regulus just like the first ruling. The quadric consists of the points on the two rulings. There is one line of each ruling through each point of the quadric, and the plane containing these two lines is tangent to the quadric. But for further discussion of this question the reader must be referred to the article on surfaces (*see* SURFACE) and to the appropriate chapters in books on projective and analytic geometry. The ruled quadric from the point of view of Euclid is either a hyperbolic paraboloid or a hyperboloid of one sheet, according as the plane at infinity is or is not tangent to it.

One-dimensional Forms.—This by no means exhausts the list of seemingly complicated geometric figures whose theory can be deduced from the simple propositions about one-dimensional projectivities. The essential element in any such deduction is to find a family of geometric figures which are in such a correspondence with the points of a line that the theory of projectivities can be applied. Any such family of geometric figures is called a *one-dimensional form*. Examples are: a range of points, a pencil of lines, the set of all planes having a line in common, the points of a conic section, the lines of a regulus, the generating lines of a cone, the points of a rational cubic curve in space, the tangents to a conic section, the set of all conic sections having four points in common, and so on. When the general ideas about projectivities of one-dimensional forms are combined with simple theorems about the particular figures to which they are being applied, they often give us flashes of insight into unexpected branches of mathematics, such as, for example, quaternions (*q.v.*) and biquaternions.

Cross Ratio.—If two points, A,B, go by projection to two points, A',B', there is no general relation between the distance AB and the distance $A'B'$. The same remains true of the ratios

$$\frac{AB}{AC} \text{ and } \frac{A'B'}{A'C'}$$

of two sets of collinear points A,B,C, and A',B',C'. But it is not true of the ratio of two ratios

$$\frac{AC}{AD} \div \frac{BC}{BD}$$

(each ratio computed with proper regard to algebraic sign). The fact is that

$$ABCD \barwedge A'B'C'D'$$

if and only if

$$\frac{AC}{AD} \div \frac{BC}{BD} = \frac{A'C'}{A'D'} \div \frac{B'C'}{B'D'}$$

provided the points in each set of four are collinear. Such a ratio of two ratios is called a *cross ratio* or a *double ratio* or an *anharmonic ratio*.

A cross ratio of four collinear points is the same as the corresponding cross ratio of any four points into which they are projected. This fact enables us to define the cross ratio of any four elements of any one-dimensional form, and in each case the cross ratio has a significant geometrical meaning. For example, we can define the cross ratio of four points of a conic as that of any four points of a straight line which are projective with the given four points of the conic. It then can be proved very simply that whenever the cross ratio $ABCD$ is -1 the tangents to the conic at A and B intersect on the line CD; and conversely, if the tangents at A and B intersect on the line CD then the cross ratio $ABCD$ is -1. Whenever the cross ratio $ABCD$ of any four elements of a one-dimensional form is -1 we say that the four elements form a *harmonic set* and that the elements AC *harmonically separate* the elements BD.

Co-ordinates in One-dimensional Forms.—If A,B,D are three elements of a one-dimensional form (*e.g.*, three points of a line) any fourth element C is uniquely determined by its cross ratio $ABCD$. That is, if C is given, the cross ratio is a unique number x, and if a number x is given, there is one and only one element C such that x is the cross ratio $ABCD$ (if $C=A$, $x=0$; if $C=B$, $x=\infty$; if $C=D$, $x=1$). The number x is what we call the *co-ordinate* of the element C of the one-dimensional form. A co-ordinate is a number which serves as a name for the element; and these names have been assigned in such a way that any two distinct elements have distinct names. It can be proved that any projectivity by which each element of a one-dimensional form corresponds to an element of the same form, can be represented by an equation

$$\bar{x} = \frac{ax+b}{cx+d}, \quad ad-bc \neq 0.$$

That is to say, for any projectivity of a one-dimensional form, there are four numbers a,b,c,d such that every element x is carried by the projectivity to that element whose name $\bar{x}$ is related to x by the equation written above.

Invariants of Binary Forms.—This theorem opens the way for a study of projective geometry by means of algebra. In practice it is found advantageous to use homogeneous co-ordinates (*see* CO-ORDINATES). An element whose non-homogeneous co-ordinate is x is represented by any pair of numbers x_1,x_2 such that

$$\frac{x_1}{x_2} = x.$$

In case $x_2=0$, the pair of numbers $(x_1,0)$ represents the element ∞ (represented by B in the discussion above). Homogeneous co-ordinates give a multiplicity of names for the same element, for whenever

$$\frac{x_1}{x_2} = \frac{y_1}{y_2}$$

(x_1,x_2) and (y_1,y_2) represent the same element. Any homogeneous algebraic equation represents a finite number of elements. For example

$$px_1^3+qx_1^2x_2+rx_1x_2^2+sx_2^3=0$$

represents three elements, because there are three values of the ratio x_1/x_2 which satisfy this equation. The left-hand member of a homogeneous equation of this sort, of any degree, is called a *binary form* (binary because there are two variables: *see* FORMS, ALGEBRAIC).

A projective transformation is represented in homogeneous co-ordinates by linear homogeneous equations of transformation

$$\bar{x}_1 = ax_1+bx_2 \qquad \bar{x}_2 = cx_1+dx_2 \qquad ad-bc \neq 0$$

and the projective geometry of one-dimensional forms reduces, algebraically, to the study of the effect of transformations of this sort upon binary forms. This study centres about the theory of *invariants* (*see* ALGEBRAIC FORMS) of binary forms, an invariant being a function which is unaltered except for a factor by the transformations. In geometric applications it is found, in general, that the vanishing of an invariant represents a geometric property which is unaltered by projectivities.

Two-dimensional Projective Geometry.—It is natural to call such collections of elements as the set of all points in a plane, or the set of all lines in a plane, or the set of all planes through a point, etc., *two-dimensional forms*. The concept of a projective transformation can be extended to two dimensions without difficulty. It turns out that any projective transformation of a two-dimensional form is fully determined by the fate of any four elements no three of which are in the same one-dimensional form.

Non-homogeneous co-ordinates are introduced in such a way that an element is named by an ordered pair of numbers $(x,y$, the first and second names of the element). If the elements are points, then these co-ordinates are ordinary cartesian co-ordinates (*see* ANALYTIC GEOMETRY). Homogeneous co-ordinates are sets of three numbers (x_1,x_2,x_3) such that

$$x = \frac{x_1}{x_3}, \qquad y = \frac{x_2}{x_3},$$

and projective transformations of the points of a plane into points of the same plane are given by equations of transformation of the type,

$$\bar{x}_1 = a_1^1 x_1 + a_1^2 x_2 + a_1^3 x_3$$
$$\bar{x}_2 = a_2^1 x_1 + a_2^2 x_2 + a_2^3 x_3$$
$$\bar{x}_3 = a_3^1 x_1 + a_3^2 x_2 + a_3^3 x_3,$$

in which the determinant of the coefficients is not zero. These transformations are also called *collineations* because they transform collinear points into collinear points.

Geometry of the Complex Domain.—Since it is possible to perform all the operations of algebra with complex numbers (*see* COMPLEX NUMBERS)—that is to say with the numbers of the form $u+v\sqrt{-1}$ where u and v are real—it is possible to work out the algebraic theory of projective transformations on the assumption that the co-ordinates, x_1,x_2,x_3, and the coefficients of the equations of transformations, are complex numbers. The objects which are transformed are sets of triads of numbers (x_1,x_2,x_3) where a given set contains all triads $(\rho x_1,\rho x_2,\rho x_3)$ obtained by letting ρ be any real or complex number except zero. We call these objects *complex points*. The collection of complex points which satisfy a homogeneous first degree equation

$$ax_1+bx_2+cx_3=0$$

is called a *complex line*, and the collection of complex points which satisfy a homogeneous second degree equation a *complex conic*, and so on. The totality of complex points is called a *complex projective plane*. Thus there is built up, by simple algebraic processes, a *complex projective geometry*.

The propositions of this geometry are, to a large extent, the same as those of the projective geometry of reals. Two points determine one and only one line; two lines meet in a point; five points, no three collinear, determine a conic; and so on. But a great many propositions assume a simpler and more symmetric form than they do in the real geometry. For example, in the real geometry a line which is not tangent to a conic may meet it either in two points or not at all; in the complex geometry a line which is not tangent always meets the conic in two points. This is because the problem of finding the points of intersection of a straight line and a conic reduces to the solution of a quadratic equation. In general any geometric problem depending on the solution of an algebraic equation of higher than the first degree will assume a simpler form in the complex than in the real domain.

Among the complex points there is a sub-class consisting of those for which the ratios x_1/x_3 and x_2/x_3 (or x_1/x_2, if $x_3=0$) are real. The co-ordinates of these points can always be taken to be real, so that these points can be identified with the ordinary real points. Hence the real projective plane is habitually thought of by mathematicians as immersed in a complex projective plane. Every real straight line or real conic is thought of as containing not only all its real points but also a collection of complex points. Moreover, free use is made of imaginary straight lines, conics, and so on. For example, if we were to limit attention to real figures we should have to say that from certain points of the plane it is impossible to draw lines tangent to a given conic. From the point of view of complex geometry we say that there are two tangents through any point not on the conic; if the point is exterior to the conic the two tangents are real lines, but if the point is interior they are conjugate imaginary lines. No attempt is made to visualize the "imaginary" complex elements. We simply make such inferences about them as follow by the rules of logic from the definitions adopted. The results so obtained are bound to be as self-consistent as any theorems about numbers.

Geometry of *N* Dimensions.—Three-dimensional projective geometry can be approached from the point of view of elementary geometry much as we have approached one and two-dimensional projective geometry in the discussion above; or it may be derived by a purely logical process on the basis of its own axioms; or it may be taken up analytically in the manner explained above for the two-dimensional complex geometry. Points are then defined in terms of sets of homogeneous co-ordinates (x_1,x_2,x_3,x_4). If these co-ordinates are restricted to real numbers we obtain the real projective geometry of three dimensions. If they are allowed to be any complex numbers we obtain the complex projective geometry of three dimensions.

From the algebraic point of view, there is no reason why the number of homogeneous co-ordinates should be restricted to four, and no such restriction is made by mathematicians. A point in a projective space of n dimensions is defined by $n+1$ homogeneous co-ordinates $(x_1,x_2,\ldots,x_{n+1})$ and projective transformations are defined by equations of the form

$$\begin{aligned}
\bar{x}_1 &= a_1^1 x_1 + a_1^2 x_2 + \cdots + a_1^{n+1} x_{n+1} \\
\bar{x}_2 &= a_2^1 x_1 + a_2^2 x_2 + \cdots + a_2^{n+1} x_{n+1} \\
&\cdots\cdots\cdots\cdots\cdots\cdots \\
\bar{x}_{n+1} &= a_{n+1}^1 x_1 + a_{n+1}^2 x_2 + \cdots + a_{n+1}^{n+1} x_{n+1}.
\end{aligned}$$

If the co-ordinates and coefficients are real we arrive at the real projective geometry of n dimensions, if complex, at the complex projective geometry of n dimensions

As the number n increases the geometry becomes more complicated because the number of primary figures to consider becomes greater, but it does not become more difficult in principle. It is no longer possible to visualize our results as we do in the one-, two- and three-dimensional cases, but the logical processes by which they are proved remain the same. In order to explain the situation rapidly we have based the conception of an n-dimensional space on the notion of co-ordinates, but this is not necessary. It can also be developed without the use of co-ordinates from a purely descriptive set of axioms.

Projective, Affine and Metric Geometry.—The set of all projective collineations of a plane form a group (*see* the article GROUP). The properties of any figure which remain unaltered when this figure undergoes the transformations of this group are called *projective properties*. For example, the property of a curve of having a second degree equation, *i.e.*, of being a conic section, is unaltered. Likewise the property of a point, line and conic section, that the point is the pole of the line with regard to the conic, is a projective property. The theory of all projective properties of plane figures is the subject matter of the projective geometry of the plane.

The set of all projective collineations of a plane which leave a particular straight line invariant is a group which is called an *affine group*, and the theory of those properties of plane figures which are unaltered when the figures undergo the transformations of this group is called affine geometry (*see* AFFINE GEOMETRY). The invariant line is called the line at infinity of the affine geometry. An affine group has several subgroups, the most interesting being the ones determined by requiring that two points of the line at infinity shall be invariant. If the two points are real, the subgroup is one studied in the special theory of relativity (*q.v.*) and includes the Lorentz transformations. If they are conjugate imaginaries, the group is the group of similarity transformations of Euclidean geometry.

The Euclidean geometry can be characterized as the group of theorems which state those properties of figures which are left unaltered by the group of similarity transformations. Thus it makes no essential distinction between a large triangle and a small one which is similar to it, though it does deal with the ratio of the two triangles. But the latter is an attribute of the figure composed of the pair of triangles, not of either triangle separately. The theorems of affine and projective geometry are all included in Euclidean geometry, because any property which is left invariant by the projective group is of course left invariant by all its subgroups. Thus affine geometry is a subclass of very general theorems of Euclidean geometry which it seems desirable to isolate from the rest and study together. Projective geometry is a still smaller class of still more general theorems. We seem by leaving out some of the details which distract our attention in the more elementary way of looking at geometry to get a deeper insight and a better grasp of the subject as a whole. Afterwards we are able to return to these details and grasp them rapidly by studying the particular subgroup which determines the Euclidean metric. A

study of the latter group with special reference to the two invariant points gives a rapid and comprehensive survey of Euclidean geometry. For example, the circles are the conic sections which pass through these two points, and the points are therefore called the *circular points at infinity*. Perpendicular lines are pairs of lines which meet the line at infinity in pairs of points which harmonically separate the circular points. The four tangents to a real conic from the circular points meet, in general, in four other points. Two of these are real and are the foci of the conic, and so on.

Non-Euclidean Geometry.—Another subgroup of the projective group which is of great interest is the group leaving a conic invariant. In the real geometry there are two cases to consider according as the conic is real or is composed entirely of imaginary points. The theorems stating properties invariant under the first group constitute what is called the hyperbolic non-Euclidean geometry (*see* GEOMETRY: *Non-Euclidean Geometry*), those stating properties invariant under the second group constitute what is called the elliptic non-Euclidean geometry. The metric geometry or system of measurement of geometric figures, which is developed in these geometries is quite different from, though analogous to, the system followed by Euclid. Historically they were developed in antithesis to the Euclidean system, but they have the same projective geometry.

Axioms.—In attempting to give an introductory sketch of projective geometry we have started from the point of view of elementary Euclidean geometry and freely made use of conceptions which do not belong in projective geometry as the subject is finally defined with the aid of the group idea. This is probably the course which will be generally regarded as advisable in first approaching the subject. But since projective geometry is a collection of general and significant propositions from which it is possible to specialize in a variety of directions, it is an attractive idea to make projective geometry the starting point of the logical formulation of geometry as a whole and arrive at the various more special branches by a process of specialization. The still more general branches will of course continue to be reached by the process of generalization. The problem of stating the axioms in purely projective terms and deriving the theorems from this foundation by purely logical processes has engaged the attention of several mathematicians in recent years and is quite fully developed in the last two books cited in the bibliography below.

History.—The conception of points at infinity goes back to G. Desargues (*cf.* his *Brouillon-projet,* 1639, in *Oeuvres de Desargues,* 1864), and many of the individual conceptions of projective geometry can be traced back to remote antiquity; but it may be said to appear first as a definite branch of science in 1822 in the *Traité des propriétés projectives des figures* of J. V. Poncelet. The development of the science was participated in by nearly all the geometers of the 19th century, notably by L. N. M. Carnot, C. J. Brianchon, J. D. Gergonne, M. Chasles, A. F. Möbius, G. Monge, J. Steiner, J. Plücker, W. K. Clifford, L. Cremona, H. J. S. Smith and H. Wiener. The clear separation of projective from metric properties dates from the publication of the *Geometrie der Lage* of K. G. Ch. von Staudt (Nuremberg, 1847) and his *Beiträge zur Geometrie der Lage* (Nuremberg, 1857). The formulation of the group-theoretic classification of geometries is due to F. Klein. The study of the axioms and the logical organization of the science as a separate entity has been participated in by many mathematicians, notably by M. Pieri.

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PROJECTIVE METHODS IN PSYCHODIAGNOSIS represent a comparatively late approach to the psychological study of personality. Though the term is usually dated from a paper by L. K. Frank in 1939, the techniques in question had been employed in one or another form since the turn of the 20th century. In all of them an attempt is made to fathom the inner organization and content of the individual personality by encouraging the subject to express himself spontaneously in response to stimulus objects that are only partially structured or defined. By noting systematically the ways in which the person has supplied meaning or structure where it was previously nonexistent in the stimulus materials, the examiner is able to discover what has been "projected" from within the person and thus to infer the nature of the individual's needs, traits, interests and other psychological functions. The emphasis in these methods is thus away from testing the subject's skills, through observing the extent to which he can solve problems posed by a structured environment, and toward the revelation of the individual personality from the standpoint of its private world. This orientation was part of a larger change in personality theory epitomized in the term "idiodynamics."

Historically the word-association method, introduced by Francis Galton in 1879, may be regarded as the first formally instituted projective procedure. Other approaches, especially that of handwriting analysis, antedate Galton's method but were never accepted as a formal part of psychology in the same fashion. Sigmund Freud modified the word-association technique into the method of free association as employed in the interpretation of dreams (1900) and in the conduct of psychoanalysis generally. Carl G. Jung shortly thereafter attempted to validate some of the psychoanalytic concepts by using the word-association technique under various experimental conditions to reveal complexes and their relationships to the unconscious personality. It was largely from his work that the word-association method became a projective test device in the years following. In 1921, Hermann Rorschach, a Swiss psychiatrist, published a monograph entitled *Psychodiagnostics* in which he presented a projective method for studying normal and abnormal personality through the use of ink-blot interpretations. Early in the century, play technique, for use primarily with children, was developed by H. von Hug-Hellmuth, Melanie Klein and Anna Freud. C. D. Morgan and H. A. Murray in 1935 introduced the Thematic Apperception test, described below. After 1930 several other devices, including the picture-association method and various art techniques, came into use.

The projective methods proceed on a basis which had long been recognized by literary men and, to some extent, even by common sense. It had repeatedly been noted that an individual discloses the nature of his experiences, his likes and dislikes and his ways of thinking in his spontaneous behaviour. The freer the play of imagination, the greater is the likelihood that the underlying personality will be projected in the productions. An author is thus more likely to reveal himself in his fictional works than in his consciously written autobiography. The art of personality appraisal from this projective standpoint consists essentially in the capacity to "read out" meanings which the individual has read into the world about him.

The projective techniques may accordingly be said to have the following characteristics in common: (1) The psychological reality rather than the physical reality of the subject's world supplies the essential data for analysis. The so-called facts of the person's life may or may not have determined his personality but his present opinions, attitudes, ideals, conflicts and fantasies—the population of his private world—are inescapably significant in affecting his adjustment or maladjustment. These aspects of psychological reality are the ones scrutinized in the projective procedures. (2) The stimulus presentation, while in some degree standardized, is always relatively neutral, ambiguous or partially equivocal. Meaning, significance and organization as these are impressed by the subject upon the undefined stimulus materials reveal his nature. For such projective purposes, ink-blots, ambiguous pictures, incomplete stories or sentences, plastic materials, auditory stimuli of low intensity and any number of other media may be employed. (3) The aim of the methods is primarily to expose the unconscious or implicit aspects of the personality rather than to describe the manifest traits of behaviour. The principles of psychoanalysis and of psychodynamics generally are thus closely interwoven with

the projective techniques.

For the present purpose, the projective methods may be classified as motor-expressive, perceptive-structural and apperceptive-dynamic. The motor-expressive methods are those in which the individual reveals his personality by the manner in which adaptive actions are carried out. The analysis of handwriting, of gait, style of verbal expression, voice and other manifestations of a motor sort lend themselves to such analysis when emphasis is placed not upon the ends served by the behaviour but upon dimensions such as intensity, speed and amplitude. Cues of the type here involved have long been considered significant for the understanding of personality, as, for example, in the essays of Johann Lavater (1741–1801), but only much later did the professional psychologist come to regard these aspects of behaviour as being of serious interest in relation to personality diagnosis. Among the workers in this area may be mentioned Ludwig Klages, Robert Saudek, Werner Wolff, P. E. Vernon and G. W. Allport.

The perceptive-structural approach is represented more generally in the practice of clinical psychologists. Here the subject is permitted to organize such undefined stimuli as ink-blots and report what they seem to him to signify. Most of the interpretations given by the subject are produced at the level of perception, and from this process may be inferred the structural aspects of the personality—organization of emotional life, direction of interest (extraversion or introversion) and related functions. In this area the Rorschach Method of Personality Diagnosis was probably the most widely used projective procedure in clinical practice in the 1940s. Ten ink-blots are presented one at a time to the subject with the instructions that he describe what he sees in them—what they could represent or what they call to mind pictorially. The data thus obtained are supplemented by elaborations elicited later in the procedure and together the total responses provide a basis for scoring and interpretation. The scoring is directed primarily to certain formal characteristics, secondarily to the content of what the subject sees. Among the formal categories considered are whether the whole or parts of the blots are used in the responses, how shapes and colours, shading and the movement of living creatures enter into the associations. Whether the person has seen plants, houses or other objects is taken into account to a lesser extent. From the scores for single categories and even more so from the total configuration of the subject's scored responses it is possible to interpret the record as revealing not only the intellectual capacities of the person but the status of the emotional life and various individual traits such as impulsivity, anxiety, practical-mindedness and neurotic conflict. Norms derived from the productions of subjects in various fairly well-defined groups—normals, neurotics and psychotics—make possible the comparison of the subject's record with these others as a basis for personality classification. The technique has been employed not only for the understanding of the individual person but for diagnosing mental patients psychiatrically. Adequate application of the method requires competence of a very high degree since the general clinical skill of the psychologist and broad experience with this particular method are more vital in practice than the incomplete and tentative norms that are available for scoring and interpretation. Nevertheless, it should be clear that such criteria for scoring and interpretation do exist.

After its introduction in 1921, the Rorschach method was employed more and more widely. Several modifications were also available, including an adaptation for the examination of groups, parallel series of blots for retest purposes, and a graphic supplement in which the individual draws the figures he has previously reported. The last named device is similar in some respects to William Stern's Cloud Pictures. A variation of the ink-blot approach that extends to another sense modality, hearing, is found in the Verbal Summator or Tautophone introduced under the former name by B. F. Skinner as a method for studying latent speech and rechristened as a projective approach to personality diagnosis by David Shakow and Saul Rosenzweig. A phonograph record here reproduces groups of meaningless syllables at low intensity and the subject is instructed to listen for and report meaningful speech.

Operating at a more highly organized psychological level than either the motor or perceptual thus far described are the apperceptive-dynamic procedures. These stress more complex intellectual functioning such as imagination and judgment—hence the designation "apperceptive"—and yield products from which are interpreted the motives, drives, interests and central themes of the individual personality—hence the term "dynamic." The dynamic trends disclosed are often outside the subject's conscious awareness, representing instead tendencies that are implicit in his life behaviour. It is in this area that the earliest of the formally instituted projective methods roughly belongs—the word-association procedure. The subject is presented with a list of words, one at a time, with the instruction to respond with the first word that enters his mind. The time required for giving each response and the content of the response are noted. Analysis of deviant reaction times, unusual associative content and other indicators makes it possible to disclose certain of the subject's sentiments, attitudes and anxieties extending sometimes to unconscious complexes. In addition to the pioneer work by Galton and Jung, later important investigations were conducted by David Rapaport and by Florence Goodenough. As extensions of the word-association method may be mentioned the sentence-completion and the story-completion techniques. Another variation, the picture-association method, is best exemplified in the Rosenzweig Picture-Frustration Study. Here pictures of social situations are substituted for words as the stimulus material. The subject examines the cartoonlike drawings, each of which represents an everyday situation of frustration or stress, and is instructed to give the first verbal response that occurs to him as appropriate for the anonymous figure who is shown in the picture as being frustrated. Since the method shares with all the apperceptive-dynamic ones the assumption that the subject identifies with the character in the situation for whom he is giving associations, his responses are interpreted as revealing how he might feel or react under frustrating conditions—how he uses and directs his aggression. Of similar interest is the Szondi Test in which the subject reveals his latent personality traits through the preferences he expresses for a number of photographs each of which represents an individual of supposedly different psychopathological syndrome.

Of much greater complexity and far more revealing in its output than the preceding apperceptive-dynamic techniques is the Thematic Apperception Test. The method involves a series of pictures, arranged in groups appropriate for male or female adults, or for children, which are shown to the subject as if they were illustrations for stories that he is instructed to imagine and narrate. The stories are recorded verbatim as told and the result analyzed for leading themes and figures. In the analysis the examiner must, of course, consider the frequency with which a particular story type has occurred among other comparable subjects. But of greater significance is the recurrence of a given theme within the record of the particular subject. Such recurrent trends are interpreted as revealing the implicit habits of thought, the ideals, attitudes and needs of the individual as well as the characteristics of the inhabitants of his private world—father and mother, sister, brother, husband or wife. The Thematic Apperception Test, like the Rorschach, demands great skill and broad clinical experience for its proper application.

For use with children, who are limited in verbal expression, are various forms of play technique in which the subject is allowed to construct scenes or build in other ways by employing dolls, toys, blocks and similar materials. This approach has been employed not only as a projective method for understanding personality but even more frequently as an instrument for the treatment of behaviour problems. Several attempts have been made to standardize play technique for psychodiagnostic use, as, for example, in the World Test (Margaret Lowenfeld; Charlotte Buehler and Gayle Kelly; Hedda Bolgar and Liselotte Fischer).

Most of the projective methods are mixed, in the sense that they are not fully classified under any one of the three foregoing rubrics. For example, the play techniques just described often involve motor-expressive and perceptive-structural features in addition to the apperceptive-dynamic ones that are predominant. Similarly mixed in approach are various art techniques that elicit paintings, drawings and productions of modelling from the individual under study. Notable in this group is fingerpainting, an invention of Ruth Shaw, in which paintings are executed with a soft, pastelike substance applied directly by the fingers. The method has a fairly wide application both in education and in personality study.

The projective methods considerably broadened the psychodiagnostic functions of the clinical psychologist. The better known and older psychometric tests, like those of intelligence, emphasized the relationship of the individual to some group with which it was possible to compare him in standing on the basis of statistical norms. These approaches seldom were successful outside the field of intellectual capacity and allowed little room for the understanding of the person in his inner organization. The projective methods, by contrast, emphasize the unique organization of the individual personality and employ group norms to a limited extent only. The productions of the subject are interpreted largely in relation to each other and an attempt is thus made to obtain a picture of the person in terms of his individual norms. Idiodynamics, which treats all the events in the universe of a single individual as a psychological population, is the approach in personality theory which undertakes to systematize such interpretations. While this extension of the clinical psychologist's functions has clear advantages both for psychological theory and for clinical practice, it is obvious that many pitfalls are thus introduced which make abuses by the untrained and inexperienced easily possible.

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PROKOFIEV, SERGEI (1891–1953), Russian composer, was born at Ekaterinoslav, South Russia, April 23, 1891. In 1910 the Rubinstein prize was awarded him for his first piano concerto. From the first his compositions attracted attention by their originality and audacity. In writing for the stage he chose subjects which had elements of grotesqueness or harsh satire, such as *Chout* (*The Buffoon*), played by Sergei Diaghilev's ballet corps in Paris (1921) and *The Love for Three Oranges*, a fable, produced in Chicago in the same year. His *Scythian Suite* for orchestra had also an obvious program. Other orchestral works include the *Symphonie Classique*, a *Sinfonietta*, the *Overture on Yiddish Themes* and *Peter and the Wolf* (1936). He died near Moscow on March 4, 1953.

PROKOP, the name of two prominent Hussite generals.

1. Prokop, surnamed "Veliky" (the great) or "Holy" (the bald), was a married utraquist priest who belonged to an eminent family of Prague. Though a priest, he became the most prominent leader of the advanced Hussite or Taborite forces during the latter part of the Hussite wars, commanding them at their great victories at Usti nad Labem (Aussig) in 1426 and Domažlice (Tauss) in 1431, during their frequent incursions into Hungary and Germany, particularly the Bohemian invasion of Saxony in 1429, after which Prokop concluded the treaty of Kulmbach (Feb. 6, 1430) with Frederick of Brandenburg, burgrave at Nuremberg. He was the most prominent member of the Bohemian embassy to the council of Basel (1433). On the return of the embassy from this fruitless journey, when renewed fighting broke out, he besieged the Romans at Plzeň but was forced by indiscipline in his own camp to raise the siege and return to Prague. The Bohemian nobility, both Romanist and utraquist, having leagued itself against the Taborites, a struggle began at Prague. Aided by the nobles, the citizens of the old town took the more democratic new town, which Prokop unsuccessfully attempted to defend. He now called to his aid Prokop "the Lesser." (*See* below.) They jointly retreated eastward from Prague; but their forces, known as the army of the towns, were defeated by the nobles at Lipan, between Kourim and Kolin, Prokop the Great perishing in this battle (May 30, 1434).

2. Prokop "the Lesser," or Prokupek (the Bohemian diminutive of the word Prokop), was one of the greatest Hussite generals. Little is known of his early life. He took part in all the later campaigns of Prokop the Great in Germany, and succeeded him as commander of the Taborite army that besieged Plzeň. After the formation of the confederacy of the nobles he was recalled by Prokop the Great, with whom he shared the command of the army of the towns at the battle of Lipan, in which he also perished.

See Count Lützow, *Bohemia, an Historical Sketch* (1896); F. Palacky, *History of Bohemia*, 5 vol. (1836–67); H. Toman, *Husitské Válečnictví* (Prague, 1898).

PROKOPOVICH, THEOFAN (1681–1736), Russian archbishop and statesman, one of the ablest coadjutors of Peter the Great, was educated at the Orthodox academy of Kiev in Poland, and at Rome in the College of the Propaganda. On his return to Russia he became professor, and subsequently rector, of the academy of Kiev. He reformed the teaching, substituting the historical method of the German theologians for the antiquated orthodox scholastic system. In 1709 Peter the Great, while passing through Kiev, was struck by the eloquence of Prokopovich in a sermon on "the most glorious victory" (*i.e.*, Poltava) and in 1716 summoned him to St. Petersburg. Theofan was rapidly promoted, becoming in 1718 bishop of Pskov and, finally, in 1724 archbishop of Novgorod. As the author of "the spiritual regulation" for the reform of the Russian Church, Theofan must, indeed, be regarded as the creator of "the spiritual department" superseding the patriarchate and better known by its later name of the Holy synod, of which he was made the vice-president.

See I. Chistovitch, *Theofan Prokopovich and His Times* (St. Petersburg, 1868); P. Morozov, *Theophan Prokopovich as a Writer* (St. Petersburg, 1880).

PROLEGOMENON, a preface or introduction to a book, especially a preliminary introductory essay to a learned work, or a treatise which serves as a general survey or introduction to the study of some subject or as a special survey of the subject. The word is more often used in the plural.

PROLETARIAT. In ancient Rome the proletariat (*proletarius*) constituted the body of poor, landless freemen. It included artisans and small tradesmen who were gradually impoverished by the extension of slavery. The proletariat was the lowest rank among Roman citizens, literally "producers of offspring" (*proles*); the first recognition of its status was traditionally ascribed to Servius Tullius. Its power resided exclusively in the rights its members enjoyed as Roman citizens. In some periods of Roman history it played an important role, not as an independent force but as a mass following, in the political struggles between the Roman patricians and the wealthy plebeians. Since it had little opportunity for productive work, which was performed in the main by slaves, its existence was largely parasitic on the Roman economy. On occasions it was quieted by doles of bread from the state and diverted by spectacles.

The proletariat, in the usage adopted by Karl Marx, designates, strictly speaking, the class of wage workers engaged in industrial production whose chief source of income is derived from the sale of their labour power. As an economic category it is distinguished in Marxian literature from the poor, the working classes and the *Lumpenproletariat*. Because of its position in a capitalist society and the effects of periodic depressions on wages and employment, the proletariat is described by Marxians as usually living in poverty. But it is not therefore identified with the poor, for some members of the proletariat, the highly skilled or labour aristocracy, are recognized as not poor, and some members of the entrepreneurial class as not wealthy. Despite synonymous use in agitational literature, the term proletariat is distinguished from the working class as a generic term. The former refers to those engaged in industrial production, the latter to all who must work for their living and receive wages or salary, including agricultural labourers, white-collar workers and hired help occupied in the distribution services. The *Lumpenproletariat* consists of marginal and unemployable workers of debased or irregular habits and also includes paupers, beggars and criminals.

The proletariat in this sense appeared comparatively late on the historical scene. Its existence is essentially bound up, according to Marxian analysis, with the development of modern capitalism. Many causes have been assigned for the emergence of the proletariat, the chief of which is the expropriation of the peasants from their individual holdings by enclosures, forced sales and bankruptcies, thus compelling them to drift to the cities where they could find a market for their power to work. The proletariat was therefore considered as an urban phenomenon whose size was vastly extended by the Industrial Revolution. Among the contributory factors of the process of proletarianization have been cited the breakup of the mediaeval guilds, the dispersion of the monasteries, the liberation of the serfs, and large increases in the population relative to the possibilities of employment in traditional vocations. The incidence of these factors on the rise of the proletariat varied from country to country.

According to the Marxian analysis, the existence of the proletariat as a definite class presupposes the existence of the capitalist class. Where the capitalist class disappears or becomes subordinate in the control of production to other social groups that abrogate the free market, there is no longer a proletariat. This conclusion, together with the prediction that in the course of its evolution capitalist society necessarily becomes polarized into two classes, was questioned in the light of 20th-century developments in Germany, the U.S.S.R. and the United States. The assumption that in time the proletariat would constitute the overwhelming majority of the population was also challenged on the ground that increasing mechanization and rationalization of production led to a relative decline in the number of unskilled, manual workers and an increase in the numbers of those engaged in managerial functions and distribution services.

More significant in Marxian theory than its meaning as a strictly economic category is the social-psychological conception of the proletariat. Slowly educated by their hardships and their struggles for better conditions and wages, the workers are believed to become conscious of the objective antagonisms that divide them as a class from their employers. The first stage in their awareness is usually marked by the organization of trade-unions within the existing framework of

society. The second is their acceptance of doctrines which teach either that they cannot permanently improve their human existence in a commodity-producing society because unemployment, crisis and war are endemic to its operation, or that a more just and efficient organization of social relations is possible which would increase their material welfare and remove invidious social distinctions. The third stage is reached in the development of political parties which take on the designation of labour or socialist parties whose ultimate program is directed not to the improvement of the individual lot of the worker or to facilitating social mobility from class to class, but to the reconstruction of the whole society which, in abolishing all traditional economic classes, would abolish the proletariat as a class.

Further, by setting up a common faith and objects of ideal allegiance, Marxians seek to unify the diverse ethnic, religious and national differences among the proletariat and to reinforce the sense of solidarity which is presumably born out of consciousness of common material interests. In respect to this function of proletarian ideology, it should be observed that it enjoyed some limited success in overriding ethnic and religious differences among the members of the proletariat, but failed almost completely in transcending consciousness of national differences. In times of national conflict, the proletariat behaved no differently from the bourgeoisie of their respective countries.

Marxians seek organizational support for their ideology primarily, but not exclusively, among industrial workers for two reasons. The first is the assumption that whereas the economic grievances of all other working groups, such as the farmers, intellectuals and lower middle classes, can be removed without fundamental social change, the position of the industrial worker is so tied up with the exigencies of capitalist production that he cannot be liberated except by transformation of capitalism itself. The second is the expectation that, in the event of a struggle for power, the industrial workers will be most strategically situated in determining the issue—an expectation also called in question by the development of modern industrial and military technology.

The appeals of proletarian ideologies nevertheless have been addressed to the community at large, to all men of "insight" and "good will," couched in moral terms which try to invoke the ideals of justice, humanity and human freedom. Many elements in the population are won to adherence to proletarian causes whose social antecedents are by no means proletarian. It has been widely observed that many outstanding political leaders of working-class parties in all countries have been drawn from other classes. And since most inspirers of proletarian ideologies have rarely been members of the working class, it has been inferred that the working class, left to itself, is not likely to develop beyond the level of trade-unionism. The universalism implicit in the premises of proletarian ideologies led their carriers to proclaim that they represented the best understood interests not only of one class in the community, but of the masses or people. In this way the voice of moral prophecy acts to give force and persuasive effect to the analysis of historical destiny. The result, sometimes concealed, sometimes acknowledged, is a broadening of the meaning of proletariat from a term designating a narrow economic class to a term that loosely encompasses all who support the ideology of the class, and ultimately to the masses who are presumed to enjoy its future benefits.

The various ambiguities in the meaning of the term proletariat come to a head in the phrase "the dictatorship of the proletariat." As Marx used it, it denotes the political rule of the proletariat, through representative organs, during a transitional period from capitalism to socialism. It is a dictatorship in that political power is used to abolish the social relations of production which create profit and rent. Since Marx assumed that the proletariat would constitute the overwhelming majority of the population as the polar class to the bourgeoisie, the dictatorship of the proletariat was conceived as a form of workers' democracy. It was not conceived as a dictatorship of the minority or of a political party, but of a social class, and emphatically not the dictatorship of a political party over the proletariat. This is evidenced not only by the language of the *Communist Manifesto,* but also by F. Engels' public reference to the Paris Commune as an illustration of a proletarian dictatorship.

After the Russian October Revolution of 1917 the meaning of "the dictatorship of the proletariat" changed. Nicolai Lenin, L. Trotsky and Joseph Stalin declared that it represented substantially the dictatorship of a minority political party. This party consists of the self-denominated vanguard of the proletariat, although its members need not be proletarian in origin. It speaks and acts for the whole of the proletariat and ultimately for the whole working class. The latter, however, cannot freely accept or reject its leadership since no rights of opposition to the ruling party are recognized. To add to this shift in meaning, it should be observed that although the Soviet Union was officially proclaimed to be a socialist society without any classes, it continued to be characterized as a dictatorship of the proletariat. Under such circumstances the term proletariat is emptied of differentiating content and functions more as a sloganizing device than as a precise designation of a social or economic group. Because of these ambiguities, the term must always be interpreted in relation to the specific historical situation and the concrete social context in which it is employed.

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PROLOGUE, a prefatory piece of writing, usually composed to introduce a drama. The Greek πρόλογος, included the modern meaning, but was of wider significance, embracing any kind of preface. In Attic drama, a character, often a deity, stood forward or appeared from a machine before the action of the play began, and made from the empty stage such statements as it was necessary that the audience should hear. It was the custom to explain everything that had led up to the play, the latter being itself, as a rule, merely the catastrophe following on the facts related in the prologue. The importance, therefore, of the prologue in Greek drama was very great. With Euripides, as has been said, it takes the place of "an explanatory first act." On the Latin stage the prologue was often more elaborately written than in Athens, and in the careful composition of the poems which Plautus prefixes to his plays we see what importance he gave to it; sometimes, as in the preface to the *Rudens,* Plautus rises to the height of his genius. Molière revived the Plautine prologue in the introduction to his *Amphitryon:* Racine introduced Piety as the speaker of a prologue to *Esther.* The tradition of the ancients vividly affected our own early dramatists. Not only were the mystery plays and miracles of the middle ages begun by a homily, but when the modern drama was inaugurated the prologue came with it, directly adapted from the ancient practice. Thomas Sackville prepared a sort of prologue in dumb show for his *Gorboduc* of 1562; and he also wrote a famous *Induction* (practically a prologue) to a miscellany of short romantic epics by diverse hands. In the Elizabethan drama the prologue was very far from being universally employed. In the plays of Shakespeare it is rare. After the Restoration, prologues became *de rigueur.* They were always written in rhymed verse, and were generally spoken by a principal actor or actress. *See* also EPILOGUE. (E. G.; E. E. K.)

PROME, a district in the Pegu division of lower Burma, with an area of 2,938 sq.mi. and a pop. (1941) of 436,714. It occupies the breadth of the valley of the Irrawaddy, between Thayetmyo district on the north and Henzada and Tharrawaddy districts on the south, and originally extended to the frontier of independent Burma, but in 1870 Thayetmyo was formed into an independent jurisdiction. There are two mountain ranges forming respectively the eastern and western boundaries. The Arakan Yoma extends along the western side. The portion of the district on the right bank of the Irrawaddy is broken up by thickly wooded spurs running southeastward. Cultivation is confined to the parts adjacent to the river. On the eastern side lies the Pegu Yoma, and north and northeast of the district its forest-covered spurs form numerous valleys and ravines, the torrents from which unite in one large stream, the Na-win. The principal river is the Irrawaddy, which intersects the district from north to south; next in importance are the Tha-ni and its tributaries and the Na-win system of rivers. The district lies on the southern borders of the dry belt and the rainfall ranges from about 35 to 60 in. The staple crop is rice, but cotton and tobacco are grown, while the custard apples are famous. The forests yield teak and cutch.

The early history of the once flourishing kingdom of Prome is veiled in obscurity. After the conquest of Pegu in 1758 by Alompra, the founder of the last dynasty of Ava kings, Prome remained a portion of the Burman kingdom till the close of the second Burmese war in 1853, when the province of Pegu was annexed to British territory.

Prome, the chief town, is on the Irrawaddy, 161 mi. N. of Rangoon, pop. (1931) 28,295. It has a somewhat evil reputation for infectious diseases.

South and southeast the town is closed in by pagoda-topped hills, on one of which stands the conspicuous gilded Shwe Tsandaw. The town was taken by the British in 1825 and in 1852. In 1862 it was almost entirely destroyed by fire. It became a municipality in 1874. Other towns are Shwedaung (pop. 8,408) and Paungdé (pop. 13,479).

PROMETHEUS, son of the Titan Iapetus by the sea nymph Clymene or by Themis (occasionally other parents are named).

He was the friend and benefactor of mankind. He defended men against Zeus, who, according to a widely diffused mythical theory, desired either to destroy the human race and supplant it by a new and better species, or to avenge himself because men had got the better of him. The pedigree and early exploits of Prometheus are given by Hesiod (*Theog.*, 510–616). At a meeting of gods and men at Mecone, it was the business of the assembly to decide what portions of slain animals the gods should receive in sacrifice.

On one side Prometheus arranged the best parts of the ox covered with offal, on the other the bones covered with fat, as the meat was covered in Homeric sacrifices. Zeus, invited to make his choice, chose the fat and found only bones beneath. A similar fable of an original choice, in which the chooser is beguiled by appearance, recurs in Africa and North America. *See* also Ada Thomsen in *Archiv f. Religionswissenschaft*, XII, 460 *et seq.* Zeus, enraged at this trick, according to Hesiod, or, according to other versions, desirous of exterminating the few people who had escaped the deluge of Deucalion, either never bestowed the gift of fire, or later withdrew it. Prometheus stole fire, concealed in a hollow fennel stalk (Hesiod, *Works and Days*); and a fennel stalk is still used in the Greek islands as a means of carrying a light (*cf.* Pliny, *Nat. Hist.*, XIII, 126). According to some legends, he gained the fire by holding a rod close to the sun. Probably the hollow fennel stalk in which fire was carried got its place in myth from the fact of its common use. Prometheus is thus found in the position of the fire bringer, or fire stealer, and so connected with a very wide cycle of similar mythical benefactors, divine, human or bestial, among all sorts of peoples from the Murri of Gippsland[1] to Europeans and Vedic Indians[2].

In considering the whole question of fire mythology, one must beware of the hasty analogical method of reasoning too common among mythologists. For example, when a bird is spoken of as the fire bringer, we need not necessarily conclude that, in each case, the bird means lightning. Again, because a hero is said to have stolen or brought fire, we need not regard that hero as the personification of fire nor explain all his myth as a fire myth. The legend of Prometheus has too often been treated in this fashion, though he is really a culture hero, of whose exploits, such as making men of clay, fire stealing is no more than a single example. This tendency to evolve the whole myth of Prometheus from a belief that he is personified fire, or the fire god, has been intensified by Kuhn's ingenious and plausible etymology of the name Προμηθεύς, which he would connect with Skr. *prāmantha*, a fire stick.

But there is no real reason to reject the classical interpretation, "fore-thinker" (*cf.* his brother Epimetheus, "after-thinker," "wise after the event"), for, as already shown, the myth of the stealing of fire and of the fire stealer is current among races which are not Aryan and never heard the word *prāmantha*.

Prometheus and Hephaestus (*q.v.*) are frequently brought into contact, generally as opponents; in some forms of the legend, Prometheus steals fire from Hephaestus' workshop, not from heaven. It is quite possible that Prometheus was an old and genuinely Greek deity, whose province included fire and its earlier industrial applications, but that he was later superseded by the popular oriental deity. If such were the case, it must have been very early, before either Homer or Hesiod wrote, probably not long after the first coming of the Achaeans to Greece. (A. L.; H. J. R.)

See Preller-Robert I, 91 *et seq.*; L. R. Farnell, *Cults of the Greek States*, v, 378 *et seq.*

PROMETHIUM (symbol Pm, atomic number 61), is often referred to as the missing member of the rare earth series. Considerations, based on the Mosley diagrams and modern theories of atomic structure, indicate that an element should exist with this atomic number, having the properties of the trivalent rare earths. Numerous claims have been made concerning its existence based on new lines observed in the arc spectra of rare earth concentrates or on X-ray lines observed in connection with these concentrates. In 1926 B. S. Hopkins, J. A. Harris and L. F. Yntema were the first definitely to claim the discovery and concentration of this element and offered considerable evidence in support of their claims, based on the arc spectra, the absorption spectra in solution and the X-ray emission spectra. They named the element illinium after the University of Illinois where the work was performed. In the same year J. M. Cork, C. James and H. C. Fogg claimed its independent discovery and measured its X-ray spectra. L. Rolla and L. Fernandez claimed priority in this discovery and named the element florentium. This element is definitely known to occur among the fission products of plutonium, thorium and uranium and considerable quantities (grams) are known to exist in the residues from the atomic chain reacting piles built during World War II. In 1947 J. A. Marinsky, L. E. Glendenin and C. E. Coryell first isolated element 61 from atomic reactor residues. Later it was claimed that the absorption spectra and arc spectra of element 61 isolated from the uranium chain reactions are different from the spectra of that element as claimed by Hopkins. As a result of these claims, the International Union of Chemistry accepted the name promethium for this element, as suggested by Glendenin and Marinsky, instead of illinium as suggested by Hopkins. Controversy continued as to whether nonradioactive element 61 existed. Evidence indicated that if it did exist naturally it must be present in nature in very minute quantities. (*See* Rare Earths.) (F. H. Sp.)

PROMISSORY NOTE: *see* Bill of Exchange.

PROMOTER: *see* Company Promotion.

PRONAOS, in architecture, the porch, portico or colonnade in front of the *naos*, *cella* or enclosed portion of a classic temple.

PRONGHORN or **PRONGBUCK,** the sole existing representative of a family (Antilocapridae), intermediate between deer and cattle; the forked horns resemble those of the latter group, but are annually shed and renewed. Standing about 3 ft. high at the shoulder, the male pronghorn has the black horns rising vertically above the eyes. The colour is bright sandy fawn, with much white on the face, three white bars on the throat and white under parts and buttocks. The long white hair on the buttocks can be erected and expanded into bunches, these being guides to the herd when in flight. The tail is short. Female pronghorns produce one or two young at a birth, and are either hornless or furnished with more or less rudimentary horns. Pronghorns (*Antilocapra americana*) are among the swiftest running mammals. They inhabit the open plains of the temperate districts of western North America, where they were formerly abundant.

PRONUNCIATION. By means of his organs of speech man has at his disposal, for the purpose of speech, certain devices. He can make a great variety of sounds, and, subject to the limitations imposed upon him by the physical structure of his speech apparatus, he is able to modify these sounds in certain ways:

(1) He can modify the length of time during which a sound persists.

(2) He can modify the degree of physical energy devoted to the production of a sound.

(3) He can, in the case of sounds that involve a periodic vibration of the vocal cords, regulate the periodicity of this vibration so as to produce varieties of pitch.

These modifications of length, stress and pitch may serve different purposes, or may be used in various combinations.

Nature.—The spoken variety of a language consists of a certain number of sounds, influenced by the three modifications outlined above. These features, in the case of any given spoken language, constitute what may be termed the acoustic matter of the language, and the reproduction of these acoustic features by a speaker is what is known as a pronunciation of the language. The term "pronunciation" is used to denote the general acoustic features of a language; thus we speak of English pronunciation,

[1] *See* Brough Smith with Howitt, *Native Tribes of South-east Australia, Aborigines of Victoria;* Kuhn on bird fire-bringer in Isle of Man, *Die Herabkunft des Feuers*, p. 109; Van Gennep, *Mythes et légendes d'Australie.*

[2] *Cf.* Bergaigne, *La Religion védique*, i, 52–56 and Kuhn's *Herabkunft;* and *see* the essays by Steinthal in appendix to English version of Goldziher's *Mythology among the Hebrews.*

or the pronunciation of Marathi. It is also used to denote the particular variety of acoustic phenomena used by an individual speaker, or by a particular section of a community; thus we may speak of disliking a man's pronunciation, or of liking the pronunciation of a certain district or social class.

Analysis of Pronunciation.—Detailed analysis of the pronunciation of individual speakers is the foundation of knowledge of the pronunciation of languages and dialects, and those whose business it is to carry out such analysis should so train themselves that they can give reliable and accurate information upon all the aspects outlined above. Sounds must be described in detail, and the modifications, their function and distribution must be noted. Such detailed description of pronunciation is necessary for:

(1) The study and teaching of the mother tongue, and of foreign languages.

(2) The devising of scientific systems of orthography for hitherto unrecorded languages.

(3) Comparative philological work.

(4) Pronouncing dictionaries.

Pronunciation and Language.—A spoken language persists as a language so long, and only so long, as those who speak it pronounce it in such a way as to be readily intelligible among themselves throughout the area in which the language is spoken. Local variants, or fashions of pronouncing, arise in proportion to the extent of the territory over which the language is spread, but so long as those who use these local variants are conscious that they are in the main using the same language, and provided that they continue to use the written language common to the rest of their compatriots, their speech will be regarded as a variant, a dialect, of the main language.

If, for political or other reasons, any one group of dialect speakers desires a linguistic tradition of its own, and proposes to make a new written form of its pronunciation, embodying a new and local vocabulary, then the seed of a new language is sown. In the past, whenever a language has, through the political expansion of a nation, spread over an area larger than that which gave it birth, disintegration has set in, beginning with divergence of pronunciation, ending with the establishment of new languages. Thus Sanskrit has given birth to the Aryan languages of India—Hindi, Bengali, Marathi, Gujarati, etc.; Latin has given us Italian, Spanish, French, Portuguese and Rumanian.

Pronunciation and Nationality.—Speech habits, among which must be included habits of pronunciation, differ from language to language. There is, however, a certain measure of similarity between the pronunciation of the various languages of a language family; and the language families of the world differ among themselves as considerably in the matter of pronunciation as in any other respect. The clicks of the Hottentot Bushman languages are found only in certain of the Bantu languages. The cerebral consonants of the Aryan and Dravidian languages of India are seldom found in other language families. When a language takes over words from another language and embodies what are called foreign words, the pronunciation of such words will be made to fit in with the general scheme of pronunciation of the borrowing language. French words taken into English will receive English sounds, English rhythm, English stress and English intonation. The very considerable Arabic element in Persian is pronounced in the Persian way, for the pronunciation system of Persian has nothing in common with that of Arabic. So European words are squeezed into Japanese moulds.

It very seldom happens that a language will adopt exotic sounds, or embody in its system sounds other than those which are its linguistic heritage. Instances of this, however, do happen. The cerebral consonants of the Indo-Aryan languages, which are uncommon in the rest of the world, are presumed to have been taken over from the Dravidians. The Arabic ق is preserved in educated Urdu, but in southern Urdu colloquial is replaced by χ (the sound of "ch" in "loch"), and in Persian, except in the case of speakers who are influenced by a knowledge of Arabic, it is generally replaced by ɣ (the sound of Arabic غ).

Representation of Pronunciation.—Among a civilized community, language consists of two forms—a series of sounds, and a series of visual symbols, or letters, representing sounds. This method of making a visual language is known as a phonetic method of writing, and the system of symbols used is known as an alphabet.

On the other hand the visual language may be made without any apparent reference to the pronunciation of the oral language. Such a system is known as an ideographic system.

Most of the languages of the world have a phonetic visual form, the important exception being Chinese. The most widely used alphabets are the Roman, the Arabic and the Indian, each with certain additions and modifications. The Arabic alphabet, for instance, is made to represent such widely diverse phonetic systems as those of Arabic, Malay, Hausa, Persian, Urdu and, until recently, Turkish.

So it has come about that alphabets, designed to represent the pronunciation of specific languages spoken many centuries ago, have spread over the modern world and are used to express the pronunciation of many languages that have nothing in common with the pronunciation systems for which they were designed.

Since, as has been said, sight and sound are irreconcilable, it follows that any attempt to represent by means of visual symbols things that have no visual existence will be at best but partially successful, and will rest upon a variety of conventions. Each symbol will originally do duty for one "sound"; various devices may be employed to indicate the relative length of sounds, if it is felt desirable to denote this feature of the pronunciation; the position of what is known as the stress or accent may, or may not, be marked; it may be evident from other data. The intonation is not as a rule indicated, but there are certain devices, such as punctuation marks, interrogation and exclamation marks, and the use of a form of type differing from the rest, which are conventionally associated with certain features of the intonation.

The phonetic medium, although evidently the most expedient, is a clumsy one for the general purpose of representing language, but it is the only one for representing pronunciation. The world's great alphabets are, as is seen, in reality obsolete, because each was designed to represent the pronunciation of one language many centuries ago. When extended to other languages they have proved either inadequate or redundant. The Roman alphabet, suitable for a language such as Latin with its simple system of five vowel sounds, is completely inadequate for English with its twelve vowel sounds. The Arabic alphabet, designed for the peculiar word formation of Arabic, with its scanty vowels and abundant consonants, is inadequate for the Persian vowel system, and redundant for the Persian consonant system. Similarly the Devanagari alphabet proves inadequate to represent the pronunciation of the modern Indian vernaculars.

When, for various reasons, the visual language is a poor representation of the existing state of the pronunciation of a language, the language is commonly said to be unphonetic. This means that there is an absence of regularity in the conventional relationship between sound and symbol, which may be due to the unsuitability of the alphabet, or to the fact that the visual language, having become established in popular use at some distant period, has refused to register the phonetic changes that have taken place since. Attempts to readjust the relationship between spelling and pronunciation are usually vigorously resisted in all languages, there being a universal desire, apparently, to see in the historical form of the visual language something either sacred, as in the case of Arabic, or etymologically valuable, as in the case of English. In some parts of the English-speaking world tentative attempts at this readjustment, which is known as spelling reform, are being made.

Where, as in the case of many African languages, no traditional visual languages exist, systems of writing, usually with the Roman alphabet, less frequently with the Arabic alphabet, have been designed; but there again the inadequacy of the alphabets has proved a serious obstacle. The sound systems of the great African language families have nothing in common with the sound systems of Europe, and little in common with one another. It is interest-

ing to note that there a special alphabet has been designed, based largely on the Roman, suitable for the representation of the pronunciation of the principal African languages.

To remedy the deficiency of traditional alphabets, many more detailed and adequate visual systems have been designed for the representation of pronunciation. These are of four classes:

(1) Based on no existing visual forms; *e.g.*, the Bell-Sweet system.
(2) Based on a code; *e.g.*, Jespersen's Analphabetic system.
(3) Based on existing Roman letters with abundant diacritical marks; *e.g.*, the Lepsius alphabet.
(4) Based on existing Roman signs, but using new letters instead of diacritical marks; *e.g.*, the International Phonetic Association alphabet.

One or other of these systems must be used when it is desired to describe a pronunciation in detail, as in pronouncing dictionaries, descriptions of languages, and in comparative philological works.

Phonetically there is little to choose between these systems, but recent investigation into their comparative merits would appear, upon psychological, pedagogical and typographical evidence, to favour alphabets of the fourth class.

Influence of Spelling upon Pronunciation.—There is observed, in the case of highly civilized and educated communities, where the majority of the speakers are familiar with the visual language, a very marked influence exerted by the visual language upon the pronunciation. The visual language, which was originally designed to represent the pronunciation and to be subservient to it, tends to become the criterion of accuracy and to dominate the pronunciation.

As familiarity with the visual language increases, so a new standard of accuracy in pronunciation arises, namely, the printed word. This is very evident from a consideration of the pronunciation of English place names. Historical pronunciations are being abandoned in favour of pronunciations more in keeping with the visual forms which became familiar only with the advent of postal and railway communication. Daventry is now pronounced as written, though a local pronunciation, Daintry, existed for centuries. It is interesting to record these old pronunciations, but it is doubtful whether they can now be restored to general use. If Daintry is to be admitted at the expense of Daventry, then "ain't" must be given preference to "haven't," for the principle that governs the disappearance of the medial "v" is the same in both cases. The influence of the visual upon the spoken language is likely to be a prominent feature in determining the future pronunciation of language.

Standards of Pronunciation.—The impression that one form of pronunciation is better than all others appears to be common in the languages of most civilized communities; it is found even in the case of those African languages that have never been written. The prestige of this form of pronunciation varies from language to language, and the degree of adverse criticism levelled at those who do not use it varies from country to country. It is by no means certain that there is now, or that there has ever been at any time in any language, with the possible exception of classical Arabic, what is popularly called a standard pronunciation; but it is quite evident that the desire for such a criterion is widespread.

The greater the territorial extent of the nation, the greater will be the number of metropolitan centres; the more organized and complex the social life, the greater will be the number of social classes, each with its own conventions of pronunciation. Where, as in the case of English, separate nationalities, at different ends of the earth, speak the same language, there will tend to grow up in each centre of national life a different ideal as to what is considered the most desirable pronunciation. There is no more evident manifestation of national entity than a national language, and a new national language will begin when any one of the national groups of the English-speaking world desires to establish a national standard of pronunciation at variance with that in vogue in the geographical area where the language was born. History tends to teach that disintegration was inevitable in the conditions that prevailed in the past; it may be checked by increased oral communication, increased intermingling of population, but most of all by the definite teaching throughout the area of *one* form of pronunciation. This teaching has preserved the entity of classical Arabic; it has not prevented the disintegration of the Arabic into the various colloquial pronunciations that prevail in the different parts of the Arabic-speaking world.

In England there are local variants and class variants of pronunciation. The higher we ascend the social scale in all districts, the greater the uniformity in the pronunciation. The uniformity of the educational system—public school and university—of certain social classes leads to a uniformity in the pronunciation of those classes. This type, provided it is free from pedantry and affectation, is generally regarded as the nearest approach to a standard pronunciation of southern English. It is the style of pronunciation heard most often in public speech, in parliament, in the church, in the law courts, in the universities and the public schools, and in such of the state schools as recruit their teaching staff from the ranks of those who use this style of pronunciation. In detail it may differ slightly from county to county, from school to school, from speaker to speaker, but in the main it is recognizable as one pronunciation. Those who use it have approximately the same vowels; its rhythm is the same wherever it is heard; its intonation follows the same general principle; it uses the same means to achieve the effects of emphasis; and it is characterized, among other things, by a peculiar treatment of the "r" sound. In most of these respects southern pronunciation differs from what is known as northern pronunciation, and in all of them it differs from U.S. and Canadian pronunciations which have their own vowels, their own rhythm, their own intonations, their own distinctive treatment of the "r" sound, which reacts in no uncertain manner upon their vowel systems. The U.S. and Canada have their own pronunciation problems, for their enormous geographical extent is giving rise to local varieties and localized standards. There is no standard pronunciation of English in these countries, any more than there is in Great Britain. The increased use of intercontinental oral communication by means of telephone and wireless broadcasting, the interchange of teachers and actors, and the use of the speaking film, *may* tend toward a certain degree of uniformity in the pronunciation of the English-speaking world, but these must be supported by definite action on the part of those responsible in all countries for the teaching of the mother tongue. It is agreed that a uniform pronunciation of English is desirable, but it is by no means certain how it is to be brought about.

In 1926 the British Broadcasting corporation set up an advisory committee to deal with doubtful questions of English pronunciation, and to settle, in the case of (1) unfamiliar words, (2) words having alternative pronunciation of equal currency and authority, (3) foreign words, upon one pronunciation to be used by the official speakers of the corporation. The first list of this committee's recommendations was published in 1928.

Change of Pronunciation.—The study of language reveals an inability, on the part of pronunciation, to persist unchanged in any given place or community over a long period of time. The universal law is change; during their lifetime languages change slowly, imperceptibly, but nevertheless surely. It is not possible to assign any adequate reason for this universal and eternal change. It is possible that the change has its origin in man's physical and mental limitations. The link that holds the speech of one generation to that of the next is but a feeble one; speech persists as a series of recollected auditory images, associated with certain kinesthetic movements, which are however of secondary importance as far as the speaker is concerned. He is more concerned with the expression of his thought than with the physical adjustments by means of which his thought receives audible expression. This combined mental and physical process appears to produce upon the mind of the listener impressions of a fugitive character, which are less durable than the impressions created by the combined visual and physical processes involved in the visual language. Speech, as such, perishes instantaneously, having no permanent existence, being handed on

by oral tradition, and suffering during the centuries like all else that lives only by word of mouth. So pronunciation changes from age to age, partly because it hangs on so fragile a thread as man's aural memory, and partly because the unconscious physical processes that give rise to the sounds in themselves suffer modification owing to the lack of consciousness with which they are controlled.

"Pottage" and "porridge" are now different words. They are in reality but two pronunciations of the same word, and the curious story of their separate existence can still be learned by listening to the bus conductor who announces Swiss Cottage as Swiss "Corridge." It is probable that wider study will tend to establish the fact that a given speech sound, under given conditions, will always change in a certain way. But it must not be forgotten that it has hitherto proved impossible to define what is meant by the term "speech sound," and it should be remembered that the governing conditions are likely to prove more complicated than they appear upon examination of cases that have happened in the past. The principles governing the change in vowel sounds, the formation of which involves no tactile sensation in the mouth, appear to have nothing in common with the principles governing the change of consonant sounds, in the formation of which there is definite contact between two parts of the mouth, or enough constriction to give an impression of contact.

Teaching of Pronunciation.—The study of the mother tongue, and of foreign languages, if it is to be sound, must rest upon a knowledge of pronunciation, which lies at the root of things so widely apart as sentence structure, syntax, rhythm and systems of versification.

The teaching of pronunciation requires, on the part of the teacher, training of a highly specialized order, and it should not be considered that a teacher is competent to teach the pronunciation of a language merely because that language happens to be his mother tongue. We are all, without special training, unaware of the various features that constitute the pronunciation of our language; we become conscious that there is a highly complicated system underlying our pronunciation only when we hear the system disturbed by foreigners who speak our language badly; *i.e.*, with the pronunciation system of their own.

The pronunciation of most European languages has been studied on modern phonetic lines, and there is an abundance of reliable literature on the subject. Research into the phonetic structure of American, Asiatic and African languages is proceeding, and reference libraries of gramophone records of languages and dialects are being established in many universities.

Pronunciation of the mother tongue is taught in the principal centres of education in the countries of Europe and America. It has already been stated that the traditional pronunciation of Arabic, reputed to have been that used by Mohammed, is still regularly taught throughout the Mohammedan world.

In Europe there is, in the case of French, a traditional stage pronunciation taught at the Conservatoire in Paris, and used in the state theatres and opera house. In Germany an attempt has been made to standardize a form of German pronunciation suitable for the theatre throughout German-speaking countries.

No such attempt at standardization has been made in England or America. As far as England is concerned, the pronunciation current upon the stage is that used by the educated people in the southeastern part of the country.

This pronunciation, with, however, a certain degree of latitude, is taught in England for use on the stage, in public speaking, and in singing. In the universities and public schools of England the pronunciation is left to look after itself, but there is a strong tradition as to what is and what is not permissible.

In the state schools there appears to be an awakening to the importance of equipping children with a form of pronunciation that will not prove a handicap in social life; and endeavours are being made to provide instruction.

Conclusion.—It is difficult to forecast the future, for we are faced with a new set of conditions. Increased speed of transport has made the world smaller; the complication of modern life leads to an international vocabulary; increased travel and increased oral communication familiarize us with hitherto unfamiliar pronunciations; the increase of education familiarizes millions with visual language, while wireless broadcasting tends to make the inhabitants of a widely spread linguistic area acquainted with a selected form of pronunciation. It is possible that these combined forces may tend to prevent linguistic disintegration of the principal languages of the modern world. (A. Ll.-J.)

PROOF, that which establishes the truth of a fact or the belief in the truth (*see* Logic). In law, proof is the establishment of the facts in issue in a particular case, by proper legal means, to the satisfaction of the court (*see* Evidence); specifically, documents so attested as to form legal evidence, written copies of what a witness is prepared to support on oath, and the evidence of any case in the court records are all termed proofs. In Scots law the term is used of a trial before a judge alone as opposed to trial by jury. A trial impression, in printing, on which corrections and additions can be made (*see* Proofreading) and, in engraving and etching, one of a limited number of impressions made before the ordinary issue is printed, are known as proofs. In the earlier history of engraving a proof was an impression during the process of printing made for the artist's inspection. In the modern use of the term, where the impression has been taken before the inscription has been added to the plate, it is called a proof before letter.

PROOFREADING, the process of correcting for the press the printed proofs of articles or books or other matter before publication. Signs commonly used in proofreading follow:

Delete	Em dash
Delete and close up	En dash
Reverse	Insert semicolon
Close up	Insert colon and en quad
Insert space	Insert period and en quad
Paragraph	Insert interrogation point
Indent one em	Query to author
Move to left	Use ligature
Move to right	Spell out
Lower	Transpose
Elevate	Wrong font
Insert marginal addition	Set in **bold face** type
Even space	Set in (roman) type
Broken letter	Set in *italic* type
Push down space	Set in CAPITALS
Straighten line	Set in SMALL CAPITALS
Align type	Set in lower case
Insert comma	Lower-case letter
Insert apostrophe	Let it stand
Insert quotes	Run in same paragraph
Hyphen	Insert lead between lines

PROOF SPIRIT. The term is applied to standard mixtures of ethyl alcohol and water which form the basis of customs and excise duties in Britain, U.S. and elsewhere. A distilled liquor was originally defined as proof spirit if, when poured over gunpowder and lighted, it would burn and finally ignite the powder. If the alcohol content is less than 49.3% by weight, the water left after the burning of the alcohol is sufficient to prevent ignition of the powder.

In the United States proof spirit is held to be that alcoholic

liquor which contains one half its volume of alcohol of a specific gravity of 0.7939 at 60° F., referred to water at 60° F. as unity (*Gauging Manual,* U.S. treasury department). Proof spirit has, at 60° F., a specific gravity of 0.93426 (*in vacuo*) 100 parts by volume of the same consisting of 50 parts of absolute alcohol and 53.73 parts of water. The difference of the sum of the parts of alcohol and water and the resulting 100 parts of proof spirit is caused by the contraction which takes place when alcohol and water are mixed. The specially designed hydrometers used in determining the alcoholic strength of aqueous solutions are so graduated as to indicate the number of parts by volume of proof spirit equivalent to 100 parts of liquor at the standard temperature of 60° F.; and they read 0 for water, 100 for proof spirit and 200 for absolute alcohol.

In Great Britain the Spirits act of 1816, legalizing Sikes' hydrometer for revenue purposes, gave for the first time a legal definition of proof spirit as follows: "that which at the temperature of 51° F. weighs exactly $\frac{12}{13}$ of an equal measure of distilled water." Unfortunately, the act did not specify the water temperature thereby giving rise to considerable controversy. Subsequently, documentary evidence was produced which established that the temperature of the water was intended to be 51° F. Later investigation established the fact that at 60° F. proof spirit has a specific gravity of 0.91976, compared with water at the same temperature, and that it contains 49.28% by weight or 57.10% by volume of ethyl alcohol.

Spirits at strengths other than proof may be described as containing a percentage of proof spirit or as being overproof or underproof. The percentage of proof spirit is that number of volumes of proof spirit which can be obtained from 100 volumes of the mixture. Thus at 50° F., 100 volumes of absolute alcohol if diluted with water to proof strength give 175.35 volumes. It is therefore said to contain 175.35% proof spirit or to have a strength of 75.35% overproof.

In the Dutch system, proof spirit contains 50% of anhydrous alcohol at 15° C. (59° F.). (D. G. Z.)

PROPAGANDA is the making of deliberately one-sided statements to a mass audience. It is an act of advocacy in mass communication. Although the fact of propaganda is old, the term is comparatively modern. Usage was affected when the organization set up in 1622 by the Roman Catholic Church to carry on foreign missionary propaganda was called the College for the Propagation of the Faith.

In order to reach the mass audience, propagandists rely upon every medium of communication—oral, printed, pictorial, plastic, musical or dramatic. Every new channel is promptly laid hold of. When the art of printing from movable type appeared in Europe, the printed word began at once to overtake oral media as the preferred means of persuasion. In the 20th century the motion picture, radio and television helped restore the spoken word to its former eminent position.

Communication effects are sometimes obtained with the aid of physical devices which are not usually employed for the purpose. The act of killing is no ordinary method of communication, yet killing is spoken of as "propaganda of the deed" when political assassinations are carried out as a means of affecting attitudes. Since any act of policy may influence mass opinion regardless of the means employed, an important part of total policy is the calculating and managing of psychological impacts. The most comprehensive term is "propaganda" or "communication" policy. When directed against an enemy in wartime, this is "psychological" or "propaganda" warfare.

Propaganda as an act of advocacy is distinguished from such closely allied uses of communication as instruction, information and inquiry. It is advocacy to editorialize or to select the content of channels of communication for the purpose of influencing attitudes on controversial issues. When the government distributes a pamphlet on the care and feeding of babies, the act is informative and instructive, not propagandistic, unless there is doubt about the authenticity of what is said, or the desirability of babies is in debate. It is inquiry, not propaganda, to analyze controversial doctrines for the sake of sharing enlightenment. Private arguments among intimates are not spoken of as propaganda unless they are part of a campaign to spread controversial viewpoints, which indeed they often are. The mass audience with which the propagandist is ultimately concerned is not only characterized by size, but by the relative impersonality and shallowness of the tie that exists between the communicator and his audience.

Determiners of Propaganda.—The study, as well as the practice, of propaganda has a long history. The use of mass means of communication for military purposes was advised in *The Book of War* in the 5th century B.C. Sun-tzu wrote that "In night fighting beacons and drums are largely used; in day fighting, a great number of banners and flags, and the enemy's eyes and ears are confounded." In the East Indian classic of statecraft, Kautilya's *Arthaśāstra,* it is noted that "Astrologers and other followers of the king should infuse spirit into the army by pointing out the impregnable nature of the array of his army." Secret agents should circulate among the enemy, spreading rumours of their certain defeat.

From Graeco-Roman times are inherited manuals on how to win an argument and even how to win an election. The literature of propaganda has manuals on converting the heathen, indoctrinating the young, instigating subversion, preventing subversion, obtaining gifts and making sales. Indeed, there are few purposes for which there is no book of know-how.

Despite these practical guidebooks, it was only in comparatively modern times that scholars and scientists began to assess the place of mass persuasion in the social process. Many incentives for propaganda activity are known. Leaders of political and social revolutions often see that they can save soldiers and money by using symbols to induce obedience to a new regime. The foundation was laid for large and enduring empires when conquerors learned to convert rather than exterminate the conquered. The fifth-column technique of penetrating a state with political propaganda was probably the result of observing the successful missionary operations of the great proselyting religions of Buddhism, Zoroastrianism, Christianity and Mohammedanism.

Propaganda is a favoured instrument in the hands of political oppositionists, since it is both elusive and cheap. The unification of Germany, Italy, and of every modern state was preceded and accompanied by the fervent promotion of national sentiment, often by persecuted minorities. The propagandas of social revolution developed modern methods of persuasion to the highest pitch, working especially through party and auxiliary organizations.

Nonpolitical movements depend upon propaganda to induce hostile authorities to refrain from interfering with them. A movement is nonpolitical when it disclaims any intention of changing the institutions of power and favours rendering unto Caesar that which is Caesar's. All movements have consequences, however, which in some degree affect the internal and external balance of power, regardless of conscious purpose. The holders of power, sensing the degree to which all social processes are linked together, often persecute minority movements or try to manipulate them for political ends. Nevertheless, propaganda has sometimes been effective in staving off political intervention, especially when the propaganda appeal is made in the name of natural or divine law.

It is no surprise to discover that incentives to engage in propaganda decline when hopes are frustrated. Labour movements have gone through periods of revulsion against "mere talk" in favour of "strictly economic" methods or even terror.

Perhaps the greatest incentives for propaganda in the 20th century have been economic and connected with the growth of industrialism. Advertising fanned the spirit of speculation which fed the reservoirs of capital upon which the expansion of commerce and industry depended. Since the advantages of large-scale production could be realized by the successful stimulation of consumer demand, advertising trained hundreds of millions of buyers to change their tastes in clothes, interior decoration, personal adornment, cooking and amusement.

The use of mass persuasion was furthered by the spread of

literacy and of education generally, and by the enormous growth of mass media. In free countries the media generate special interests of their own in propaganda, since controversy makes circulation and circulation boosts revenue from advertising.

The volume of propaganda is affected by whatever discredits the old or reduces the difficulty of acting in new ways. In the United States arose a "culture pattern of novelty," with great zest for the new gadgets turned off the assembly lines of industry. In order to reduce the difficulties connected with acquiring something new, simplified designs appear continually on the market. Consumer credit, liberal allowances on trade-ins and related practices are examples of ways invented to ease the path of the purchaser.

Of significance to propaganda is the sheer size and heterogeneity of a population. Even in totalitarian states a vast labour of internal persuasion is essential to overcome the bonds of attachment to the old, or the sentiments of fear, hatred and confusion at the prospect of a new way of life. In soviet Russia (after 1921) the full orchestra of poster, broadcast and lecture was mobilized in a series of gigantic campaigns on behalf of literacy, proper care of tractors and elementary habits of personal hygiene. Glacierlike resistance was thawed by the blowtorch of symbols supported by every other influence.

The most general conclusion about propaganda is that it increases whenever the equilibrium of society is threatened or upset, and decreases with the restoration of the imperilled equilibrium or with the emergence of a new level of adjustment. This hypothesis needs to be more specific in order to account for the use of propaganda, rather than coercion, when social equilibrium is endangered. In addition, the likelihood of propaganda is increased whenever there are traditional institutions of freedom, whether free government, free market, free education or free religious proselyting.

Summing up in another way, it can be said that during any given period the volume of propaganda activity depends upon such factors as: the intensity of the determination on the part of propagandists to introduce or to discourage new acts; the availability of mass media and the prevailing level of literacy and general education; the degree of discontent with the old and the difficulty of the new; the number of persons asked to perform or to refrain from performing a new act; and the depth of devotion to persuasion in place of coercion. Whatever arouses controversy is likely to foster propaganda until the incentives which sustain the use of mass persuasion are reduced and rival methods of social action are tried; or discontent is dissipated without result (that is, catharsis occurs); or a new positive adjustment is made in prevailing social practice.

Strategy.—The proper strategy of propaganda depends upon the over-all frame of policy and the circumstances which favour or stand in the way of success. The overriding aims of policy range from the comprehensive reconstruction of society to local and immediate matters, and from complete reliance upon persuasion to the ultimate elimination of propaganda.

When a comprehensive plan of social change is pursued by peaceful means, a major problem of strategic planning is whether to expedite success by making concessions of detail. At one time in China the Jesuits dressed like native scholars as a means of modifying the strangeness of the Christian mode of living. The pope decided to forego immediate advantages and put a stop to these practices. In the absence of unified command, Marxian Socialists split into many branches over the nature and timing of revisions. Leading revisionists softened or abandoned the doctrine of violent class struggle and entered electoral or cabinet coalitions.

A related question of strategy is how far to concentrate upon the teaching and preaching of doctrine, and how far to go in using auxiliary appeals. Lenin insisted upon the necessity of propaganda, which he defined as indoctrination, and also of agitation, which meant the exploitation of concrete grievances. In foreign missionary work, auxiliary activities became standard means of providing an indirect approach to prospective converts. Buddhist missions always encourage charity, but it is reported that in China the translation of the Buddhist canon played a more important part than good works, since the translation aroused the curiosity of the scholar class. On a humbler level, it is known that it has long been established commercial practice to supplement the verbal appeal of advertising with "giveaways" and prizes.

Sometimes the task of propaganda is to prepare the way for activities which, if fully disclosed in advance, would unquestionably fail. Before the seizure of power in Germany, the National Socialist strategy was to prevent a combination of Socialists, Communists and conservatives which would have stalled their advance. Once the National Socialists were in power, the problem was transferred to the arena of world politics and became that of forestalling joint action by west and east while the country rearmed, occupied the Rhineland, absorbed Austria, partitioned Czechoslovakia and began war against Poland. After the break with Russia, the major strategic aim was to pry apart east and west in order to escape from two-front war. Historians of the American propaganda of secession and independence from Britain, such as Evarts Greene, commented upon the skill of the leadership in carrying along many moderate persons who, though not desiring independence, had co-operated with the radicals to such an extent that they could not effectively withdraw.

The correlation of propaganda inside the frame of totalitarian policy involves many fundamental and, at first sight, paradoxical problems. One long-run objective of totalitarian policy is the substitution of ritual and ceremony for discussion and persuasion, hence of propaganda. A totalitarian state is a command state that swallows the whole of society. The task of managing the media of communication under such conditions is to foster a world of fantasy wherein the hero at the top of the pyramid is the champion of all against the encircling forces of evil which, though powerful, cannot ultimately prevail. The propagandist does not use current happenings for news and comment, but for sermons and fables adorning the dogma as infallibly interpreted by the ruling machine. Since commands from above allow no answering criticism from beneath, healthy self-assertion is repressed or turned against the lower strata or the outside world. In such a garrison-police state leaders live in perpetual anxiety of losing control and require the reassuring balm of ritual adulation. All this is in vivid contrast to the operation of a free society which revels in the clash of news and views.

Tactics.—The tactical problems of the propagandist are to adapt the situation to the limits imposed by strategy. This implies that some policies, persons, groups and institutions must be presented in a favourable light, while others are put at a disadvantage. Appropriate audiences and channels must be chosen to obtain the desired effects. An organization capable of the degree of devotion and expertness called for by the objectives sought must be assembled. The choices open to the tactician are ultimately to disseminate, to withhold or to modify a statement; to use, omit or block a channel; to select or reject a person.

In deciding what to disseminate, the perspectives of the audience must be given careful consideration. These perspectives consist in conceptions of the self and in cherished demands and expectations. Perspectives can be conveniently classified according to culture, class, crisis and personality. Assume that the tactical problem is to induce as many surrenders as possible from among enemy soldiers and officers. The propagandist will take note if enemy culture has long inculcated the ideal of military honour. He will try to discover whether there are circumstances in which the enemy admits that it is honourable to give up. Let us suppose that the answer is "yes, when no military purpose can be served by resistance," and "when an authoritative procedure is laid down" for members of the armed forces. The propagandist therefore circulates statements to the effect that further resistance has no military sense. He will also provide an authoritative-appearing directive to be obeyed. For use among the Germans in World War II, a "safe conduct" pass was developed which was a surrender leaflet printed in an official shade of green ink, with parallel translations in three languages and signed by the supreme commander. The propaganda tactician took class differences into account by working out special ways of addressing officers and men on programs. It was also recognized that the youth of Germany had grown up in a crisis period in which their values and loyalties had been given special shape. Appeals were therefore aimed at different age levels in the German army. Personality differences were considered on the theory that the older army leaders were less ruthless types than the fanatical youth.

In deciding what to withhold, the perspectives of the audience continue to be crucially important to the tactician. In World War II it was generally understood that German audiences were wary of being "deceived once more" by Allied statesmen, and that they were on guard against propaganda. British and U.S. propagandists decided to take the long road of winning confidence through accurate reporting. The plan was to win the "battle of credibility" by adhering to the truth, especially by playing up statements which the audience could directly verify. As a result of studying what the audience of a totalitarian country could believe, true statements were often toned down, not to deceive, but to sound plausible. Military successes, weapon production, food supplies and quantities of equipment were sometimes understated in order to carry conviction.

In deciding whether to remain silent or to reply in response to an accusation, it is essential to bear in mind that the pattern of conduct deemed appropriate for an honourable man differs widely. In some upper class circles only statements by a class equal are taken with enough seriousness to warrant reply. Sometimes the honourable man is expected to display the utmost indignation in denying accusations. Elsewhere the badge of innocence is calmness. In many cases it is difficult to judge how much influence an adverse whispering campaign can have. When Pres. Woodrow Wilson was the target of a campaign against his character, he declined to take any notice of it on the ground that it was false and that all who knew him understood it was false. He thought that he would give more currency and dignity to the "smear" by replying in public than by keeping silent.

So far as facts are concerned, it is generally agreed that some facts cannot be successfully concealed from an audience. Hence it does less damage to release bad news promptly than to appear both unreliable and inefficient. Railroads learned to release news of accidents and air lines followed suit. Often there are facts which are extremely disagreeable to both sides if disclosed. In bitter controversies it is customary for propagandists to obtain from intelligence services material which can be used privately to intimidate an adversary from spreading material that stigmatizes one's own candidate or cause.

Innumerable devices are at the command of the working propagandist for nullifying statements. Thus a Russian spokesman re-

marked that the nazis had created a new category of war casualty, the "slightly killed." Wit, humour, calmness, the casting of doubt upon sources, the combining of favourable and unfavourable news, and the playing down of unfavourable statements are standard ways of modifying adverse references. Also there are ample means of inflating favourable statements by emphasis and elaboration.

A continuing tactical problem is how much to praise the self and to condemn rivals or enemies. Commercial competitors for the same large market usually refrain from attacking one another on the theory that doubt is cast upon the type as well as the brand of product. Unlike business propaganda, it is characteristic of political propaganda to present politics as a drama in which the forces of good and evil stand opposed to one another. Revolutionary or urgent reform movements commonly try to induce a sense of guilt among opponents and self-righteousness among adherents. This tactic may succeed in provoking conflicts of conscience, since agreed value standards are applied to the disadvantage of the old and the advantage of the new.

In selecting media the propagandist keeps in mind considerations similar to those which apply to the choice of statements. If the problem is to win the support of the rich, powerful and wellborn, favourable mention in organs which they look down upon is no asset. If the aim is to win confidence among the masses, the task is to enlist the leaders and media which they trust.

In the choice of media time considerations are important, since if aims can be accomplished over long periods the more permanent media, such as scholarly books, magazines and schools, have a significant role. If the goals are short run, the tactician must adapt to the existing network and employ fast rather than slow media.

The audience of a going channel has selected itself on the basis of predispositions which cannot be disregarded. During World War II, U.S. broadcasters to Germany quickly learned that crisis audiences differ from other kinds. Clandestine listeners who had risked their lives to hear news and comment from the outside world were furious when they tuned in on entertainment.

In the choice of personnel for propaganda work, one question is when is it a good thing to be emotionally involved. The history of propagandas of religion and revolution make it clear that dangerous propagandas need to be in devoted hands. Where less sacrificial considerations are at stake professional talent can be employed in the same way that a lawyer takes over the claims of a client, not because the claim is right but because the client has a right to be heard.

The 20th century has been notable for the rapid application of the social and psychological sciences to the problems of propaganda technique. It is standard operating procedure to pretest posters, labels, slogans and other details before they are brought to the notice of the eventual audience. A pretest uses a small group which is representative of the large audience which it is planned ultimately to reach. Posttests are utilized in the hope of evaluating the effectiveness of propaganda messages or channels. These tests are of the utmost diversity. They may be based on brief or prolonged interviews, upon the participant observation of behaviour, upon the analysis of a wide range of responses such as voting, giving, buying, selling, depositing, hoarding, investing, quarrelling, fighting, joining, seceding, boycotting, striking or attending. Methods have been devised to describe in quantitative terms the contents of the media of communication. Research is also done upon the control pattern that prevails in different countries, such as the degree of government monopoly or regulation, of private monopoly or competition.

Control.—It is impossible to scan the long history of attempts to control propaganda without being impressed by the power that men attribute to words. The fear of propaganda is fed by apprehension of the magical potency of language for the infliction of harm. These primitive attitudes continue to be an undercurrent in civilizations where the dominant attitude about language is detached and managerial. The only control problems that disturb a modern totalitarian regime are questions of expediency in the realm of power. In nations where the dignity of man is upheld, the issues are more complex, since the institutions appropriate to a free society include freedom of information, propaganda and political decision. Freedom is part of the respect due to the individual and is a condition of enlightenment and democracy.

But freedom of utterance is nowhere without qualification. No free society fails to use community coercion against some forms of speech on the ground that the results endanger important values without corresponding gain. Some gestures are condemned as obscene because we believe that youth will be corrupted if they are exposed to or use such gestures. Some communications are called fraudulent, libelous or slanderous, and left outside the protection of the community. In controlling propaganda the aim is to safeguard news and comment without permitting incitement, which is an act of coercion.

A consensus arose about the more extreme situations in which words become part of a coercive act. It is incitement when uniformed, armed and trained formations organize and act. Such activities signify that society is dissolving and can be restored only by bringing coercion back into the hands of organized government.

There is less agreement about what to do about statements provocative enough to arouse the anger of members of an audience whose religious, ethnic or political sentiments are affronted. One view is that restrictions must be imposed when there is "clear and present danger" to public order. A more daring conception is that it is the purpose of a free society to maintain a kind of public order where coercive acts are not permitted in response to words, however offensive.

In time of war, popular governments are compelled to recognize that statements circulated by an enemy are part of the enemy's coercive activities. But what of statements uttered by members of the commonwealth who have no connection with a foreign power? Some defenders of freedom assert that enough protection is given to the body politic if repressive measures against domestic propaganda are kept at a minimum and reliance is put upon the positive advocacy of the majority viewpoint, coupled with the disclosure of parallels, intended or unintended, between domestic propaganda and the line taken by the enemy. At the same time, it is conceded that without remarkably successful civic training in self-restraint, the police and the courts, to say nothing of the ordinary citizen, may be unable to tolerate dissent in the midst of crisis.

One of the greatest dangers arising from the prevalence of propaganda in a free society is that the vigorous prosecution of special interests prevents the formation of a genuine public will. In times of general crisis this may put democratic countries at a disadvantage when, on the assumption that the globe is in a chronic state of civil war, the ruling groups of totalitarian countries institute and maintain strict censorship and propaganda. The purpose on the one hand is to insulate the home audience from outside influences, and on the other to obtain maximum access to nontotalitarian audiences.

The very presence of propaganda raises searching problems for the friend of freedom. Does the calculated manipulation of attitudes imply a denial of respect for freedom of opinion? This is true if the forum of communication is not equally accessible to all and if educational opportunities are open only to the privileged. Hence, in countries that aspire toward freedom, stress is laid upon measures designed to achieve genuine equality. The legislative and judicial institutions of society proceed by the use of discussion in order to subject rival propaganda claims to a common discipline of balanced presentation and of critical evaluation of evidence.

Whatever solutions of the control of communication are achieved, it is evident that the degree of protection received by unpopular opinion and propaganda will continue to be one of the chief working tests of freedom.

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PROPELLANTS are materials used to expel the projectiles of various guns, ranging from small pistols and shotguns to the largest artillery pieces. Similarly compounded materials are also used for the propulsion of rockets (*q.v.*). Gun propellants are properly divided into two major classes: black or gunpowder and smokeless powders.

Friar Roger Bacon is credited with the discovery of nitre and the making of the first crude black powder of the occidental world in the 13th century. The name of a German monk Berthold Schwartz ("black") is also associated with this discovery and with the invention of guns. Until well into the 19th century black powder was the only explosive in practical use and hence had to serve both as a gun propellant and as a bursting or demolition explosive. As an explosive it is weak and, being nondetonable, is too slow for many applications. As a gun propellant it is objectionable because of low performance, poorly controllable burning and dense smoke. Consequently it is seldom used now as a propellant, except for some sporting ammunition.

In its long history, gunpowder underwent some changes but its constituents at mid-20th century were still largely the original potassium nitrate, sulphur and charcoal. The proportions had been altered to fit the use, and sodium nitrate had occasionally replaced the potassium salt. Increasing the content of sulphur makes for more rapid and violent deflagration; such mixtures are favoured for blasting. The reduction in sulphur proportions and the use of less fully carbonized "caked cellulose" instead of charcoal yield compositions with slower and more controlled deflagration rate. Under the name of "brown powder" such compositions were widely used for artillery guns during the 19th century.

The manufacture of gunpowder involves the mixing of the powdered ingredients and their incorporation with a little water under the heavy wheels of the wheel mill. The resulting cake

is broken up and is pressed in hydraulic presses. The remaining steps consist in the process of corning into granules of desired size and their polishing. The art of gunpowder manufacture lies largely in the knowledge of the making of charcoals of the right degree of carbonization and of the proper texture.

All smokeless powders contain nitrocellulose as their main ingredient, but some also contain nitroglycerin or other closely related nitric esters. Consequently, they are classed as single-base and double-base powders. The latter, in turn, are divided according to manufacturing methods into solvent-extruded and solventless powders.

The manufacture of single-base powders starts with the kneading, or incorporation, of dehydrated nitrocellulose with a volatile solvent, usually an alcohol-ether mixture. This process is continued until the nitrocellulose is partially colloided or gelatinized and the product looks like moist brown sugar. To improve gelatinization the mass is pressed into blocks, extruded in "macaroni" presses and blocked again. The final graining of the "dough" is done either by rolling into sheets of desired thickness which are then cut into platelets of chosen size, or by extrusion through suitably designed dies from hydraulic presses to form cords or perforated strands. These are then cut to uniform length. The final process is the drying by air; this is carried out in several stages, the grains being finally heated to eliminate tenaciously held solvent. The modern practice favours a preliminary extraction of the solvent in water, followed by drying in air. Thus, a considerable reduction of the total drying time is accomplished.

For the manufacture of single-base powders, several grades of nitrocellulose have been in use. Typical powders contain either a single grade of nitrocellulose (an example is the U.S. naval "pyro" powder) or a mixture of grades, some of the collodion grade being soluble in the ether-alcohol solvent, and some of the guncotton grade (examples are U.S. NH sporting and military powders, French poudre B). The blending of nitrocellulose is claimed to make possible a better control of gelatinization and consequently to lead to better physical properties in the finished powder. All modern smokeless powders contain a small percentage of special stabilizers whose function in the finished powder is to react with the nitrogen oxides formed in the spontaneous decomposition of nitrocellulose and thus to prevent their catalytic action (*see* CATALYSIS) on the decomposition reaction. Typical stabilizers are diphenylamine and centralite, or diethyldiphenylurea. Sometimes (as in NH powders) nitrated aromatic hydrocarbons (dinitrotoluenes, etc.) are also added. Together with the above-mentioned stabilizers they act as plasticizers of single-base powders, softening nitrocellulose gel and ensuring that the grains are not brittle. In the absence of nonvolatile plasticizers, it is common to leave some volatile solvent in the powder to obtain equivalent results.

In double-base propellants the proportion of nitroglycerin varies between about 20% and 50%. Most of them contain additionally the same types of stabilizers and plasticizers as are used in single-base powders. In the solvent manufacturing process, nitrocellulose, usually the guncotton grade but sometimes also the collodion grade, is gelatinized with nitroglycerin and a volatile solvent (usually acetone) then extruded and dried, the steps resembling those used in single-base powder manufacture (examples: M2 military powders in the United States, cordite MD in Great Britain). The manufacture of solventless powders starts with the mixing of an aqueous slurry of nitrocellulose (of the collodion type) with nitroglycerin, stabilizers and nonvolatile plasticizers. After the elimination of excess water, nitrocellulose, which has absorbed the other ingredients with partial gelatinization, is passed through heated roll mills until the moisture has been eliminated and nitrocellulose is well gelatinized. The sheets are then either rolled to required thickness and cut into platelets or placed in a heated hydraulic press and extruded through dies to form cords or perforated strands (examples: the original Nobel ballistite, U.S. and French ballistites, British Ardeer cordite). Since long burning-times of the propellant grains are desired for the propulsion of rockets, and since thick webs (*see* below) are therefore required, rocket powders are now largely made by the solventless method. The forbiddingly long drying-times and the undesirable distortion of grains, which are almost unavoidable in the solvent manufacturing method, are thus avoided.

As a result of the deficiency of oxygen in practically all smokeless-powder formulations, the deflagration products contain considerable proportions of inflammable gases as they emerge from a gun's muzzle. Their temperature is high and hence an ignition with atmospheric oxygen readily occurs. To suppress the resulting intense and brilliant flash, which is objectionable in military applications, certain inorganic salts, most frequently potassium sulphate or potassium chloride, are included in many powder formulations. These flash-suppressors inhibit the reaction with atmospheric oxygen and eliminate the flash except under the most severe circumstances. However, they also add to the undesirable smoke (example: U.S. FNH powders).

Gelatinized propellants deflagrate layerwise, the reaction at any moment being limited to a thin layer on the entire surface of the grain. The primary chemical reaction is a partial decomposition of the constituents of the powder into volatile products which escape from the surface and thus expose the next layer. This volatilization is not accompanied by much heat evolution and, unless heat is supplied from an outside source, the grain surface cools and the reaction subsides. However, the volatilized products undergo further reactions after leaving the surface, and these reactions serve to heat the latter. Such reactions result eventually in the formation of the final products, largely carbon monoxide and dioxide, hydrogen, water vapour and nitrogen. So much heat is released thereby that a flame is formed which surrounds the deflagrating grain of a smokeless powder. The reactions occur faster when the density of the primary products is greater; that is, when the grain is surrounded by gases at higher pressure. Under such circumstances, the reactions occur nearer to the surface on which the decomposition is taking place. Because of the shorter distance, more heat is then conducted to the surface, the decomposition of which is therefore accelerated. Quantitative measurements show indeed that the rate of deflagration of propellants is approximately proportional to the pressure surrounding the grains.

From this basic law of deflagration of propellants it is readily deduced that the burning time of a grain is proportional to its web thickness and inversely proportional to the pressure at which deflagration occurs. Because of this relation it is possible to use the same powder formulations for guns and for rockets. Thick-webbed grains are used for the latter and the pressure in the rocket motor is adjusted to only a few thousand pounds per square inch. Deflagration times are then nearly a second long. For guns, the web thicknesses are chosen 10–100 times smaller and the pressure is allowed to rise to more than 30,000 lb. per square inch. Consequently, the deflagration is complete in a little more than a thousandth part of a second.

Other factors being the same, the propulsive effectiveness, or the potential, of a powder is proportional to the product of the volume of gases formed and the temperature which they reach in the flame. The reaction which causes the intense heat evolution in the deflagration process is the combination of the loosely held oxygen of the nitro groups with the carbon and hydrogen of the rest of the molecule. Most powder formulations are deficient in this oxygen and consequently every change in formulation which increases the proportion of nitro groups (inclusion of nitroglycerin, higher degree of nitration of nitrocellulose) makes for "hotter" propellants. Addition of plasticizers, etc., cools the powder. Under otherwise identical conditions hotter powders deflagrate faster than the cool ones. However attractive from the purely ballistic point of view is the use of hot propellants, it has serious disadvantages because of increased erosion of gun barrels and increased flashing. Consequently, hotter propellants are commonly reserved for small-arms ammunition, whereas cooler compositions are used in big guns.

Studies of gun ballistics have shown that, in order to obtain economically the maximum projectile velocity, it is advantageous to let the pressure rise gradually in the gun while the projectile is

being accelerated in the bore. Consequently, in modern powders the grain web is tailored to fit a specific type of gun and is in general thicker the bigger the calibre and the longer the barrel of the gun. Further advantage is derived from designing the grains so that the deflagrating surface continues increasing until almost complete consumption of the grain. Such powders (multiperforated grains) are called progressive burning. Similar advantages are obtained by making the surface layer of the grain burn more slowly than the interior. This result is accomplished by incorporating in the surface layer a cooling agent deficient in oxygen or "deterrent-coating" the grains.

Nitrocellulose propellants are rather difficult to ignite and, therefore, at least in larger guns, the flame from the primer (*q.v.*) is made to ignite a small charge of black powder which, in turn, ignites the main propelling charge.

(*See* GUN, MACHINE; BALLISTICS; EXPLOSIVES; NITROCELLULOSE; NITROGLYCERIN; SMALL ARMS, THE DEVELOPMENT OF.)

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(G. B. K.)

PROPELLER. For a description of the propeller as applied to aircraft *see* the article AIRSCREW. For marine propellers, *see* SHIPBUILDING.

PROPERTIUS, SEXTUS (*fl.* 30–15 B.C.), the greatest of the elegiac poets of Rome, was born of a well-to-do Umbrian family at or near Asisium (Assisi), the birthplace also of the famous St. Francis. We learn from Ovid, that Propertius was his senior, but also his friend and companion; and that he was third in the sequence of elegiac poets, following Gallus, who was born in 69 B.C., and Tibullus, and immediately preceding Ovid himself, who was born in 43 B.C. We shall not then be far wrong in supposing that he was born about 50 B.C. His early life was full of misfortune. He lost his father prematurely; and after the battle of Philippi and the return of Octavian to Rome, Propertius, like Virgil and Horace, was deprived of his estate to provide land for the veterans, but, unlike them, he had no patrons at court, and he was reduced from opulence to comparative indigence. The widespread discontent which the confiscations caused provoked the insurrection generally known as the *bellum perusinum* from its only important incident, the fierce and fatal resistance of Perusia, which deprived the poet of another of his relations, who was killed by brigands while making his escape from the lines of Octavian. The loss of his patrimony, however, thanks no doubt to his mother's providence, did not prevent Propertius from receiving a superior education. After, or it may be, during its completion he and she left Umbria for Rome; and there, about the year 34 B.C., he assumed the garb of manly freedom. He was urged to take up a pleader's profession; but, like Ovid, he found in letters and gallantry a more congenial pursuit. Soon afterwards he made the acquaintance of Lycinna, about whom we know little beyond the fact that she subsequently excited the jealousy of Cynthia, and was subjected to all her powers of persecution (*vexandi*). This passing fancy was succeeded by a serious attachment, the object of which was the famous "Cynthia." Her real name was Hostia, and she was a native of Tibur (iv. 7, 85; iii. 20, 8). She was a courtesan of the superior class, somewhat older than Propertius (ii. 18, 20) but, as it seems, a woman of singular beauty and varied accomplishments. Her own predilections led her to literature; and in her society Propertius found the intellectual sympathy and encouragement which were essential for the development of his powers. Her character, as depicted in the poems, is not an attractive one; but she seems to have entertained a genuine affection for her lover. The intimacy began in 28 and lasted till 23 B.C. These six years must not, however, be supposed to have been a period of unbroken felicity. Apart from minor disagreements an infidelity on Propertius's part excited the deepest resentment in Cynthia; and he was banished for a year. The quarrel was made up about the beginning of 25 B.C.; and soon after Propertius published his first book of poems and inscribed it with the name of his mistress. Its publication placed him in the first rank of contemporary poets, and amongst other things procured him admission to the literary circle of Maecenas. The intimacy was renewed; but the old enchantment was lost. Neither Cynthia nor Propertius was faithful to the other. The mutual ardour gradually cooled; motives of prudence and decorum urged the discontinuance of the connection; and disillusion changed insensibly to disgust. Although this separation might have been expected to be final, it is not certain that it was so. It is true that Cynthia, whose health appears to have been weak, does not seem to have survived the separation long. But a careful study of the seventh poem of the last book, in which Propertius gives an account of a dream of her which he had after her death, leads us to the belief that they were once more reconciled, and that in her last illness Cynthia left to her former lover the duty of carrying out her wishes with regard to the disposal of her effects and the arrangements of her funeral. Almost nothing is known of the subsequent history of the poet. He was alive in 16 B.C., as some allusions in the last book testify. And two passages in the letters of the younger Pliny mention a descendant of the poet, one Passennus Paullus. Now, in 18 B.C. Augustus carried the *leges Iuliae*, which offered inducements to marriage and imposed disabilities upon the celibate. Propertius then may have been one of the first to comply with the new enactments. He would thus have married and had at least one child, from whom the contemporary of Pliny was descended.

Propertius had a large number of friends and acquaintances, chiefly literary, belonging to the circle of Maecenas. Amongst these may be mentioned Virgil, the epic poet Ponticus, Bassus (probably the iambic poet of the name), and at a later period Ovid. We hear nothing of Tibullus, nor of Horace, who also never mentions Propertius. This reciprocal silence is probably significant. In person Propertius was pale and thin, as was to be expected in one of a delicate and even sickly constitution. He was very careful about his personal appearance, and paid an almost foppish attention to dress and gait. He was of a somewhat voluptuous and self-indulgent temperament, which shrank from danger and active exertion. He was anxiously sensitive about the opinion of others, eager for their sympathy and regard, and, in general, impressionable to their influence. His overemotional nature passed rapidly from one phase of feeling to another; but the more melancholy moods predominated. A vein of sadness runs through his poems, sometimes breaking out into querulous exclamation, but more frequently venting itself in gloomy reflections and prognostications. He had fits of superstition, which in healthier moments he despised.

The poems of Propertius, as they have come down to us, consist of four books containing 4,046 lines of elegiac verse. The first book, or *Cynthia*, was published separately and early in the poet's literary life. It may be assigned to 25 B.C. The dates of the publication of the rest are uncertain, but none of them was published before 24 B.C., and the last not before 16 B.C. The unusual length of the second one (1,402 lines) has led Lachmann and other critics to suppose that it originally consisted of two books, and they have placed the beginning of the third book at ii. 10, a poem addressed to Augustus, thus making five books, and this arrangement has been accepted by several editors.

The subjects of the poems are threefold: (1) amatory and personal, mostly regarding Cynthia—72 (60 Cynthia elegies), of which the last book contains three; (2) political and social, on events of the day—13, including three in the last book; (3) historical and antiquarian—six, of which five are in the last book.

The writings of Propertius are noted for their difficulty and their disorder. The workmanship is unequal, curtness alternating with redundance, and carelessness with elaboration. A desultory sequence of ideas, an excessive vagueness and indirectness of expression, a peculiar and abnormal latinity, a constant tendency to exaggeration, and an immoderate indulgence in learned and literary allusions—all these are obstacles lying in the way of a study of Propertius. But those who have the will and the patience to surmount them will find their trouble well repaid. For power and range of imagination, for freshness and vividness of conception, for truth and originality of presentation, few Roman poets can compare with him when he is at his best. And this is when he is carried out of himself, when the discordant qualities of his genius are, so to say, fused together by the electric spark of an immediate inspiration. His vanity and egotism are undeniable, but they are redeemed by his fancy and his humour.

Two of his merits seem to have impressed the ancients them-

selves. The first is most obvious in the scenes of quiet description and emotion in whose presentation he particularly excels. Softness of outline, warmth of colouring, a fine and almost voluptuous feeling for beauty of every kind and a pleading and melancholy tenderness—such were the elements of the spell which he threw round the sympathies of his reader and which his compatriots expressed by the vague but expressive word *blanditia*. His poetic *facundia*, or command of striking and appropriate language, is more noticeable still. Not only is his vocabulary extensive but his employment of it is extraordinarily bold and unconventional. New settings of use, idiom and construction continually surprise one and, in spite of occasional harshness, secure for his style an unusual freshness and freedom. His handling of the elegiac couplet, and especially of its second line, deserves especial recognition. It is vigorous, varied and even picturesque. In the matter of the rhythms, caesuras and elisions which it allows, the metrical treatment is much more severe than that of Catullus, whose elegiacs are comparatively rude and barbarous; but it is not bound hand and foot, like the Ovidian distich, in a formal and conventional system. An elaborate symmetry is observable in the construction of many of his elegies, and this has tempted critics to divide a number of them into strophes.

Propertius' poems bear evident marks of the study of his predecessors, both Greek and Latin, and of the influence of his contemporaries. He tells us himself that Callimachus and Philetas were his masters (iii, 1 *et seq.*) and that it was his ambition to be the Roman Callimachus (iv, 1, 64). But, as Teuffel has said, his debt to these writers is chiefly a formal one. Even into his mythological learning he breathes a life to which these dry scholars are strangers. We can trace obligations to Meleager, Theocritus, Apollonius, Rhodius and other Alexandrines and among earlier writers to Homer, Pindar, Aeschylus and others. Propertius' influence upon his successors was considerable.

There is hardly a page of Ovid which does not show obligations to his poems, while other writers made a more sparing use of him.

BIBLIOGRAPHY.—There is no existing ms. of Propertius older than the 12th century. Up till the publication of Bährens' edition (1880), the oldest one, Neapolitanus (N., now at Wolfenbüttel), was universally regarded as the best, and even now critics are found to maintain its paramount claims. But the more judicious admit the value of the four mss. collated by Bährens. Vossianus, *c.* 1300 (A); Laurentianus, end of the 14th century (F); Ottoboniano-Vaticanus, 15th century (V); Daventriensis, 15th century (D), to which has to be added the Holkhamicus, 1421 (L), collated by Postgate, *Cambridge Philological Transactions*, vol. iv (1894).

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PROPERTY: *see* COMPENSATION; LAWS RELATING TO REAL PROPERTY AND CONVEYANCING; PERSONAL PROPERTY.

PROPERTY, DEVOLUTION OF: *see* INTESTACY; LEGITIMACY AND LEGITIMATION; WILL.

PROPERTY, LAW OF: *see* LAWS RELATING TO REAL PROPERTY AND CONVEYANCING.

PROPERTY, PRIMITIVE. Property is bound up with every aspect of social life. It gives a stimulus to economic effort, enters into questions of marriage, family life and inheritance, forms the subject of legal judgments, provides compensation for offenses and acts as a frequent incentive to war. It is held in goods such as food, clothing and weapons; and immaterial items (songs, personal names, mythological tales, magical spells, social offices) are in many communities a matter for precise ownership. The tie between man and property is often not one of mere economic interest; the basis of attachment is of the nature of a sentiment, a complex set of emotional considerations centring in the object. Thus, to the Maori his tribal land is his greatest treasure, a fact which is illustrated by many proverbial sayings; *e.g.*, "The blood of man is the land" or "Man perishes but the land remains." This love of his ancestral soil is a factor which greatly complicates the economic aspect of alienation. The association of ownership with a tie of sentiment is common to other primitive communities, as with the Lango and their cattle.

The precise meaning of ownership is different in every culture, varying according to custom, tradition and the relative social status of those who enjoy its privileges. Failure to recognize the essential nature of the primitive conception of ownership has led to the formulation of many unreal hypotheses in anthropology—and, in the practical sphere, to misunderstanding and conflict between native and white man.

Primitive Communism.—From a partial study of the evidence, certain social theorists, as Friedrich Engels, were lured by their political ideals—for which this notion formed a useful precedent—to advance the thesis that the most primitive form of ownership was communism. This idea was championed on more scientific grounds by W. H. R. Rivers, who thought he had discovered in Melanesia evidence for the existence of a communistic type of economy marked by a lack of differentiation of personal interests. The institutions of every primitive people show a much closer relation between the individual and his group than that which animates European culture and a greater readiness (inspired by custom) to yield to the corporate claims of the society. Thus, among the Gilyak the catch after fishing is freely divided among the members of the community, even families which have taken no part in the work receiving a share. Yet at the same time private ownership is distinctly recognized in such articles as swords, shields, etc. Among the Mekeo people, again, a pig, an item of family property, is seldom killed except by command of a chief. At the same time the close grip retained by communal interests upon even a man's personal property does not indicate any sweeping suppression of his individuality. Communism, if this term be employed, signifies not a lack of recognition of individual interests, but a conscious subordination of them in major affairs—under the pressure of custom and public opinion—to the control of the group as a whole. That the process is one of integration of interests, not mere blind absence of any sense of individuality, is shown by the existence of complicated individual claims and privileges within the sphere of communal ownership. Thus, in the case of the Melanesian canoe, the management of which was adduced by W. Rivers as a proof of communism, the deeper researches of B. K. Malinowski reveal a complex system of control with one man as master of the vessel and paramount owner, the others having lesser shares, each well defined, and all having specified duties and responsibilities to their fellow members. No irrational, undifferentiated absorption of the individual in the group can be discovered. This position is supported by the results of intensive research in material from old Peru, Australia and New Zealand, while study of the problem of ownership in more general context suggests that this blend of "communism" with individualism is characteristic of all primitive society.

Land Tenure.—These conclusions apply also to the specific case of ownership in land, the precise system of which varies according to the economic conditions and social structure of the community concerned. Among hunting peoples the measure of tribal control of the territory over which they range appears to be fairly communal, though even here, as in the case of the northeastern Algonkin tribes or the Vedda of Ceylon, the portion of land on which each family catches game may be sharply

demarcated and protected by heavy penalties from intrusion on the part of neighbours. With changes in the form of economy the partition of interests varies, until among people such as the Melanesians the delimitation of rights allows of ownership of the land by one man and of the fruit trees upon it by another. Again, a person's admitted status as an owner is often qualified by rights of other people, such as relatives, the chief or the village magician, to certain portions of the produce. The key to the understanding of a system of native land tenure lies in realizing the inadequacy of such simple labels as "communistic" or "individualistic" and in grasping the complex scheme of titles, claims, privileges and obligations on the part of individuals and the community with which the native himself invests the control of the soil.

Attempts have been made by Kohler, de Laveleye, Lafargue, Bücher, Lewinski and others to group the various types of ownership in a chronological sequence, to trace their origins, and on this basis to lay down theories of the evolutionary development of the idea of property. Such efforts, however, lack reality, and the undoubted contributions of these writers have come incidentally from their descriptive and analytical studies.

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PROPHET (προφήτης), a Greek word used in the Greek Old Testament to translate the Hebrew *Nābī* נביא and consequently adopted into other European languages. In classical Greek it denoted one who, uttering or interpreting an oracle, was believed to speak not his own thoughts but a revelation "from without"; *cf.* the description of Cassandra (*Agam.*) and the Prophet of Apollo (*Eumen.*), by Aeschylus; of the blind seer, Teiresias, by Sophocles (*Oed. Tyr.*), and by Euripides (*Bacchae*); of the Cumaean Sibyl, by Virgil (*Aen* vi.); and note Plato, *Timaeus* 71 b., where he argues that persons who seek to give rational meaning to oracles "are not to be called prophets at all," but only those who speak in ecstasy. At the Delphic Oracle, however, not the frantic priestess, the Pythia, was designated "prophet," but the Guardians of the Shrine who ostensibly shaped her frenzied ejaculations into comprehensible replies. Etymologically προφήτης denoted "forth-telling," not "fore-telling"; but since προ could mean "before" in time, and since prophecies constantly dealt with future events and foreknowledge is not deemed to occur in conditions of normal consciousness, the notion that prediction and ecstasy are the essential elements in prophecy was an easy growth. Thus in the Hellenic period Philo of Alexandria looked on divination and oracular interpretation as imposture, but had high regard for the ecstatic who "speaks nothing of his own." Προφήτης was the best word available in Greek, for rendering the Hebrew *Nābī* (it was preferable to μάντις), but the Hellenistic view of prophecy as ecstatic prediction obscured for centuries the wealth of religious interest in the Hebrew prophets. Why προφήτης was used to translate *hm-ntr*, the title of certain Egyptian priests, is unascertained.

HEBREW PROPHECY

The Hebrew noun *Nābī* ("Prophet," *pl. Nᵉbi'im*) is obscure in origin. Derivations implying intense excitement (נבע "to bubble up"; נבע Assyr., "to fall in transports") are etymologically improbable. The verbal form (an intensive) used in Hebrew often denotes frenzy or even lunacy, but this may reflect merely one aspect of prophetic development, and the fact that it is an intensive stem may imply simply that it is a loan-word in Hebrew. Conceivably it is not Semitic at all—there are Hittite possibilities. The likeliest Semitic connections are Arab. *naba'a* "to announce" (conjug. ii.); Bab.-Assyr. *nabû* "to name" (*cf.* the god, Nebo, Is. xlvi. 1). *Nābī*, like προφήτης, may thus in origin be a colourless term: "One who utters a god-given message."

The Fanatical Prophets.—From a trustworthy narrative in I Sam. x. we learn that bands of prophets (*Nᵉbī'im*), devotees of the national deity, Jehovah (Yahweh), existed *c.* 1000 B.C. at Hebrew localities (Gibeah, Ramah). Stimulated by rhythmic music, dancing and chanting, they wrought themselves into ecstasies when their frenzied behaviour and abnormal physical power exercised hypnotic effect over onlookers (I. Sam. x. 5–13), and, as it seemed to testify the might of the god whose spirit possessed them, encouraged popular trust in Jehovah and resistance to the Philistines. Since there is no earlier reference to collective prophesying in Hebrew history (Nu. xi. 25 *sqq.* cannot be regarded as of the Mosaic age), probably it was a feature of Palestinian-Syrian religion, first evoked in Israel in Samuel's time. There is no direct evidence for Wellhausen's assertion that "among the Canaanites such Nᵉbi'im had long been familiar" but the indirect evidence is impressive. An Egyptian record (*c.* 1100 B.C.) relates how an envoy, Wenamon, secured a hearing when a youth in attendance on a Phoenician prince prophesied ecstatically in Wenamon's favour. Very instructive is the famous passage in I. Kings xviii. 19 *sqq.* concerning the 850 prophets of the (Phoenician?) Baal and of the Asherah, maintained by Queen Jezebel. At a much later period the orgiastic rites celebrated by devotees in honour of certain ostensibly Greek deities (Apollo, Dionysos) prove to have connections with the Baal worship of Syria and Phoenicia (so T. H. Robinson). When parallel phenomena are still exhibited by the dervish fraternities in Islam, it seems probable that this form of religious excitement was peculiarly congenial to the peoples of Western Asia Minor, and may well have been of immemorial antiquity in Palestine.

Certain it is that fanatical prophets became a feature of Israelitish society. They are mentioned in connection with many towns of special sanctity and importance, *e.g.*, Bethel, Jericho, Samaria. Possibly they had some organization (the phrase "schools of the prophets" has no warrant), and were supported by popular piety or by kings anxious to obtain inspired counsel in perilous moments. Along with the priests and the wise men, they were esteemed one of the three indispensable sources for the guidance of the State (Jer. xviii. 18). Even in the post-exilic period they lingered on, distinctive by their rough mantle and leathern girdle, mouthing out oracles for the superstitious (*cf.* the χρησμολόγος in Aristophanes, *Birds*, 959 *sqq.*)—so great a public nuisance that father and mother are exhorted to slay the son turned "prophet" (Zech. xiii. 3). The causes of degeneracy can be discerned. Thanks to Eastern respect for the psychologically abnormal, the calling afforded a livelihood and might attract impostors, for it was easy to share in, or simulate, ecstasy, and declare "Thus saith Jehovah." The violent emotions were dangerous to the moral stability of even the honest Nᵉbi'im, and if simpler means of inducing ecstasy failed, the temptation to use noxious drugs was great.

The fanatical prophets, it may be concluded, manifested a real patriotism that helped to establish the State during the Philistine and the Syrian conflicts, but contributed nothing to the discernment of those dynamic religious beliefs which, as the power of Assyria and Babylon rose and engulfed the petty monarchies of Israel and Judah, alone made possible the astounding survival of the Jewish nation.

The Seer.—But the word *Nābī* acquired a wider connotation. Later than the age of Samuel it came to be applied to persons who in earlier times would have been called Seers (*Rō'eh*, "Visionary"; or *Hōzeh*, "Gazer": I Sam. ix. 9). The Seer, ubiquitous in antiquity and ranging in dignity from the itinerant soothsayer to the guardian of some famous sanctuary, was credited with power, through interpretation of omens or (more impressively) through trance-visions, to gain knowledge from a spiritual being inaccessible to ordinary men: he was, as others were not, a "man of God." Balaam (Nu. xxii.–xxiv.) is typical: "essentially an Arab *Kāhin* or seer of that early type which combined the priest's offices of ritual and sacrifice, the diviner's reliance on omens and lots, and the prophet's experience of ecstasy and dreams" (G. A. Smith). The possibilities in the calling for good and evil are obvious. Affinities with the baser forms of divination—wizardry, necro-

mancy, etc.—were close, and degenerate seers became only too numerous in Israel (Is. ii. 6, Mic. iii. 7), notwithstanding a strong tradition that such arts were peculiarly abhorrent to the God of Israel (I Sam. xxviii. 3, *sqq.* Ex. xxii. 18, Is. viii. 19). But the famous seers created the expectation of individuals in mysterious contact with God, "standing in his counsel," "knowing his secret," whose words should therefore have absolute authority in hours of crisis. Much more than the N^{e}bi'im with their collective "inspiration," the seer is of the lineage of the great prophets. Yet a distinction may be drawn. The ordinary seer made his powers his profession and livelihood (Am. vii. 12), and his functioning was habitually passive: he waited to be consulted. The great prophets were men of diverse callings, driven by an irresistible constraint actively to declare to Israel the word of its God. Thus to his contemporaries Samuel was not one of the N^{e}bi'im but the Priest-Seer of Ramah, whom a Saul could consult about strayed animals. Later generations rightly accounted him a prophet of the great type because of his initiative in rousing the people against the Philistines, in creating a monarchy, and later in rejecting Saul for David.

The Higher Prophecy.—But all the seers and prophets of antiquity would have but infinitesimal interest, were it not for the appearance in Israel of certain individuals of amazing spiritual insight, whom we, like their contemporaries, for lack of a better word must call "prophets." Their work and words endow Prophecy with almost inexhaustible importance for religion and for social organization. The diversity of the occupations and circles to which these higher prophets belonged is significant. A few, especially in the earlier period, pertained to the professional prophetic class: Samuel was a famous seer, Gad and Nathan official prophets of David's court, Micaiah one of the recognized N^{e}bi'im (I Kings xxii.—a passage which should be studied). But Elisha was a prosperous farmer, Amos a shepherd of Judaea, Isaiah a citizen of Jerusalem, Micah a Judaean villager, Jeremiah a youth of ancient priestly family, Ezekiel a priest of the Temple. The unifying characteristic is that to each came an overmastering conviction that, temporarily or permanently, he must forsake his way of life and declare what God would say to His people. Their prophesying was the constraint of a vocation, not the pursuit of a profession. When their teaching is coordinated certain principles they held in common can be analysed (*see* articles on the several prophetical Books, HEBREW RELIGION, etc.) with results sufficiently impressive. But such surveys are meagre and mechanical: what counts is the stress of circumstance from which the great ideas were won, and the heroic application of beliefs to events. Knowledge of Hebrew prophecy is knowledge of the lives of glorious personalities; only when name after name of the prophets calls up the memory of lonely insight into truth, of unbreakable loyalty to duty, maintained through scorn and hatred and despite despair, can its splendour be realized.

Historical Development.—Complex as are the Pentateuchal narratives concerning Moses, it seems certain that an influential section of the mixed population under the Hebrew monarchies held a tradition that a great leader of prophetic character (yet not an ordinary seer, Nu. xii. 6–8; but such as Samuel had been, a man whom a Hosea or Jeremiah could call a Prophet, Ho. xii. 13, Jer. xv. 1) had led their ancestors out of Egypt to the independence of the desert, and had fired them with such confidence in the God Jehovah as had given them the unity necessary for a successful assault on Canaan. However dimly recalled, and by however few, the tradition of Moses, it may be held, preserved potent ideas: that Jehovah required a standard of morality that differentiated Him from other gods, and that in Moses himself—remembered as a life of splendid patience and mercy, of unswerving integrity and awe-inspiring intimacy with the invisible God—there had been seen a true servant of Jehovah. Subsequently in Canaan the leadership of Samuel not only established the national existence, but created in the popular consciousness the sense that their kingdom was truly, and not nominally, a theocracy, where kings must heed the word spoken by God's prophets to an extent startling in the ancient East (I. Kings xxi. 7). The vigilance of prophetic censorship over the dynasty was notably displayed against David (by Gad and Nathan), against Solomon (by Ahijah), against Rehoboam (by Shemaiah); and momentously in Elijah's adamantine opposition to Ahab and Jezebel, whereby the alliance with Phoenicia was broken and Israel left to face unsupported the impending attack by Damascus.

The deep motives in the higher prophecy now became apparent. Not by political wisdom was Elijah actuated, but solely by an imperious religious instinct which swept aside all other considerations in the assertion that Jehovah demands an absolutely exclusive worship, and that He champions the rights of the humblest against even the king. This principle holds good throughout. Attempts (*cf.* Winckler) to explain the actions and attitude (*e.g.*) of Isaiah or Jeremiah primarily by political foresight or predilections can be shown in detail to be misconceived. Prophecy had created the nation, and wished to sustain it; not, however, in the interests of the nation, but in the interests of its God. The important account of Elijah's flight to Horeb, I. Kings xix. (taken in conjunction with the sequel: Elijah's sense of a commission to anoint Jehu king over Israel, and Hazael over Syria, followed by the achievement of those ends by Elisha, his disciple, and by high-minded prophets) shows that the parable read by Elijah in the quiet of the enduring mountain, following the storm, was not that the ways of God are gentleness alone, but on the contrary that the prophet's resolve to overthrow the house of Ahab must be pursued to its bitter end through revolution in Israel and war with Syria. The nation must pass through the tumult: thereafter the unalterable good purpose of its God would be apparent. In face of the grim realities of evil true religion must send first not peace but a sword.

The Golden Age.—A century later (*c.* 750 B.C.) the Golden Age of Hebrew prophecy, wherein the universal aspects of religious truth were perceived as the real significance of Israel's national faith in Jehovah, began with the oracles of Amos and Hosea in Northern Israel, to be continued in Judah, especially by Isaiah, Micah and Jeremiah. For Amos there is but one God of the whole earth, controller of other nations as well as Israel, whose favour everywhere is determined solely by such concern for moral conduct that not even the wrongs of a slave go unheeded by Him. Amos is styled the "Prophet of the *Justice* of God," but the phrase is wholly inadequate. Positive goodness, forbearance, mercy, kindness are the inexorable divine demand. Between Jehovah and Israel a special relation exists; but the implication is not (as the people imagine) favouritism, but responsibility: "to whom much is given, of them shall much be required" (Am. iii. 2). Faced by the iniquities of their times, earlier prophets had assailed the dynasty at whatever risk to the national fortunes; but Amos, appalled by corruptions that rotted society from top to bottom, uttered logically a judgment almost incomprehensible to the ancient mind—God will bring overwhelming ruin upon the nation itself (Am. vi.–ix. *passim*). Lastly, Amos marks a new era for religion by his special declaration that the immemorial forms of worship —sacrifices, fasts and feasts—are sheer futility: God is to be sought not through material offerings, but spiritually in upright and generous conduct (Am. v. 5, 14, 21–24). Here is the enunciation practically, if not also theoretically, of ethical monotheism. The profundity of these beliefs, which thenceforth became the gospel of the higher prophets, needs no emphasising. Not unjustly Amos has been called the forerunner of Kant.

To Hosea love seemed fundamental in the attitude of God to Israel. Deeper than the necessity for moral retribution lay the divine love. It has been observed that Amos and Hosea significantly complement one another; they "form a pair—law and love" (S. A. Cook).

Taught, it would seem, by some poignant personal experience, Hosea agonized with the dilemma: God must shatter the sinful nation, yet to do so would seem to end his gracious purpose in defeat (Ho. xi. 8, 9). What if the disaster, which is sure, be after all a means to an end—*πάθει μάθος*? Out of the ashes of Retribution, Hope must rise (Ho. ii. 15). Far more deeply than Amos, Hosea probed the problem of sin. The cultus was not merely futile; it was a prime source of iniquity, and must be abolished. He pities the masses; they sin indeed, but it is for lack

of knowledge (Ho. ii. 8). Thus was prophecy released from pessimism. However near and overwhelming the "day of the Lord" in judgment, the prophet must exhort men to penitence and belief in an ultimate divine salvation.

The view (Gressmann, Gunkel) that Amos and his successors inherited a cut-and-dry eschatological expectation of woe followed by bliss—whether derived from native Israelite sources (Sellin) or influenced by Egyptian (Ed. Meyer) or Babylonian literature—rests on inadequate or misinterpreted evidence. The message of doom announced by Amos was startling to his hearers, and it would seem that the higher prophets' anticipation of some impending judgment catastrophic yet congruous with an undefeated divine purpose was radically the unaided product of their own reflection on the righteousness, power and goodness of God. In Hosea and Isaiah the element of hope beyond catastrophe is prominent. Whether it was conceived very vaguely, or more definitely (Messianic) depends on the dubious authenticity of certain passages (*see* APOCALYPSE, MESSIAH). For the achievement of an order of perfect righteousness apocalyptic cataclysm is, in reality, irrelevant; since love cannot be compelled. In their passionate pleading for reform the prophets were feeling their way to a deeper comprehension, which at last was attained when Jeremiah based his hope of a divine consummation simply on faith in God's effecting the moral regeneration of the human heart (Jer. xxxi. 31–34).

Isaiah and Jeremiah.—The task which lay before the great prophets of Judah (*c.* 740–586 B.C.)—who, in contrast to the facile optimism of the ordinary prophets "healing lightly the hurt of the daughter of Zion," continued convinced that the ruin of the State was at hand—was to discover how faith in Jehovah could survive the political destruction. In effecting this infinitely difficult task it was their sublime achievement "to liberate the eternal truths of religion from their temporary national embodiment, and disclose their true foundation in the immutable character of God and the essential nature of Man" (Skinner).

To Isaiah is due the conception of an Israel within Israel, a believing nucleus; a "Church of God." Convinced that he knew the mind and power of the living God ("Mine eyes have seen the King, the Lord of Hosts," Is. vi. 5), he reasserted on a higher level the earlier prophetic claim to control the national policy. Thorough social reform must accompany quiet trust in God, and in Him alone, for the fate of the nation (*cf.* Is. xxx. 15). Assyria is resistless, not in virtue of its vaunted might but because it is the weapon in Yahweh's hand against his sinful people (Is. x.). Whatever sufferings it inflicts, in invading Judah will be the discipline of divine wisdom, and will leave behind a purified remnant of the faithful in Zion, through whom God's purpose shall be fulfilled (*cf.* Is. x. 20–23, xxviii. 16). Rejected by king and people, apparently he gave substance to his hopes by seeking disciples who accepted his principles (Is. viii. 16). At the crisis of the Assyrian invasion (701 B.C.?), he foretold the inviolability of Zion and this momentary form of his teaching was preserved in popular memory superstitiously apart from its spirit and the moral conditions on which his doctrine of Faith (Trust) rested (*cf.* Jer. vii. 1–15).

"Prophecy had already taught its truths, its last effort was to reveal itself in a life"—the life of Jeremiah. Living through the dreadful years which saw the two successful sieges of Jerusalem by the Babylonian armies, ending in the destruction of the city and temple and the deportation of its chief inhabitants, Jeremiah found himself forced either to utter unrelieved predictions of ruin to a people distracted alternately with panic and delusive relief, or, being silent, to deny the conviction of inspired knowledge that burned like a fire in his bones. The task entailed for him desperate loneliness, hatred and persecution—sufficient torment to a man of shrinking and sensitive temperament. But further he was tortured at times by doubt of his inspiration. Was he but self-deceived or even deceived of God? Were the confident prophets of peace right? And if the nation perished, how could the worship of Jehovah survive? "Hitherto there had been nations with their religions, but there never had been in the world a religion without a nation to act as its embodiment" (A. C. Welch). Out of the agony of his perplexity, preserved in some infinitely moving passages (Jer. xv. 10–18, xviii. 9, 10, 14–18, xx. 7–18) came the solution: recognition of how wonderful was the fact of the relation between his conscious self and the Divine Being he longed to serve. In his ultimate peace in God and victory over "fears without and fightings within," we mark the beginning of the modern view of religious faith. Whatever the function of the nations in God's sight, no conception of a moral God is credible unless the unit of divine interest be the human personality. Jeremiah had discovered that, wheresoever men live, they may find God, if in humility they do justice and love mercy. So he wrote (xxix. 4–14) to the exiles in Babylonia to live there that life of goodness which the prophets had seen to be the worship God desires: a momentous letter, for in the acceptance of his belief lay the continuance of the Jewish race, and the future of religion. "The spirit of Jeremiah, which breathed out on his people after his death, bore fruit in an experience of fellowship with God which satisfied the deepest aspirations of the human soul" (Skinner).

It was now conceivable that religion might survive the State. The last act of the higher prophecy was to give effect to the possibility. Through the constructive idealism of Ezekiel, and the magnificent, monotheistic, oracles preserved in Is. xl.–lv., and no less through the courage and insight of Haggai and Zechariah, whose exhortations effected the rebuilding of the temple in Jerusalem (520 B.C.) and thus set religion in the forefront of the renascent community's life, the Jews—sole link between the ancient Semitic empires and the new era of Persian and Greek domination—began both to preserve their identity in exilic settlements, and in Palestine to revive as a people increasingly conscious that it existed through, and for, its distinctive faith.

The Achievement of Prophecy.—The prophets were thus the saviours of their people. But their achievement should be realized in a wider setting. In their declaration of monotheistic belief and social idealism the world received an interpretation of human life applicable to every people and every age.

Ethical Monotheism. For intelligent men they shattered for ever the mental and moral dangers of polydaemonism and polytheism, proclaiming instead the reality of one only God, to be conceived as the infinitude of moral perfection. If modern terminology is permissible, they held both the transcendence and the immanence of God, and whatever the philosophical obscurities, this doctrine of God, as not less than "personal" in His relation to us, has been the succour of the human spirit, and the source of high and generous virtue for Western civilization. The precise stage at which monolatry (God as the only Being his people must worship, but one among other gods) rose into the pure monotheism patent in II. Isaiah—whether it goes back to Amos, to Elijah, to Moses—cannot be determined; for who shall measure genius? Perhaps the question is wrongly put. In antiquity no one ceased to believe in the existence of many spiritual beings (*cf.* Eph. vi. 12), and practical monotheism was achieved whenever it was felt that there is but one creative Spirit, alone meriting worship, other "gods" being wrong conceptions of God as He truly is, or lesser Spirits who beguile men's worship, and their images assuredly "non-entities," the works of men's hands.

The Worth of the Individual. The prophets discovered the immeasureable worth of human personality. It may be that not until Jeremiah did the significance of the individual's aspiration towards God become vividly apparent; but his experience was creative, and thereafter, aided by Ezekiel's teaching concerning individual responsibility, the instincts of personal piety were liberated to reach out, even through the problem of death, into deeper confidence in Man's worth to God. But this religion of the individual, the product of Prophecy's fundamental thinking and genius for ultimate values, was in no wise individualistic. The heart of prophetic doctrine had been insistence that the will of God is to create a world-order of perfect justice, and that, so long as the moral obligations of each and all go unhonoured, and the lowliest is denied mercy and kindness, there shall be no peace for Man. To the prophets therefore we owe that inestimable incentive for good, the idea of the "Kingdom of God" as the goal of social order.

Worship. "In primitive life," wrote Robertson Smith, "all spiritual and ethical ideas are still wrapped in the husk of a material embodiment. To free the spiritual truth from the husk was the great task that lay before the ancient religions . . . but none of the ritual systems of antiquity was able by natural development to shake itself free from the congenital defect inherent in every attempt to embody spiritual truth in material forms. A ritual system must always remain materialistic, even if its materialism is disguised under the cloak of mysticism." (*Religion of the Semites,* ed. S. A. Cook, whose note, p. 676, should be studied.) The prophets' criticism of worship was revolutionary, but fundamental and constructive, because they saw with absolute lucidity that true worship is a relation of personality, therefore spiritually, and not materially, determined. The human spirit can so use, or regard, material objects that (with vigilance) they may be symbolically or aesthetically helpful to the communion of God and man; but the material must never under any circumstances be treated as in itself an indispensable aid, or barrier, to the reception of divine influence by man. To suppose so is fatally to misapprehend the essential nature of a personal relationship. The prophets were clear: "God's favour is to be found by man's becoming, like Himself, just and merciful . . . Not gifts but fellowship, and the way to fellowship lay not through the sacrificial system re-interpreted, but through conduct; not gifts but justice, not sacrifice but mercy" (G. Buchanan Gray, *Sacrifice,* p. 44).

Privilege. The prophets did not abandon the old idea of Israel as a nation privileged of God; but they transfigured it by the contention that privilege is responsibility, election a call to service. And prophecy itself culminated in the vocation of Jeremiah to a life of sorrow and suffering, heroically accepted for a nation that hated him; and secondly, in the Servant-Songs of II. Isaiah (*see* ISAIAH) where the function of Israel is conceived as a *self*-sacrificial consecration, through unparalleled trials, for the redemption of mankind.

Knowledge of God. There were very many prophets in Israel. How came it that the few advanced towards a rational faith, and the many—equally convinced that their "Word" was from the Lord—failed? To whom, and why, is revelation given? Here again Jeremiah is illuminating. No outward criteria, he felt, avail to discern the true from the false prophets. Ultimately he saw that they were not sensitive, as he was, to the moral obliquity around them, or alive to the evil in their own heart; and he rested at last on the faith that if he surrendered himself absolutely to God's service, accepting whatever loneliness, pains or even death it might entail, God would speak truly through him (Jer. xv. 19). But this attitude had been the basic fact regarding all the great prophets; diverse in many ways, they were men of absolute sincerity and self-surrender. The example of their character is the last and greatest gift of the prophets to mankind, for it is the clue to sound religious experience everywhere: "the pure in heart shall see God."

The Prophetic Consciousness.—Until as late as the 17th century A.D., interest in the prophetic writings was almost exclusively concentrated on the predictive element.

As to this aspect, it should be noted that there are indeed instances of fulfilled presentiments (*e.g.,* Ez. xxxiii. 21, 22), and close correspondences of events with prophetic anticipations; but the prophets are wronged when, as is still sometimes maintained, the validity of their inspiration is felt to depend crucially on fulfilment of predictions, instead of broadly on the rightness of their interpretation of Life as ethical duty, dependent on the reality of the living God. The Suffering Servant anticipates Jesus Christ because the prophet was inspired by the vision of a life of absolute self-sacrifice, and Jesus accepted the conditions of that life and endured its issues. After the Reformation recognition of the poetical form of the prophetic literature led to the necessary analysis of the Books bearing the prophets' names. Criticism in the 19th century was marked by enthusiasm for the prophets as preachers of social righteousness; but present research, psychological and historical, reveals them primarily as men of religious genius, who must be studied in intimate connection with their Eastern environment. Recently it is urged (especially Hölscher) that the inner experiences, and outward behaviour, of the great prophets were closely akin to the ecstasies of the early N^{e}bi'im. Certainly the subconscious is a highly important consideration in studying Hebrew prophecy, but the theory has been pushed to extremes and is sometimes maintained by grotesque forcing of the evidence. There ought to be more careful discrimination of terms, and "ecstasy" reserved for conditions in which the subject has lost all control of mind and body. Stress, inducing at times trance, with audition and vision, is exemplified in the great prophets (especially the "Call" experiences, *cf.* Is. vi.); but to argue that these men virtually never felt conviction break on them at any less intense level of the infinite gradations of emotion, never saw an illuminating parable in nature, never employed a symbolic action, unless in a state of uncontrolled ecstasy, is to go too far. There are indications that they distrusted increasingly the fervours of their opponents (so A. B. Davidson). Whatever resemblances they had to the ordinary prophets, it is the profound differences that will repay study. The extreme forms of the theory are ruled out by the grand consistency of the great prophets: the coherence of their teaching is the supreme psychological fact; and either the oracles we possess are the record of passionate but conscious reflection, or in these men conditions existed which caused the subconscious to produce the rational and the relevant to an unparalleled extent. In any event, an Amos or an Isaiah is infinitely better understood by the analogy of Paul, with his vision on the Damascus road and his enthusiastic yet controlled temperament, than of the ecstatic seer or frenzied N^{e}bi'im. It is true that the Hebrew prophet says, never "I saw," "I know," but "The Lord shewed me," "Thus saith Jehovah." Explanation is found in the psychological ideas which he shared with his contemporaries. H. Wheeler Robinson rightly emphasizes that Man was regarded as intimately dependent on God in his psychical as well as his physical properties; his "breath-soul" open to the invasion of spirits divine and demonic. Hence not only in the trance-experience, but under any intense emotional stress the Hebrew felt that he had "become another man," the "spirit of the Lord had laid hold upon him"; so that it is easy to realize sympathetically why the prophet was convinced that he spake never of himself but as "the messenger of Him that sent me."

The Prophetic Succession.—Hebrew prophecy possesses the unity of a single movement, having origin, development and climax. It ended not in exhaustion, but in the liberation of energy, manifested in personal piety, in efforts to systematize the great ideas (Judaism), and in inextinguishable Hope of a divine purpose in the world (Apocalypse). Hebrew Prophecy recurs not, but "true" prophets—called by many names, Saint, Preacher, Reformer, Scholar—have not ceased to be; for it was part of the work of prophecy to reveal that "all the Lord's people should be prophets," and that the prophet is he for whom God is the living God. Whenever discernment of truth in new aspects is imperative, the interpreting prophetic personality is prominent, and is ever the vitalizing element in religion. Amidst the turmoil at the close of the last century B.C. and the first A.D., it is easy to see why individuals appeared who were manifestly prophetic in type—John the Baptist, Jesus Christ (though the term be inadequate for Him), Paul, Johanan ben Zakkai.

PROPHETS IN THE CHRISTIAN CHURCH

In the nascent organization of the Christian communities (Acts xi. 27, Eph. iv. 11, 1. Cor. xii. 28) prophets are mentioned, ranking next to the Apostles. Sometimes itinerant, sometimes settled in one locality, they were the evangelists of the early Church, credited with a direct spiritual inspiration (χάρισμα) for enlightenment and edification. Men can be appointed to an office; they cannot be appointed to prophecy. The conviction that in Christ all things were made new evoked minds sensitive to spiritual issues.

Therein the Christian prophets were in the true succession; but in all else how different from the lonely Hebrew seers. The Christian prophets were expected to provide intelligible utter-

ances (I Cor. xiv, 32), and were thus differentiated from the ecstatic "speaker in tongues," while they were also distinct from the permanent local officials—catechists, deacons, presbyters, bishops. From the valuable information in the *Didache* it appears that the high regard felt for them lasted fully a century; yet their position was always precarious. Sane enthusiasm might lapse into futile ecstasy (I Cor. xiv, 29–33). Hypocrites might simulate the gift—the *Didache* insists that the prophet is worthy of maintenance and respect only if his piety is indubitable and his conduct "worthy of the Lord." The prestige of the permanent officials increased in comparison with the occasional prophet, whose sole virtue seemed to be his edifying speech. But that gift might also be found among the regular ministers: and if so, how preferable! Lastly the zeal of the prophets might claim an authority over or make ascetic demands on the church which roused antagonism. At the end of the 2nd century the wild prophesying in the Montanist party (significantly of Phrygian origin) hastened the end. Armed with the now-accepted Canon of Holy Scripture ("the law and the prophets until John"), the authorities ruled that "Ecstasy was of the devil not of God" and that "Prophets must not accept gifts," and ere long they ceased as a distinctive class in the church's organization.

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(W. A. L. E.)

PROPIOLIC ACID forms colourless crystals melting at 18° C. to a liquid that boils at 144° C. It is soluble in water and has an odour like that of acetic acid. It has the constitution of acetylenemonocarboxylic acid, $HC{:}C.CO_2H$, and is of interest as being the simplest acetylenic acid. It is obtained by the following reactions: succinic acid is brominated, and dibromosuccinic acid by the action of alcoholic potassium hydroxide yields acetylenedicarboxylic acid, $CO_2H.C{:}C.CO_2H$.

This acid or its monopotassium salt on boiling with water loses carbon dioxide, and propiolic acid is produced. Furthermore, carbon dioxide reacts with monosodium acetylide, C_2HNa, under pressure to give the sodium salt of propiolic acid. On exposure to light, propiolic acid polymerizes into trimesic acid (benzene-1:3:5-tricarboxylic acid).

(G. W. Wd.)

PROPORTIONAL REPRESENTATION, an electoral arrangement designed to secure that the representative assembly shall be an exact reflection, a "snapshot," of the voting strength of parties among the electorate. To its proponents the case for proportional representation (P.R.) is fundamentally the case for representative government; every trace of opinion, be it ever so small, ought to be represented in the legislature as near as possible to its proportional mathematical claim.

Opponents of P.R. consider the system logical only if parliament is conceived, in the words of Edmund Burke, as "a Congress of ambassadors from different and hostile interests." If, on the other hand, parliament is "a deliberative assembly of one nation with one interest, that of the whole," the majority system is required. The latter introduces a process of integration, making it necessary for all parties to appeal to a cross section of the various groups of which a country consists. Thus, a common denominator is found for all of them.

P.R. owes its intellectual standing in continental Europe and Latin America mainly to Victor Considérant, and in the Anglo-Saxon countries to John Stuart Mill. Mill emphasized the need for adequate representation of minorities; Considérant felt that while final parliamentary decision required the rule of the majority, the earlier stage of parliamentary deliberation was well compatible with the introduction into a parliamentary body of a variety of groups by P.R. The appeal of these arguments has been widespread. The end of World War I left, among the countries generally accepted as democratic, only the Anglo-Saxon countries and France with the majority system.

In the case of both the majority system and of P.R. there are a number of variations. In Great Britain, the members of the commonwealth and the United States, the plurality system dominates; in a single-member district the candidate with the highest vote is declared elected even if he has secured less than 50% of the total. Imperial Germany used the system of runoff elections; if no candidate had an over-all majority in the first ballot, a second ballot decided between the two strongest competitors. In the France of the third republic a more liberal form of the second ballot was used, in which all candidates, even those who had not participated in the first ballot, could compete. The candidate with a plurality of the votes won, although coalitions between the rightist and leftist parties usually cut down the number of candidates and made attainment of an absolute majority likely. These coalitions were often connected with unsavoury intrigues. To obviate these difficulties, Australia adopted, for its house of commons, the alternative vote, which requires an absolute majority and where there is only one ballot, in which the voter instead of marking his choice with an "X," marks the candidates in the order of his preference (whence "preferential vote" system), 1, 2, 3, etc.; and then the returning officer eliminates the bottom candidates in turn, distributing among the top candidates the preferences marked on the eliminated ballots.

All varieties of majority voting deviating from the plurality system increase the chances of minor parties and have proved incompatible with a two-party system. P.R. attempts to do more than assure an absolute majority for the victorious candidate. It begins by creating large constituencies with a number of seats. In the English Proportional Representation society's suggested program, called the "single transferable vote," a constituency of at least 300,000 inhabitants was suggested and at least five seats. In the German system prevailing between 1919 and 1933, the constituencies averaged nearly 1,000,000 electors, and 15 or 16 representatives. The severalty of representatives made it possible for any well-knit minority with a quota of votes (*i.e.,* the lowest number required, in the circumstances) to get representation. Votes cast for a member were not to be lost to the party if he personally should fail, for they were transferred or accredited to other members of the party who held them to make up the quota. This can be done in a number of ways. The system advocated in England is that the voter shall be free to indicate his preference by numbers against the long list of candidates, the returning officer then distributing the surplus preferences of successful candidates and those with no chance among those who are designated by the preferences, until all the seats are filled by those with quotas. This system leaves the voter free of party dictation.

Other list systems permit the voter to mark a preference for one or several candidates; in some cases, such preferences may even be given to candidates of more than one party. The parties get the mathematical share of the seats to which their aggregate vote entitles them. In Germany each party got one representative for each 60,000 votes it secured, while fractions of 60,000 were added together for each party (within certain limits), and again for each such 60,000 the party was permitted to nominate an extra member.

The French system of P.R., adopted in 1945, was based on party lists, in the framework of the *département.* It was feared that this election law, which, because of the D'Hondt system, favoured large parties, would, if applied in the elections of 1951, have given the Gaullists and Communists a majority of the seats even with somewhat less than a majority of the votes. Therefore, it was provided that wherever a party or a coalition of parties secured the absolute majority of the votes in a constituency, it obtained all the seats, although for Paris and its suburbs, where the extremists were strong, a form of P.R. more favourable to the centrist parties than the D'Hondt system was used.

Germany used for the bundestag elections of 1949, as well as for a number of elections within the various Länder, a system which combined single-member constituencies with P.R. In each of the constituencies the candidate with a plurality of the votes was elected. Over-all proportionality between the votes cast for a party and the seats attributed to it was attained by distributing additional seats, usually 40% of the total, on a so-called "reserve list," to the parties which had obtained fewer seats than corresponded to their share of the votes.

The merits of P.R. lie, according to its supporters, in its equity. The demerits of the system as they operate in Europe are these: (1) The personal contact between member and constituency is reduced; in its place the party machine rules by deciding the order of candidates on the list and by requiring teamwork among candidates which results in the "star" man helping the mediocrities. (2) A premium is placed upon the use of mechanical devices to make electors go to the poll—this is a direct result of a large constituency. (3) Small parties are kept in existence, or encouraged to organize themselves, which seriously disturbs the process of parliamentary government where a compact and single-party majority in office faced by an opposition similarly constituted is essential to stability, vigour and responsibility of executive. Opponents of the system hold that in a number of countries, including Italy and Germany, the various factors making for the weakness of

democracy would not have sufficed to make possible the victory of dictatorship had it not been for the dispersal and the demoralization of the prodemocratic forces by P.R.

P.R. has, in the form of the single transferable vote, also been used for a number of U.S. cities, most of which, however, later abandoned it. Adopted to facilitate the victory of reform groups over political machines, it was held to have led to the frustration of the voter who could not cope with its complexities, to the intensification of racial and alphabetical voting and (in particular in New York city) to the election of extremists. By 1952, only nine municipalities retained it, six of them in Massachusetts. The leading P.R. city is Cincinnati, O.

France took a step away from P.R. in the election law of 1951 and Italy in the election law for municipalities adopted during the same year; in 1952 the Greek government endorsed the majority system after the U.S. ambassador had, with the approval of the U.S. state department, expressed the view that P.R. led to a degree of instability which jeopardized the success of U.S. aid. The proponents of P.R. scored a success, however, when in 1950 the single transferable vote, also used in Ireland, was adopted for the Australian senate.

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PROPOSITION, in logic, means usually the verbal expression of a judgment (*q.v.*). Propositions, like judgments, are classified in various ways. *See* CATEGORICAL; JUDGMENT; LOGIC.

PROPYLAEA, the name given to a porch or gatehouse, at the entrance of a sacred or other enclosure in Greece; these usually consisted, in their simplest form, of a porch supported by columns both without and within the actual gate. The name is especially given to the great entrance hall of the Acropolis at Athens, which was begun in 437 B.C. by Pericles, to take the place of an earlier gateway. Probably because of political difficulties and the outbreak of the Peloponnesian War, the building was never completed according to the original plans; but the portion that was built was among the chief glories of Athens, and afforded a model to many subsequent imitators. The architect was Mnesicles; the material Pentelic marble, with Eleusinian blackstone for dados and other details.

The plan of the Propylaea consists of a large square hall, from which five steps lead up to a wall pierced by five gateways of graduated sizes, the central one giving passage to a road suitable for beasts or vehicles. On the inner side toward the Acropolis, this wall is faced with a portico of six Doric columns. At the other end of the great hall is a similar portico facing outward; and between this and the doors the hall is divided into three aisles by rows of Ionic columns. The western or outer front is flanked on each side by a projecting wing, with a row of three smaller Doric columns between antae at right angles to the main portico. The north wing is completed by a square chamber which served as a picture gallery, but the south wing contains no corresponding chamber, and its plan has evidently been curtailed; its front projected beyond its covered area, and it is finished in what was evidently a provisional way on the side of the bastion before the little temple of Victory (*Nike*).

From this and other indications W. Dörpfeld inferred that the original plan of Mnesicles was to complete the south wing on a plan symmetrical with that of the north wing, but opening by a portico on to the bastion to the west; and to add on the inner side of the Propylaea two great halls, faced by porticoes almost in a line with the main portico, but with smaller columns. This is questionable as it would have interfered with sacred objects such as the precinct of Artemis Brauronia and the altar of Nike. Nevertheless, the unfinished surface of the walls and the rough bosses left on many of the blocks show that the building was never completed. The Propylaea were approached in Greek times by a zigzag path, terraced along the rock; this was superseded in Roman times by a broad flight of steps. In mediaeval times the Propylaea served as the palace of the dukes of Athens; they were much damaged by the explosion of a powder magazine in 1656. The tower of Frankish or Turkish date that stood on the south wing was pulled down in 1874.

The term is also applied to various monumental gateways of modern times, especially in Germany. Outstanding examples are: the propylaea at Munich, by Leo von Klenze (finished 1862), with sculpture by Schefzky; and that in Berlin, also known as the Brandenburger Tor, by K. G. Langhaus (1784), which was directly inspired by the Propylaea at Athens.

See R. Böhn, *Die Propylaeen der Akropolis zu Athen* (1882); W. Dörpfeld, articles in *Mittheilungen d. d. Inst. Athen.,* vol. x (1885). (E. GR.)

PROPYL ALCOHOLS, two compounds of this name, with the same formula C_3H_7OH exist, and both come into prominence in connection with modern developments of industrial organic chemistry.

Normal propyl alcohol, $CH_3.CH_2.CH_2.OH$, is now obtainable as a by-product in the synthesis of methyl alcohol (*q.v.*) by condensing carbon monoxide and hydrogen in presence of a zinc-chromite or zinc-cobalt-chromite catalyst at 400° C. under 200 atm. pressure. (*See* PRESSURE CHEMISTRY.) It is a colourless fragrant liquid boiling at 97.4° C. and miscible with water in all proportions. It cannot be separated from water by distillation since the two compounds form an azeotropic mixture. (*See* DISTILLATION.) *n*-Propyl alcohol occurs in fusel oil and may be prepared by any of the synthetic methods applicable to primary alcohols. (*See* ALCOHOLS.)

Isopropyl alcohol, $(CH_3)_2CH.OH$, is now manufactured on an extensive scale from propylene, $CH_3:CH:CH_2$, obtained by the cracking of petroleum. (*See* OLEFIN.) This olefin is absorbed in sulphuric acid, the liquid diluted with water and distilled, when isopropyl alcohol is obtained. It is a colourless, fragrant liquid boiling at 82.7° C. It is used industrially in the extraction of alkaloids and other compounds of therapeutic interest.

PROPYLON, in architecture, a monumental entrance gate; in Egypt two great piers with a flat lintel set before the front pylon of a temple. In Greece a columned porch on both sides of a wall of doors gives entrance to a sanctuary or agora.

PROROGATION, a postponement, specifically, in Great Britain, the termination without dissolution of a session of parliament by discontinuing the meetings until the next session. A prorogation of parliament affects both houses, and thus differs from an "adjournment," which does not terminate the session and is effected by each house separately by resolution.

PROSCENIUM, originally, in the Greek theatre, the colonnade supporting a platform in front of the scene building (*σκηνή*, Latin *scena*). Scenery was set between the columns. In the modern theatre the word proscenium is used particularly in connection with the arch (proscenium arch) framing the stage.

PROSE, the plain speech of mankind, when written or composed without reference to the rules of verse. It has been usual to distinguish prose very definitely from poetry (*q.v.*). Pierre de Ronsard said that to him prose and poetry were "mortal enemies." But "poetry" is a more or less metaphysical term, which cannot be used without danger. For instance, an ill-inspired work in rhyme cannot be said to be poetry, and yet most certainly is not prose. On the other hand, a work of highly wrought nonmetrical writing is often called a prose-poem. This shows that the antithesis between prose and poetry is not complete. Prose, therefore, is best defined as comprising all forms of careful literary expression which are not metrically versified, and hence the definition from *prorsus* (direct or straight), the notion being that it is straight and plain, and is used for stating precisely that which is true in reason or fact.

Prose, however, is not everything that is loosely said. True, it is the result of conversation, but that conversation is not necessarily, nor often, prose. Prose is not the negation of all laws of speech; it rejects merely those which depend upon metre. What its laws are is not easy to say. But this is plain; as prose depends on the linking of successive sentences, the first requirement is that these sentences should be lucidly arranged. In prose, that the meaning should be given is the primal necessity. But as it is found that a dull, clumsy, monotonous arrangement of sentences is fatal to the attention of the listener or reader, it is needful that to plainness should be added various attractions and ornaments. The sentences must be built up in a manner which displays variety and flexibility. There should be a harmony, and even a rhythm, in the progress of style, care being taken that this rhythm and this harmony are not recognizably metrical. Again, the colour and form of adjectives, and their sufficient yet not

excessive recurrence, is an important factor in the construction of prose. The omission of certain faults, too, is essential. In every language grammatical correctness is obligatory. Here we see a distinction between mere conversation, which is loose, fragmentary and often even ungrammatical; and prose, which is bound to weed away whatever is slovenly, and to watch closely lest merely colloquial expressions should slip in. What is required is a moderate and reasonable elevation without bombast or bathos. Not everything that is loosely said is prose, and the celebrated phrase of M. Jourdain is not exactly true, for all the loose phrases which M. Jourdain had used in his life, though they were certainly not verse, were not prose either. We must be content to say that prose is literary expression not subjected to any species of metrical law.

Greek.—The beginnings of Greek prose are very obscure. It is probable that they took the form of inscriptions, and gradually developed into historical and topographical records. We come down to something definite when we reach Hecataeus and Herodorus; and, although their writings have disappeared, we know enough to see that by the 5th century B.C. the use of prose in its modern sense had been established. We even know the character of the style of Hecataeus, and we hear of its clearness, its grammatical purity, its individuality—qualities which have been valued ever since. These writers were succeeded by Hellanicus, who wrote many historical books now lost, and by Herodotus, whose noble storehouse of chronicle and legend is our earliest monument of European prose. When once non-metrical language could be used as by Herodotus, it was plain that all departments of human knowledge were open to it. But it is in Ionia and the Asiatic islands that we find it cultivated by philosophers and critics. The earliest of these masters of prose survive only in much later records of their opinions; in philosophy the actual writings of Thales, Anaximander, Pythagoras and Empedocles are lost, and it is likely that their cosmological rhapsodies were at least partly metrical. We come into clearer air when we cross to Attica: Thucydides' priceless work has most fortunately come down to us; and Xenophon continued it in the spirit of Thucydides, and carried Greek prose to a great height of easy distinction. But it is in philosophy that prose in Greece gains flexibility and variety, proving itself an unsurpassed vehicle for the finest human thought. The philosopher Plato is the greatest prose writer of Greece, and, in the view of many well qualified to judge, of the world. In his dialogues we see what splendour, what elasticity, what exactitude, this means of expression had in so short a time developed; how little there was for later prose-writers to add. The rhetoricians were even more highly admired by antiquity than the philosophers, and ancient, unlike modern, opinion would perhaps have set Demosthenes higher than Plato. In Aristotle we see the conscious art of prose-writing subordinated to the preservation and explanation of facts, and after Aristotle's day there is little to record in a hasty outline.

Latin.—The Romans obeyed the universal law by cultivating verse long before they essayed the writing of prose. The earliest historians of whom we have definite knowledge, Fabius Pictor and Cincius Alimentus, wrote in Greek. The earliest annalist who wrote in Latin was Hemina; the works of all these historians are lost. A great deal of primitive Roman prose was occupied with jurisprudence and political oratory. By universal consent the first master of Latin prose was Cato, the loss of whose chief works is to be deplored; we possess from his pen only a treatise on agriculture. In the next generation we are told that oratory was carried to the highest point by Marcus Antonius and Licinius Crassus—"by a happy chance their styles were exactly complementary to one another." Unfortunately none but inconsiderable fragments survive to display their qualities. Happily, however, those qualities were combined in a man of genius, whose writings have come down to us; this is Cicero, whose prose exhibits the Latin language to no less advantage than Plato's does the Greek. From 70 to 60 B.C. Cicero's literary work lay mainly in the field of rhetoric; after his exile he was chiefly occupied with theoretical treatises. The beautiful essays of his old age comprise two little masterpieces, *De amicitia* and *De senectute* (45 B.C.). It is to the collection of the private letters of Cicero, published after his death by Atticus and Tiro, that we owe our intimate knowledge of the age in which he lived, and these have ever since been held models of epistolary prose. Of Cicero's greatest contemporary, Julius Caesar, much less has been preserved, and this is unfortunate because Roman critical opinion placed him among the very chief of prose-writers; but we retain his *Commentaries*. The prose of Sallust, who followed Caesar, is hard, brief and sententious. The writers who succeeded him neglected these qualities, and Latin prose became more diffuse and rhetorical. But it was wielded by one writer of the highest genius, Titus Livius, who enriched the tissue of Latin prose with ornament which hitherto had been confined to poetry; this enables him "to advance without flagging through the long and intricate narrative where a simpler diction must necessarily have grown monotonous" (Mackail). The periodic structure of Latin prose, which had been developed by Cicero, was carried even further by Livy. The style of Pollio, who wrote a *History of the Civil Laws*, was much admired, and the loss of this work must be deplored. A different species of prose, the *plebeius sermo*, or colloquial speech of the poor, is partly preserved in the fragments of a Neronian writer, Petronius Arbiter. Of the Latin prose-writers of the silver age, Seneca, Quintilian and Tacitus, nothing need here be said.

English.—The independence of English prose is a fact which rests on a firm basis. "The Code of Laws of King Ine" dates from the 8th century, and there are various other legal documents which may be hardly literature in themselves, but which are worded in a way that seems to denote the existence of a literary tradition. After the Danish invasion, Latin almost ceased to be known, and translations began to be required. In 887, Alfred wrote in English, with the help of scholars, his *Hand-Book;* this, probably the earliest specimen of finished English prose, is unhappily lost. His English version of the *Cura pastoralis* was probably completed in 890. Later still Alfred produced translations from Bede, Orosius, Boethius and other Latin authors, and, in 900, closing a translation from St. Augustine, we read "Here end the sayings of King Alfred." The prose of Alfred is simple and clear without pretension. After him the first name of eminence which we encounter is that of Àelfric, who, about 997, began to translate, or rather to paraphrase, certain portions of the Bible into a very finished English. A little later vigorous prose was put forth by Wulfstan, archbishop of York (d. 1023). At the Conquest, the progress of English prose was violently checked, and, as has been said, it "was just kept alive, but only like a man in catalepsy." The *Annals* of Winchester, Worcester and Peterborough were carried on in English until 1154. Except in a few remote monasteries, English ceased to be used, even for religious purposes, and the literature became exclusively Latin or French. We may perhaps say that modern English prose begins with the *Testament of Love* of Thomas Usk (*c.* 1388). To the same period belong *The Tale of Melibee* and *The Parson's Sermon* by Chaucer; the treatises of John of Trevisa, whose style in the *Polychronicon* has a good deal of vigour; and the three versions of the *Travels* of Jean à Barbe, formerly attributed to "Sir John Mandeville." The composite text of these last-mentioned versions really forms the earliest specimen of purely secular prose which can be said to possess genuine literary value, but again the fact, which has only lately been ascertained, that "Sir John Mandeville" was not an original English writer robs it of much of its interest.

The anonymous compiler-translator can no longer be styled "the father of English prose." That name appears to belong to John Wyclif, who, in the course of his career as a controversialist, more and more completely abandoned Latin for English. The translation of the English Bible was begun by Nicholas Hereford. The completion of this work is usually attributed, but on insufficient grounds, to Wyclif himself. A new version was almost immediately started by John Purvey, another Wyclifite, who completed it in 1388. We are still among translators, but towards the middle of the 15th century Englishmen began, somewhat timidly, to write original prose. Capgrave, an Augustinian friar, wrote a chronicle of English history down to 1417; Sir John

Fortescue produced about 1475 a book on *The Governance of England;* and Reginald Pecock attacked the Lollards in his *Repressor of Over Much Blaming of the Clergy* (*c.* 1450). The prose of Pecock is sometimes strangely modern, and to know the ordinary English prose of the 15th century it is more useful to turn to *The Paston Letters.* The introduction of printing into England is coeval with a sudden development of English prose, a marvellous example of which is to be seen in Caxton's edition of Malory's *Morte d'Arthur,* in which the capacities of the English language for melody and sweetness were for the first time displayed. Caxton himself, Lord Berners and Lord Rivers, added an element of literary merit to their useful translations.

With the Renaissance, *Richard III.,* whether by Sir Thomas More or by Cardinal Morton, was a work of considerable importance; *Utopia* (1516) was unfortunately composed in Latin, which still held its own as a dangerous rival to the vernacular. In his *Governor* (1531) Sir Thomas Elyot added moral philosophy to the range of subjects thought proper for English prose. In the same year Tyndale began his version of the Bible, the story of which forms one of the most romantic episodes in the chronicles of literature; at Tyndale's death in 1536 the work was taken up by Coverdale. The *Sermons* of Latimer (1549) introduced new elements of humour and vigour. The earliest true biography was the *Life of Cardinal Wolsey,* by George Cavendish, written about 1557, but not printed until 1641. In the closing scenes of this memorable book, which describe what Cavendish had personally experienced, the perfection of easy English style is reached for the first time. The prose of the middle of the 16th century—as exemplified in Sir Thomas Wilson, Roger Ascham, and Sir John Cheke—is clear, unadorned and firm, these Englishmen holding themselves bound to resist the influences coming to them from Italy and Spain. Equal simplicity marked such writers as Foxe, Stow and Holinshed, who desired a straightforward prose in which to present their information. But Hoby and North introduced not a few exotic graces, and prepared the way for the innovations of Lyly in *Euphues* (1579). The extravagances of Lyly outdid those of his continental prototypes, and euphuism became a disturbing influence which, it may be, English prose has not, even yet, entirely thrown off. In spite of its popularity, it was opposed in its own day, not merely by the stately sobriety of Hooker, but by the sweetness of Sir Philip Sidney. Raleigh wrote an English prose perhaps more majestic than any which preceded it, but he revelled in length of sentence and ponderosity of phrase, so that the prestige of *The History of the World* on the whole delayed the emancipation of English prose. The direct influence of euphuism was seen for some time in the work of poets like Lodge and Greene, and divines like Andrewes; its indirect influence in the floweriness and violence of most prose down to the Restoration.

Donne had a sonorous majesty of style; and Burton could use English with humour and vivacity when he gave himself the chance. In spite of the skill with which, during the civil wars and the Commonwealth, authors like Jeremy Taylor, Fuller and Milton manipulated prose, and in spite of the magnificence of Sir Thomas Browne, it was not until shortly before the Revolution that English prose reached its perfection. According to Dr. Johnson, Sir William Temple (1628–99) was the first writer who gave cadence to English prose. The new tendency was all in favour of brevity and crispness of shorter sentences and easier constructions. Not a little of the majesty of the earlier age was lost; but for practical purposes prose became a far more businesslike implement than it had hitherto been. The treatises of Halifax, or the sermons of South, mark the change. The power of English speech was first comprehended perhaps by Dryden, who combined dignity and even pomp of movement with an ease and laxity on occasion which gave variety to prose, and approximated it to ordinary speech. This then may be called the foundation of modern English prose, which has extended into no departments not recognized, at least in essence, by Bunyan, Dryden and Temple. The ensuing varieties have been mainly matters of style. In the 18th century, for instance, there was a constant alternation between a quiet, rather cold elegance and precision, which was called the Addisonian manner, and a swelling, latinized style, of which Johnson is the most famous exemplar. But as far as arrangement and syntax are concerned, it cannot be said that English prose has altered essentially since about 1680. It is, however, to be noted that in the course of the 19th century attempts were made to restore the beauty and variety of early 17th-century diction.

Icelandic.—The independent invention of prose by the Icelanders is one of the most singular phenomena in history. It resulted from the fact that story-telling was a recognized form of amusement in the isolated life of an Icelandic household. Something of the same kind had existed in Norway before the exodus, but it was in Iceland that it was reduced to an art. It is remarkable how suddenly the saga, as a composition, became a finished work. The deliberate composition of sagas began about the year 1030, and it is recorded that Ari Fródi (1067–1148) was the first man in Iceland who wrote down stories. Many of Ari's books are lost, but enough survive to show what Icelandic prose was in his hands, and the impress of his rich and simple style is felt in all the succeeding masterpieces. Snorri, and the anonymous authors of *Njala, Laxdaela,* and the rest, exhibit simple prose style at its highest. The great historian, Sturla (1214–84), is the latest of these classic writers of Iceland, and after his death there was a rapid decline. The splendid prose of these two centuries stands unrelated, an unparalleled portent in European literature.

Spanish.—In Castilian, as elsewhere, verse is far advanced before we meet with any distinct traces of prose. A religious treatise is attributed to a monk of Navarre, writing in the 13th century. Between 1220 and 1250 a chronicle of Toledo was indited. But the earliest prose-writer of whom Spain can really boast is King Alphonso the Learned (1226–84), in whose encyclopaedic treatises "Castilian makes its first great stride in the direction of exactitude and clearness" (Fitzmaurice-Kelly). Almost all the creditable prose of the end of the 13th century is attributed to Alphonso, who was helped by a sort of committee of authors. The king's nephew, Juan Manuel (1282–1347), author of *Conde Lucanor,* carried prose to a further point in delicacy and precision. The poet Ayala (1332–1407) was another gifted artificer of Spanish prose, which suffered a setback in the hands of his successors, Santillana and Mena. It rose once more in *The Sea of Histories* of Pérez de Guzmán (1378–1460), in whom the lucid purity of Castilian prose is for the first time seen. In the 15th century the shapeless novel of chivalry was predominant, while in the age of Ferdinand prose decayed. The next great writer whom we meet with is Guevara (d. 1545), whose *Dial of Princes* exercised an influence which even extended to English prose (in North's well-known version). The historians of this period were of less value. The earliest picaroon novel, *Lazarillo de Tormes* (1554), introduced a new form and exhibited Castilian prose style in a much lighter aspect. Still greater elegance is met with in the writings of Juan de Valdés and of Luis de León. Of the latter Fitzmaurice-Kelly says that "his concise eloquence and his classical purity of expression rank him among the best masters." The instrument, accordingly, was ready to the hand of the supreme magician Cervantes, whose *Don Quixote* was begun a few years (about 1591) after *Los Nombres de Cristo* of Luis de León. The prose of Lope de Vega is stately and clear, but admittedly has little importance in comparison with his verse. Quevedo's style had the faults of antithesis and obscure ingenuity; but his *Visions* (1627) are of course famous. The latest struggles of a decadent critical conscience, battling against affectation, are seen in Gracián (1601–58) and Molinos (*c.* 1640–97). When Spanish prose revived in the 19th century, in the person of Larra (1809–37), the influence of French models was found to have deprived it of distinctly national character, while giving it a fresh fluidity and grace.

French.—There had long been a flourishing versified literature in the vernacular of France, before anyone thought of writing French prose. It was the desire to be exact in giving information which led to a partial divergence from metre. The translator of the *Chronicle of Turpin* mentions that he writes in prose "because rhyme entails the addition of words not in the Latin." Thus about 1200 verse began to be abandoned by chroniclers who had some definite statements to impart. They ceased to sing;

they wrote as those around them spoke. The earliest French prose was translated from the Latin, but Baldwin VI. (d. 1205) is said to have commissioned several scribes to compile in the vulgar tongue a history of the world. If this was ever written it is lost, but we possess a *Book of Stories* written about 1225 by a clerk at Lille, which may fairly be said to be the beginning of French prose history. When once, however, a taste for prose was admitted, the superiority of that medium over verse as material for exact history could not but be perceived. The earliest French prose-writer of genius was Villehardouin, who put down memoirs of his life between 1198 and 1207; he left his book, *The Conquest of Constantinople,* incomplete. In the history of prose, Villehardouin takes an eminent place. In his style are seen many of the most precious elements of French prose, its lucidity, its force, its sobriety and its charm. He had been trained as an orator, and was content to write as he had learned to speak. He was followed by other admirable writers of memoirs, Robert of Clari, Henri of Valenciennes, the anonymous chronicler of Béthune, to whom we owe the famous description of Bouvines, and the Minstrel of Reims. The last-named finished his *Récits* in 1260. These works in the new easy manner of writing were found to be as elegant and as vivacious as any in verse. They led the way directly to the earliest historian of modern Europe, Joinville, who finished his *Histoire de St. Louis* in 1309. A century later Froissart left his famous *Chroniques* unfinished in 1404, and again 100 years passed before Philippe de Commines dropped the thread of his *Mémoires* in 1511. These three are simply the most eminent figures in a great cloud of prose-writers, who helped to facilitate the use of the national language. In the 15th century, moreover, Antoine de la Salle deserves mention as practically the earliest of French novelists. But with the Renaissance came the infusion into France of the spirit of antiquity, and in Rabelais there was revealed an author of the very highest genius. The year 1532, in which the first brief sketch of *Gargantua* appeared, was critical in French literature. In 1549 appeared the *Défense et illustration de la langue française* of Joachim du Bellay, in which the foundations of French literary criticism were firmly laid. The liberation of the language proceeded simultaneously in all directions. In 1539 it was officially decreed that all judicial acts were thenceforward to be written "en langage maternal français." Calvin led the theologians, and his precise and transparent prose gave the model to a long line of sober rhetoricians. It is in Calvin that we meet for the first time with a simple French prose style, which is easily intelligible to-day. There is some pedantry in St. François de Sales, some return to the spirit of mediaeval French in Montaigne; so that the prose of these great writers seems to us more antiquated than that of Calvin. Yet the *Institution* belongs at latest to 1560, and the immortal *Essais* at earliest to 1580. We are approaching the moment when there should be nothing left for French prose to learn. But we pause at Brantôme, in whom the broad practice of French as Froissart and the mediaeval chroniclers had used it was combined with the modern passion for minute and picturesque detail. With the beginning of the 17th century there sprang up almost an infatuation for making prose uniformly dignified, for avoiding all turns of speech which could remind the reader of the "barbarous" origins of the language; the earliest examples of this subjection of eloquence to purely aristocratic forms have been traced back to the *Servitude volontaire* of La Boétie (1530–63). In the pursuit of this dignity the prose writers of the 16th century ventured to borrow not words merely but peculiarities of syntax from Greece and Rome. The necessity of remaining intelligible, however, checked excess, and after a few wild experiments the general result was discovered to be the widening of the capacities of the language. In the 17th century a great stimulus was given to easy prose by the writers of romances, led by d'Urfé, and by the writers of letters, led by Balzac, with whom French prose lost its heaviness and its solemnity; it became an instrument fit to record the sentiments of social life; here was discovered what Voltaire calls the *nombre et harmonie de la prose.* French style became capable of still more when it was used by Descartes and by Pascal to interpret their majestic thoughts. At this moment, in 1637, the French Academy was founded, for the distinct purpose of purifying and enlarging the French language; and in time, out of the midst of the academy, arose the important *Remarques* (1647) of Vaugelas, a work of grave authority, which was the earliest elaborate treatise on the science of prose in any language. Antiquated as Vaugelas now seems, and little regarded by modern writers his work is still the basis of authority on the subject. In common with his colleagues he laid down laws by which harmony of structure, a graceful sobriety and exactitude of expression, could be secured to every practised French writer. He was not accepted as infallible, even in his own age; he was immediately exposed to the criticism of La Mothe le Vayer, who, however, was radically at one with him regarding the basis of his definition. The great demerit of the early academicians was that they knew little about mediaeval French. They thrust everything aside which they regarded as barbarous, and the work of the 19th century was to recover from a past behind Rabelais elements of great value which the 17th had arbitrarily rejected. In the succeeding centuries there has been a vast extension of the practice of French prose, but in spite of all neologisms, and of the waves of preciosity which have periodically swept over the French language, the treatise of Vaugelas remains the final code in which the laws that govern French prose are preserved.

Italian.—The case of prose in Italian has this unique feature that, instead of gathering form obscurely and slowly, it came into sudden existence at the will of one of the greatest of writers. Latin had almost universally been used in Italy until the close of the 13th century, when Dante created a vernacular prose in the non-metrical part of his *Vita Nuova* (*c.* 1293). For a long time the prose of Dante stood practically alone, and Petrarch affected to despise the works which his great predecessor had written in the vulgar tongue. But about 1348 Boccaccio started his *Decameron,* which gave classic form to the prose romance of Italy. It should have been greatly to the advantage of Italy that in the hands of Dante and Boccaccio prose was born full-grown, and had not to pass through the periods of uncertain development which awaited it elsewhere. After this brilliant beginning, however, there was a decline, the writers of the next age lacking the courage to be independent of antiquity. There was a return to Latin phraseology which made many works almost macaronic in character; the famous *Hypnerotomachia* of Colonna is an instance. Something of the purity of Boccaccio was recovered by Sannazaro in his *Arcadia* (1489); even Sannazaro, however, did not see how needful it was to cast off Latin constructions. At length Machiavelli and Guicciardini succeeded in releasing prose from the yoke of Rome, and in writing undiluted Tuscan. In the 16th century the prose writers of Italy became extremely prolific, with Pietro Bembo at their head. The novelists were now prominent, but, although they take a foremost place in the history of Italian literature, there was little art in their employment of language. Many of them were born out of Tuscany, and, like Bandello, never learned the rules of pure Italian prose. Since the 16th century Italian would seem to have undergone no radical changes, and its prose has been stationary in form. At the close of the 19th century a new school of writers, with Gabriele d'Annunzio at its head, created a demand for a new prose, but the remedy suggested by these innovators was neither more nor less than a return to Boccaccio and Machiavelli.

German.—The earliest attempts in German prose belong to the age of Charlemagne, and the first example usually quoted is the *Strassburger Eidschwüre* of 842. For all literary purposes, however, metrical language was used exclusively during the *mittelhochdeutsch* period, which lasted until the end of the 13th century. What little prose there was, was limited to jurisprudence and theology. David of Augsburg (d. 1272) is named as the earliest vernacular preacher, but only one of his sermons has reached us. More important was Berthold "the Sweet" (1220–72), whose sermons were published in 1824. Historical prose began with the Saxon Chronicle of 1248. There was little to record in the next two centuries, until prose was revived by Geiler von Kaisersburg (1445–1510) in his sermons. About the same time translations were made of the *Decameron* and other Italian novelle. The devel-

opment of prose in Germany is, however, negligible until we reach Luther's Bible (N.T., 1522), on which all classic German prose is based. Johann Fischart composed important secular books in the vernacular, in particular the *Bienenkorb* (1579) and an imitation of *Gargantua* (1575), the earliest German novel. Nearly a century passes before we reach the curious picaresque romance of *Simplicissimus* (1669) of Grimmelshausen. But the neglect of prose by the German nation was still general. Even men of the stamp of Leibnitz wrote in Latin or French. What Luther had done was, however, completed and confirmed in the middle of the 18th century by Lessing, the creator of modern German prose. The critical period in this revival was 1764 to 1768, which saw the production of *Laocoön* and the *Hamburgische Dramaturgie*. We pass presently to Jean Paul Richter, and so to Goethe, in whose hands German prose became the organ of thought and eloquence which it has been ever since.

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PROSECUTION, the procedure by which the law is put in motion to bring to trial a person accused of crime (*see* Criminal Law; Indictment). In theory in Great Britain the king is in all criminal offences the prosecutor, because such offences are said to be against his peace, his crown and dignity, but in practice such prosecutions are ordinarily undertaken by the individuals who have suffered from the crime. This is a different procedure from that prevailing in Scotland and European continental countries, in all of which a public department or officer undertakes the prosecution of offences.

In the United States, crimes against the Federal Government are prosecuted by the different United States attorneys and their assistants under the general supervision of the United States attorney-general. In the States, prosecution is by district, State's or county attorneys, or their assistants, somewhat under the supervision of the State attorney-general. Sometimes a special prosecutor is named. So it has come about that those who comprise the prosecuting force are termed collectively the prosecution.

PROSERPINE, generally accounted the Latin form (*Proserpina*) of Persephone, a Greek goddess, daughter of Zeus and the earth-goddess Demeter (*q.v.*). Some, however, regard *Proserpina* as a native Latin form, not borrowed from the Greek, and connected with *proserpere*, meaning the goddess who aided the germination of the seed. (*See* Persephone.)

PROSODY, properly the study of accent, breathing and quantity. In modern use, the theory of versification. (*See* Verse.)

PROSPECTING, whether it be the search for minerals by a lone prospector, or by two or more prospectors, or by an organized party of trained men in a more or less unknown region, or by an operating company in its producing property at depth, is how our mineral deposits are discovered and developed. Geophysical prospecting has helped, particularly with petroleum. In prospecting, time, patience, optimism, and money are essentials. (*See* Geophysical Prospecting; Petroleum.)

The mineral industry of any advanced country is second in importance to its welfare, agriculture being first; therefore, prospecting for and the mining, metallurgy, and manufacturing of metals are basic to civilization.

Generally, when prospecting is mentioned, gold comes to the mind of the layman, but there are many other minerals of considerable marketable value and industrial use—antimony, asbestos, bauxite, beryllium, chromite, graphite, manganese, mercury, mica, molybdenum, nickel, platinum group, tantalum, tin, titanium, tungsten, uranium, vanadium, zinc, and zirconium, for example.

Seepages of oil and structures favourable thereto, and oil-bearing shale should be examined.

Even deposits of building stones, cement-making rock, and sand and gravel should not be overlooked.

In recent years, to list a few important deposits found throughout the world, the following minerals may be mentioned: Aluminium ores (bauxite) in Europe; chrome ore in Turkey and the Philippines; copper ores in Rhodesia and Nevada (Rio Tinto); gold in California (Golden Queen), Nevada (Jumbo), Fiji, New Guinea, and the Philippines; manganese in South Africa; nickel in British Columbia and Brazil; potash in New Mexico; and radium and silver in north-west Canada. These particular discoveries were made in regions ranging in climate and topography from the Arctic Circle to the tropics and from plains to mountains and jungle. No conditions are too severe for the determined and experienced prospector; but it can be said that the natives or mountain people of some countries, as in South America and Asia, do some searching and occasionally bring worthwhile deposits to the attention of engineers or scouts for exploration companies.

Minerals of similar appearance frequently mislead prospectors and others: Mica, iron pyrite, pyrrhotite, and chalcopyrite are mistaken for gold; graphite, for molybdenite; dolomite, for colemanite; stibnite, for bismuthinite; marcasite, for tellurides; zincite, and erythite, for cinnabar; stannite, for tetrahedrite; barite, for scheelite; garnierite, for malachite; and obsidian, for pitchblende.

Surface rocks stained by copper, iron, manganese, and mercury are misleading because frequently there is no persistence of ore at depth.

The black sands of certain beaches and river bars, and such sands caught in the sluices of hydraulicking and dredging operations, have misled many a man into believing that they are high in gold and platinum. In a few places these sands, which are mostly iron minerals, have paid to work. They have also on some dredging operations in which they are a highly concentrated product.

Gold does not exist in colloidal condition in ores and waters or in any other form such that assays cannot detect it; assays get all the gold and silver, and custom plants pay on assays only.

Because not more than one property in two hundred submitted for examination to exploration companies becomes a mine, a prospector should make sure by development and by assays of representative samples that a claim is really worth attention. An outcrop or a small pit does not mean an "enormous tonnage," nor will companies that are looking for deposits consider such a showing.

Prospecting is permitted on public lands in certain countries under regulations which require that a certain amount of work be done each year. If work is not continued each year, claims become forfeitable to anyone who re-stakes or re-pegs them. No prospecting is permitted on private property unless an arrangement is made with the owner. There are regulations for placers and for lodes.

At one time, and now in some regions, prospectors set out afoot or with a burro, mule, horse, camel, or canoe for some area they had in mind; nowadays, for those who can afford it, transport is made easier by motor-cycle, motor-car, motor-truck, and aeroplane. The aeroplane leaves men and departs, but a motor-car or truck is locally useful in getting supplies and for haulage, and often is a source of power for any small equipment.

Many veins reveal themselves by their outcrops; and by stripping away the country rock and trenching across them, any oreshoots may be discovered and developed. If the outcrop of a vein has been eroded and only pieces of "float" ore are to be seen on a hillside, these should be traced to what appears to be their source. Then some trenching may uncover the vein.

A prospector should have a pick, shovel, hammer, short drills, dynamite, pan, and something for crushing samples, say a mortar and pestle. The pan is used for washing gravel or crushed ore for gold, cinnabar, tin, and heavy sulphide minerals. A good hand lens is a more useful device for magnifying minerals than is generally recognized. A man should have ample food and clothes suitable to the district he is prospecting.

When a prospect shows enough ore for a small mill or for shipment to a custom mill or smelter, the owner should try to arrange for this. An ore may be suitable for sorting out the waste rock and then shipping the remainder to a custom plant, or it may be sorted and treated locally.

Several firms in the United States, Canada, Australia, New Zealand, and Africa make milling and treatment plants for prospects.

The question arises: Where to search for minerals? Semi-desert, rivers, foothills, and mountains have produced much wealth. Mountain chains are or may be, as they have been, great future sources of minerals—the Rocky mountains; the Cascades; the Sierra Nevada and Coast Range; the chains of Idaho, Nevada, and Arizona; the Sierra Madre of Mexico and the Andes of South America, have been productive. Some mountains have not revealed much. Volcanic areas or those made up of flow rocks are generally favourable. Faulting, folding, and intrusions of igneous rocks are part of the formation. Every outcrop, especially of quartz, should be closely examined, sampled, and panned. If a formation is "likely" in appearance, prospect it thoroughly before moving camp. Placers may occur at high elevation: the drift gravels of the Sierras and gravels of the Rockies, or along and at the mouths of rivers. They may contain gold, precious stones, tin, tungsten, and zircon.

Prospectors and miners with ambition and money enough can attend the special, free summer courses given by certain schools of mines, some of which send lecturers into the field. In such manner, prospectors can enlarge their knowledge of minerals and the occurrence and identification of them. Booklets and sets of minerals are available at a low price.

Makers and dealers in mine machinery and equipment are always glad to send information to those who would like to install some type of plant. Several books on general prospecting or on gold alone are procurable at reasonable charge from firms in New York city; Gardendale, Quebec; London; and Sydney, Australia. By such means the prospector becomes better informed regarding rock formations and the minerals likely to be in them, as well as in methods of testing what the minerals are.

To some extent, governments encourage and aid prospectors and engineers through their State or Provincial and Federal Bureau of Mines, Departments of Mines, and Geological Surveys. Various investigations are made and the results are published and are available free or at a low charge. This statement refers particularly to the United States, Canada, and the British Empire. Some governments appropriate money for certain field investigations and some allot cash loans to prospectors, miners, and small companies. Sometimes free assays and tests on ores are run, and free identification of minerals is made. In some countries the government operates mills for small producers. (M. W. v. B.)

PROSPECTUS: *see* COMPANY LAW.

PROSPER OF AQUITAINE or PROSPER TIRO (*c.* 390–*c.* 465), Christian writer and disciple of St. Augustine, was a native of Aquitaine, and seems to have been educated at Marseilles. In 431 he appeared in Rome to interview Pope Celestine regarding the teachings of St. Augustine and then all traces of him are lost until 440, the first year of the pontificate of Leo I., who had been in Gaul and thus probably had met Prosper. In any case Prosper was soon in Rome, attached to the pope in some secretarial or notarial capacity. Gennadius (*De script. eccl.* 85) mentions a rumour that Prosper dictated the famous letters of Leo I. against Eutyches. The date of his death is not known, but his chronicle goes as far as 455, and the fact that Ammianus Marcellinus mentions him under the year 463 seems to indicate that his death was shortly after that date. Prosper attacked the Pelagians in a polemical poem of about 1,000 lines, *Adversus ingratos,* written about 430. After Augustine's death he wrote three series of Augustinian defences, especially against Vincent of Lerins (*Pro Augustino responsiones*). His chief work was against Cassian's *Collatio,* his *De gratia dei ut libero arbitrio* (432). He also induced Pope Celestine to publish an *Epistola ad episcopos Gallorum* against Cassian. He corresponded with Augustine and made an abridgment of his commentary on the Psalms, a collection of sentences from his works. He also put into elegiac metre, in 106 epigrams, some of Augustine's theological dicta.

Prosper's *Epitoma chronicon* is a careless compilation from St. Jerome in the earlier part, and from other writers in the later, but the lack of other sources makes it very valuable for the period from 425 to 455 of which he had personal knowledge. There were five different editions, the last of them dating from 455, after the death of Valentinian. For a long time the *Chronicon imperiale* was also attributed to Prosper Tiro, but without the slightest justification, for it exhibits Pelagian tendencies.

The *Chronicon* has been edited by T. Mommsen in the *Chronica minora* of the *Monumenta Germaniae historica* (1892). The complete works are in Migne's *Patrologia latina.* Tome 51. *See* L. Valentine, *St. Prosper d'Aquitaine* (Paris, 1900) and A. Potthast *Bibliotheca historica* (1896).

PROSTEJOV or PROSSNITZ, an old town in Moravia, lies in the fertile valley of the Hanna, a tributary of the Morava. Pop. (1930) 33,487. Germany occupied the town in March 1939, at the time of Czechoslovakia's dismemberment.

PROSTITUTION, a word which may best be defined as promiscuous unchastity for gain. In German law it is described as *Gewerbsmässige Unzucht.* It has always been distinguished in law and custom from concubinage, which is an inferior state of marriage, and from adultery and other irregular sexual relations, in which the motive is passion. Prostitution has existed in all civilized countries from the earliest times, and has always been subject to regulation by law or by custom. The more important of the external reasons which induce women to turn to prostitution for a livelihood in modern times are: (1) difficulty of finding employment; (2) excessively laborious and ill-paid work; (3) harsh treatment of girls at home; (4) promiscuous and indecent mode of living among the over-crowded poor; (5) the aggregation of people together in large communities and factories, whereby the young are brought into constant contact with demoralized companions; (6) the example of luxury, self-indulgence and loose manners set by the wealthier classes; (7) demoralizing literature and amusements; (8) the arts of profligate men and their agents. Alcohol is often an aid to prostitution, but it can hardly be called a cause, for the practice flourishes even more in the most abstemious than in the most drunken countries. These observations apply to the West. In Oriental countries girls are commonly born into or brought up to the trade, and in that case have no choice.

In Eastern Religions.—Among the ancient nations of the East, with the exception of the Jews, prostitution appears to have been connected with religious worship, and to have been not merely tolerated but encouraged. The code of sexual morality laid down in the Book of Leviticus is prefaced by the injunction not to do after the doings of the land of Egypt, nor after the doings of the land of Canaan, where all the abominations forbidden to the Jews were practised; and whenever the Israelites lapsed from their faith and "went a-whoring after strange gods," the transgression was always associated with licentious conduct. In Egypt, Phoenicia, Assyria, Chaldea, Canaan and Persia, the worship of Isis, Moloch, Baal, Astarte, Mylitta and other deities consisted of the most extravagant sensual orgies, and the temples were merely centres of vice. In Babylon some degree of prostitution appears to have been even compulsory and imposed upon all women in honour of the goddess Mylitta. In India the ancient connection between religion and prostitution still survives; but that is not the case in China, a most licentious country, and, considering the antiquity of its civilization, and its conservatism, we may perhaps conclude that it formed an exception in this respect among the ancient nations.

Among the Jews, who stood apart from the surrounding peoples, the object of the Mosaic law was clearly to preserve the purity of the race and the religion. Prostitution in itself was not forbidden, but it was to be confined to foreign women. Jewish fathers were forbidden to turn their daughters into prostitutes (Lev. xix. 29), and the daughters of Israel were forbidden to become prostitutes (Deut. xxiii. 17), but no penalty was attached to disobedience, except in the case of a priest's daughter, who was to be burnt (Lev. xxi. 9). This distinction is significant of the attitude of Moses, because the heathen "priestesses" were nothing but prostitutes. Similarly, he forbade groves, a common adjunct of heathen temples and a convenient cover for debauchery. Again, his purpose is shown by the severe penalties imposed on adultery (death) and on unchastity in a betrothed damsel (death by stoning), as contrasted with the mild prohibition of prostitution. So long as it did not touch the race or the religion, he tolerated it; and even this degree of disapproval was not maintained, for Jephthah was the son of a harlot (Judges xi. 1).

There is abundant evidence in the Old Testament that prostitution prevailed extensively in Palestine, even in the earlier and more puritan days. The women were forbidden Jerusalem and places of worship; they infested the waysides, and there is some evidence of a distinctive dress or bearing, which was a marked feature of the trade among the Greeks and Romans. In the later period of aggrandizement that increase of licentious indulgence which Moses had foreseen took place, associated with infidelity. The remarkable series of ordinances laid down by Moses in the interest of public health contains unmistakable recognition of venereal disease and its contagious character (Lev. xv.).

In Ancient Greece.—Passing on to the ancient Greeks, we find prostitution treated at Athens on a new principle. The regulations of Solon were designed to preserve public order and decency. He established houses of prostitution (*dicteria*), which were a state monopoly and confined to certain quarters. The *dicteriades* were forbidden the superior parts of the town, and were placed under various disabilities. They were compelled to wear a distinctive dress, and so far from being connected with religion, they were not allowed to take part in religious services. These laws do not seem to have been carried out at all effectually, and were presently relaxed. After the Persian wars more stringent regulations were again introduced. The *dicteriades* were placed under police control, and were liable to prosecution for various offences, such as ruining youths, committing sacrilege and treason against the state. It is clear, however, that as time went on the Athenian authorities experienced the difficulties encountered by modern administrations in carrying out state regulation. There were grades of prostitution, socially though not legally recognized, and women of a superior order were too powerful for the law, which failed to maintain the ban against them. The Greek *hetaerae*, who were prostitutes, not "mistresses," and the most gifted and brilliant members of their class known to history, wielded great and open influence. The test case of Phryne, in which the stern attitude previously maintained by the Areopagus broke down, established their triumph over the law, deprived virtuous women of their sole advantage, and opened the door to general laxity. In later times any one could set up a *dicterion* on payment of the tax. In other Greek cities extreme license prevailed. At Corinth, which was famous for sensual practices, a temple, with a huge staff of common prostitutes for attendants, was established in honour of Aphrodite and for the accommodation of the sailors frequenting the port. The worship of this goddess became generally debased into an excuse for sexual excesses.

Ancient Rome.—The Romans united the Jewish pride of race with the Greek regard for public decency, and in addition upheld a standard of austerity all their own. In early days female virtue was highly honoured and strenuously maintained among them, of which the institution of the vestal virgins was a visible sign. Their attitude towards prostitution differed, accordingly, from that of other ancient nations. Among them, alone, it was considered disgraceful to a man to frequent the company of prostitutes; and this traditional standard of social conduct, which markedly distinguished them from the Greeks, retained sufficient force down to the later days of the Republic to furnish Cicero with a weapon of rhetorical attack against his political opponents, whom he denounced as *scortatores*. Prostitution was more severely regulated by them than by any other ancient race. They introduced the system of police registration, which is the leading feature of administration in most European countries to-day. From the earliest days of the Republic prostitutes were required to register at the aediles' office, where licenses were issued to them on payment of a tax. They were placed under stringent control, had to wear a distinctive dress, dye their hair or wear yellow wigs, and were subject to various civil disabilities; but the severest feature of the system was that, once registered, their names were never erased, and consequently remained for ever under an indelible stain. As in our times, registration became ineffective, and neither law nor tradition could check the demoralizing influence of ease and luxury when once external conquest left the Romans free to devote their energies to the pursuit of pleasure. An attempt was made, by the enactment of severer laws against prostitution, to stem the rising tide of immorality, which threatened to taint the best blood in Rome with the basest elements in the later days of the Republic. Citizens were prohibited from marrying the descendants or relatives of prostitutes, daughters of equestrians were forbidden to become prostitutes, and married women who did so were liable to penalties. More stringent regulations were also imposed on prostitutes themselves, in addition to the old disabilities and police system, which remained in force. If these laws had any effect at all, it was to promote the general prevalence of immorality; they certainly did not diminish prostitution. The profligacy of imperial Rome has never been surpassed for gross and obscene sensuality.

Under Christianity.—The greatest change introduced by Christianity with regard to prostitution was the adoption of a more charitable attitude towards these social and legal outcasts. The Roman state tax, which had descended to the emperors and had been further regulated under Caligula, was partly given up in the 4th century by Theodosius, on the representations of Florentius, a wealthy patrician, who offered to make good the loss of revenue out of his own pocket. It was fully and finally abolished by Anastasius I. in the next century, and the old registers were destroyed. Then some of the civil disabilities of prostitutes were removed by Justinian in the 6th century. Gibbon, who never gave credit for a good motive when a base one could be found, attributes Justinian's action solely to his desire to marry Theodora, whose life had been notorious; and no doubt she influenced him in the matter, but it is permissible to assume a good motive. Even Gibbon is constrained to admit her virtue after marriage, and to give her credit for "the most benevolent institution" of Justinian's reign, the rescue home for fallen women in Constantinople, which was at any rate disinterested. Though it did not succeed, it marks a turning-point in the treatment of a class which had never met with public sympathy before. At the same time procuration and connivance were severely punished, which is in keeping with the Christian attitude. The early Christian Church laid great stress on chastity, which probably suggested to its Roman persecutors the horrible punishment of forcibly prostituting Christian maidens. Such malignity enhanced the glory of martyrdom without shaking the constancy of its victims; and the triumph of purity in an age of unbounded licence was conspicuously recognized by Alaric, the Gothic conqueror, who gave strict orders in the sack of Rome that the virtue of Christian women was to be respected. The Church, however, was not severe upon prostitutes, to whom the altar was open upon repentance, and some of the fathers explicitly recognized their trade as a necessary evil. Among them was St. Augustine, a man of the world, who saw that its suppression would stimulate more destructive forms of immorality. Gradually charity degenerated into patronage. Rome, conquered spiritually by Christianity and materially by the northern barbarians, sapped the virtue of both.

Charlemagne made an effort to suppress the prevailing disorder, but his private life was licentious, and his capitularies, which ordained the scourging of prostitutes and panders, were not inspired by any regard for morality. A period of reform followed. The rise of chivalry, with its lofty idealization of women, and the wave of Christian fervour connected with the crusades, inspired a vigorous and high-minded campaign against an all-prevalent evil. The Church became exceedingly active in prevention and rescue work, and was assisted by a devout and zealous laity. Rescue missions were organized, convents were founded everywhere for the reception of penitents, and dowries were subscribed to procure them husbands. Fulke de Neuilly was a conspicuous figure in this work. He held missions, preached, and collected large sums for marriage dowries. Pope Innocent III. (1198–1216) pronounced it a praiseworthy act to marry a prostitute; and Gregory IX., a few years later, wrote to Germany that brothel-keepers were not to prevent prostitutes from attending missions, and that clergy and laity who drew profit from prostitution were banned. "Urge bachelors," he wrote, "to marry repentant girls, or induce the latter to enter the cloister."

Regulated by Law.—In spite of such efforts, and of oc-

casional spasms of severity by individual rulers, prostitution flourished everywhere throughout the middle ages. It was not merely tolerated, but licensed and regulated by law. In London there was a row of "bordells" (brothels) or "stews" in the Borough near London Bridge. They were originally licensed by the bishops of Winchester, according to John Noorthouck, and subsequently sanctioned by parliament. Stowe quotes the regulations enacted in the year 1161, during the reign of Henry II. These were rather protective than repressive, as they settled the rent which women had to pay for the rooms, and forbade their compulsory detention. The act was afterwards confirmed in the reigns of Edward III. and Richard II. In 1383 the bordells belonged to William Walworth, lord mayor of London, who farmed them out, probably on behalf of the Corporation, according to analogy in other parts of Europe. They were closed in 1506, but reopened until 1546, when they were abolished by Henry VIII. In London we get the earliest known regulations directed against the spread of venereal disease. The act of 1161 forbade the bordell-keepers to have women suffering from the "perilous infirmity of burning"; and by an order of 1430 they were forbidden to admit men suffering from an *infirmitas nefanda*. Probably it was by virtue of this order that in 1439 two keepers were condemned to eleven days' imprisonment and banishment from the city. In 1473, again, it is recorded that bawds and strumpets were severely handled by Lord Mayor Hampton.

Elsewhere in Europe much the same state of things prevailed during the same period. Prostitution was both protected and regulated, and in many places it constituted a source of public revenue. In France prostitutes were distinguished by a badge, and forbidden to wear jewels and fine stuffs and to frequent certain parts of the town. Public brothels on a large scale were established at Toulouse, Avignon and Montpellier. At Toulouse the profits were shared between the city and the university; at Montpellier and Avignon the trade was a municipal monopoly, and farmed out to individuals; at Avignon, where the establishment was kept up during the whole period of the popes' residence, the inmates were subjected to a weekly examination. In 1254 Louis IX. issued an edict exiling prostitutes and brothel-keepers; but it was repealed two years later, though in this and the succeeding century procuration was punished with extreme severity. In some parts of France prostitutes paid a tax to the seigneur. In Germany, according to Fiducin, the public protection of *Lust-Dirnen* was a regular thing in all the large towns during the middle ages. "Frauenhäuser," similar to those in London and in France, existed in many places. They are mentioned in Hamburg in 1292; and from later records it appears that they were built by the corporation, which farmed them. So also in Ulm, where special regulations were issued in 1430. We find them existing at Regensburg in 1306, at Zürich in 1314, at Basel in 1356 and Vienna in 1384. According to Henne-am-Rhyn, admission to these houses was forbidden to married men, clergy and Jews, and on Sundays and saints' days they were closed.

The laws of the emperor Frederick II. in the 13th century contain some curious provisions. Any one convicted of a criminal assault on a prostitute against her will was liable to be beheaded; if she made a false accusation she was subject to the same penalty. Any one not going to the assistance of a woman calling for help was liable to a heavy fine. In these ordinances the influence of chivalry may be detected. At the same time prostitutes were forbidden to live among respectable women or go to the baths with them. Hospitality to important guests included placing the public Frauenhäuser at their disposal. So King (afterwards Emperor) Sigismund was treated at Bern in 1414 and at Ulm in 1434, so much to his satisfaction that he publicly complimented his hosts on it. Besides the municipal Frauenhäuser, there were "Winkelhäuser," which were regarded as irregular competitors. In 1492 the licensed women of Nuremberg complained to the mayor of this unfair competition, and in 1508 they received his permission to storm the obnoxious Winkelhaus, which they actually did. In Italy and Spain the system appears to have been very much the same. At Bologna prostitutes had to wear a distinctive dress, in Venice they were forbidden to frequent the wine-shop, and in Ravenna they were compelled to leave a neighbourhood on the complaint of other residents. At Naples a court of prostitutes was established, having jurisdiction over everything connected with prostitution. It led to great abuses, was reformed in 1589, and abolished about a century later.

The Reformation.—In the 15th and 16th centuries a great change took place. It was due to two very different causes: (1) fear of disease; (2) the Reformation. With regard to the first, there can be little doubt that both the slighter and graver forms of venereal disease existed in very remote times, but until the 15th century they attracted comparatively little attention. The constitutional character of syphilis was certainly not understood—which is by no means surprising, since its pathology has only recently been elucidated (*see* VENEREAL DISEASES)—but one would still have expected to find more notice taken of it by historical, moral and medical writers in classical and mediaeval times. Nor is it possible to explain their reticence by prudery, in view of the unbounded literary licence permitted in those ages. One can only conclude that the evil was less widely spread or less virulent than it afterwards became. At the end of the 15th century it attracted so much notice that it was supposed to have originated then *de novo*, or to have been brought from the West Indies by Columbus—both untenable hypotheses; and, as usual, each country accused some other of bringing the contagion within its borders. To speculate on the cause of this increased prevalence would be idle; it is enough to note the fact and its consequences. It was immediately followed by the Reformation, and the two together led to a general campaign against the system of licensed prostitution. The last Frauenhaus was closed in Ulm in 1531, in Basel in 1534 and in Nuremberg in 1562. In London, as already noted, the bordells were abolished in 1546. In Paris an ordinance was issued in 1560 prohibiting these establishments, and later all prostitutes were required to leave the city within twenty-four hours.

It is observed by Henne-am-Rhyn—no friend of toleration—that their suppression was followed by the appearance of the crime of infanticide, by the establishment of hospitals for foundlings and for syphilis. This suggests an indictment against humanity which is hardly justified by the facts. Infanticide was no new thing, and foundling hospitals date from the beginning of the 13th century. Their marked increase and the establishment of syphilitic hospitals came a century later than the Reformation campaign against the Frauenhäuser. The suppression of the latter did not affect the prevalence of prostitution. In the 17th century another spasm of severity occurred. In 1635 an edict was issued in Paris condemning men concerned in the traffic to the galleys for life; women and girls to be whipped, shaved and banished for life, without formal trial. These ordinances were modified by Louis XIV. in 1684. The Puritan enactments in England were equally savage. Fornication was punishable by three months' imprisonment, followed by bail for good behaviour. Bawds were condemned to be whipped, pilloried, branded and imprisoned for three years; the punishment for a second offence was death. In Hamburg all brothels were pulled down and the women expelled from the town. If these measures had any effect, it was speedily lost in a greater reaction; but they have some historical interest, as the present system was gradually evolved from them.

The Protection of Health.—It would be tedious and unprofitable to follow all the steps, the shifts and turns of policy, adopted in different countries during the 18th century for the suppression or control of an incurable evil. They involve no new principle, and merely represent phases in the evolution of the more settled and more systematic procedure in force at the present time. Its chief feature, as compared with the past, is the establishment of an organized police force, to which the control of prostitution is entrusted, coupled with a general determination to put the subject out of sight and ignore it as far as possible. The procedure on the continent of Europe is virtually a return to the old Roman system of registration and supervision, except that there is no State tax, and names can be removed from the register. The

objects are the same, namely, public order and decency, with one important addition, which has given rise to much controversy. This is the protection of health.

From what has gone before, the reader will have gathered that it is not, as frequently supposed, a new thing. Already in the middle ages the question occupied the attention of parliament in England, and a weekly examination of public women by the barber (the surgeon of that time) was instituted at Avignon. The practice was adopted in Spain from about 1500, and later in many other places. But the abolition of licensed brothels, and the consequent growth of private prostitution, rendered it a dead letter. To meet the difficulty, registration was devised. It was first suggested in France in 1765, but was not adopted until 1778. The present regulations in France are based on the ordinances of that year and of 1780 which in their turn were borrowed from those of the 16th and 17th centuries, previously mentioned. The *theory* of the modern attitude towards prostitution is clearly laid down by successive ordinances issued in Berlin. Those of 1700 stated that "this traffic is not permitted, but merely tolerated"; the more precise ones of 1792 pronounced the toleration of prostitution a necessary evil, "to avoid greater disorders which are not to be restrained by any law or authority, and which take their rise from an inextinguishable natural appetite"; and the regulations of 1850 and 1876 are headed: "Polizeiliche Vorschriften zur Sicherung der Gesundheit, der öffentlichen Ordnung und des öffentlichen Anstandes." This embraces the whole theory of present administration, and if *Gesundheit* be omitted, is not less applicable to the United Kingdom than to the continent. The last attempt to suppress prostitution in Germany is worth noting, as it occurred so late as 1845. Registration was stopped and the tolerated houses were closed in Berlin, Halle and Cologne. The attempt was a complete failure, and it was abandoned in 1851 in favour of the previous system.

White Slave Traffic.—In recent years the question of prostitution has become international through the movement to suppress the "white slave traffic." A congress was held in London in 1899, and in 1902 the French Government summoned an official conference, which resulted in the Convention of 1904, signed by the 12 principal European nations, with the exception of Austria. By this Convention the States bound themselves to coordinate information relative to the procuring of women from abroad, to keep a watch at places of entry and to repatriate women who wished it. In 1910 the United States passed the White Slave Traffic Act, which imposed severe penalties on the transport of women for immoral purposes. In the same year an international Convention for the suppression of the White Slave Traffic was signed in Paris by 13 nations, including Austria. This convention went much farther than the previous one. It bound the parties to punish anyone who had "procured, enticed or led away, even with her consent, a girl under age for immoral purposes" and also anyone who had "by fraud or by means of violence, threats, abuse of authority or any other method of compulsion, procured a girl or woman over age for immoral purposes, notwithstanding that the various acts constituting the offence may have been committed in different countries." This involved altering the internal law relating to prostitution in certain countries. Voluntary committees were formed in the principal countries to collect information and push the matter.

After the World War of 1914–18, the League of Nations took up the problem in accordance with Article 23, which entrusted the League with "the general supervision over the execution of agreements with regard to the traffic." In 1921 the League summoned an international conference at Geneva, attended by delegates from 34 nations. It proposed that the words "white slave traffic" should be altered to "traffic in women and children," that a new convention should be drafted, that an advisory committee be set up and that Governments should be invited to make annual reports on the traffic and on the measures taken for checking it. All these proposals were carried out. In 1923 the advisory committee recommended that "pending the abolition of the system of State regulation, no foreign woman should be employed in or carry on her profession as a prostitute in any licensed house"; that a questionnaire be issued to the Governments; and that a study of conditions on the spot should be undertaken by experts. In 1927 the committee of experts appointed in pursuance of the foregoing recommendation published a report in two parts containing information obtained by visits to 28 countries and the replies of Governments to the questionnaire sent out. This report has been used in the following observations on the principal countries.

Great Britain.—In Great Britain there is no system of licensed houses or registration of prostitutes. The law is mainly governed by the Criminal Law Amendment Act of 1885, as amended in 1912 and 1922, which makes procuration or attempted procuration a misdemeanour. The law further makes it a felony to have carnal knowledge of a girl under 13, and a misdemeanour in the case of a girl between 13 and 16. The same applies to the occupiers of premises who knowingly permit these offences, to persons taking a girl under 18 out of the possession of her parents or guardians for the purpose, and to the detention of any woman or girl in a brothel. The maintenance of brothels is prohibited, and by the Vagrancy Act of 1898 males are prohibited from living on the earnings of prostitutes. The traffic in women and children is dealt with by the Children (Employment Abroad) Act of 1913, which prescribes the conditions for a magistrate's license to take girls under 16 out of the country for "singing, playing, performing or being exhibited for profit"; and by the Aliens Order of 1920. The Licensing Act of 1872 contains a provision, adopted from 1847, which makes it an offence for publicans to allow "common prostitutes to assemble and continue" in licensed premises. Otherwise they are not interfered with by the police except for disorder or annoying persons by solicitation: in regard to the latter, which also applies to males, the police exercise their own discretion and exhibit much variation of practice.

There is some evidence that street-walking by prostitutes, which used to be the great feature of London as compared with other capitals, has diminished; but the diminution may be partly explained by the practice, which has greatly increased, of motor-cars waiting about and picking up girls. There is no reason to believe that prostitution has diminished; but on the other hand it is clear that the foreign traffic in girls is of very small account. Englishwomen are too independent to make good subjects, and the Criminal Law Amendment Acts have been successful in preventing such exploitation as there was. Great Britain is a party to all the international conventions.

The Question of Compulsory Examination.—No account of Great Britain would be complete without a reference to the partial adoption in certain garrison centres of the system employed elsewhere. In 1864 a Contagious Diseases Prevention Act was passed providing for the compulsory medical examination of prostitutes and the detention in hospital of those found affected. It applied to 11 garrison towns, was amended in 1866 and in 1869 was applied to 18 towns. This gave rise to a campaign in the opposite direction, with which Mrs. Josephine Butler's name was prominently associated. A royal commission investigated the question in 1871 and a select committee did the same in 1879. The majority reported in favour of the acts, being impressed by the evidence, which was strongly for them, and much of which was quite unbiased. Nevertheless in 1883 the House of Commons passed a resolution condemning the medical examination of women, and as this would have entailed refusal to vote the money required to carry on the system it was immediately dropped. In 1886 the acts were formally repealed.

In India the system was introduced for military cantonments in 1865, partially suspended in 1884 and stopped in 1888 on account of the action of the House of Commons. A new Cantonment Act was passed in 1889 and an amending act in 1893, which prohibited the compulsory and periodical examination of women. In consequence of the enormous increase of syphilis—from 75·5 to 174·1 per 1,000 for primary and from 29·4 to 84·9 for secondary cases—which followed, a new order was made in 1897, which gave power (1) to call on persons suffering from a contagious disorder to attend a dispensary, (2) to remove brothels,

(3) to prevent the residence or loitering of prostitutes near cantonments. Troops in India or in other stations abroad are in a different position from those at home and show a much larger proportion of men affected. If the army statistics of the different countries are examined over a number of years, two things appear:— (1) wide variations between the several countries, (2) a sort of epidemic rise and fall. The variations may be explained by the degree of care exercised in the regulated countries, Prussia having consistently the best record; the English figure is higher than for any regulated country. Flexner, arguing against regulation, suggests that the important factor is the size of the town, but that takes effect through the difficulty of carrying out the measures, which increases with the size.

United States.—The system is the same as in England; that is to say, there are no licensed houses or registration and periodical examination of prostitutes. The Federal Government has adhered to the convention of 1904, but not to those of 1910 and 1921, owing to the fact that the several States have their own laws in relation to prostitution. The Attorney-General of the United States is charged under the law of 1910 with the prosecution of cases of international and inter-State traffic in women and girls. The severe immigration law of 1917, which prohibits the importation of aliens for prostitution makes it difficult to pass; but there is no interference with emigrants on this account.

France.—French law has been considerably affected by the conventions of 1904, 1910 and 1921, France having signed and ratified the first two and adhered to the last. The criminal law takes no cognizance of prostitution, but the police have power to regulate it, in Paris under the prefect of police, elsewhere under that of the mayor. Brothels are licensed in two categories—(1) *maisons de tolérance* (residential), (2) *maisons de passe* or *de rendez-vous* (houses of call); the keeper of the former must be a woman who is the owner of the premises or has a registered lease. Only women of 21 and of French nationality are allowed to reside; the inmates are medically inspected every week, while other registered prostitutes are examined fortnightly. Registration is either voluntary or compulsory after repeated arrests. There are in Paris about 235 licensed houses, of which 30 are *maisons de tolérance;* the number of inmates is about 2,100 and it remains pretty constant. Girls under 18 are not registered, but are dealt with under Articles 270 and 271 of the penal code, as amended by the law of 1921, under which they are brought before the juvenile court and subjected to reforming measures. The registered prostitutes form only a small proportion of the total number. Procuration is an offence recognized by the penal code, which has been strengthened by a law passed in 1922. France appears to be the headquarters of the outgoing traffic in women and girls, especially to Cuba, Mexico, Panama and the South American republics. The incoming traffic is comparatively small. In 1924 the official returns of the registered prostitutes showed a total of 583, of whom 223 were Italians and 146 Belgians.

Germany.—Prostitution is not forbidden, but under article 361 of the penal code women are liable to arrest for practising prostitution without being under police control or for contravening regulations after being placed under control. The regulations include weekly or fortnightly medical examination, together with strict rules in regard to public demeanour and conditions of life. There are in Berlin about 6,000 registered prostitutes, and 2,200 in Hamburg; and these are reckoned at one-third of the total number. Procuration is prohibited, under the name of *Kuppelei,* by article 180 of the penal code, which was strengthened in 1927 by a provision of the law for combating venereal disease, which explicitly names the conducting of a brothel or of a business akin to that of a brothel as included in procuration. Nevertheless most large towns, except Berlin, still have them. There is (1) ordinary *Kuppelei,* which is simply assisting procuration for gain and (2) aggravated *Kuppelei,* which includes false pretences and procuration by parents, guardians, teachers, etc., and entails a much more severe penalty. With regard to the international traffic the German Government states that Germany is not at present a country of destination, but only one of transit. Foreign women, when arrested for prostitution, are expelled; eight such women were deported from Berlin in 1924 and 21 procurers. The outgoing traffic is much the same as before the war, but attempts are being made to prevent it in accordance with the international conventions, to all of which Germany is a party. A law passed in 1923 requires that all agencies providing employment abroad must be licensed and supervised, and another, passed in 1924, provides further protection for girls under 18 by requiring the consent of the juvenile court.

Italy.—After a fluctuating policy Italy has adopted the French system. Under the law of 1926 prostitution is regulated, and all inscribed women must submit to medical examination. In 10 cities there were 324 licensed houses in 1924. Strict conditions are laid down in the law of 1926. Procuration is an offence under the penal code, which was strengthened in 1923. With regard to the traffic, the law governing the outgoing traffic was made more stringent in 1919, but there appears to be considerable evasion of the passport regulations. The incoming traffic shows an increase. Out of 11,924 prostitutes interrogated in 15 months of 1923–24, 782 were found to be of foreign nationality. During 1925 that number had risen to 865, most of whom were Austrians and French.

Other European Countries.—A similar system prevails in Belgium, Portugal, Spain, Rumania, Greece, Hungary and Austria, excepting Vienna, where licensed houses have been abolished. The German or the English plan is followed, more or less, in Holland, Poland, Czechoslovakia, Switzerland and the Scandinavian countries. Colonies, dominions and dependencies usually follow the example of the mother-country.

Cuba.—The licensed areas were abolished in 1913, but conditions still remained very bad, particularly in Havana, until 1925, when a vigorous movement was initiated by the Government, under the inspiration of the League of Nations Committee, which visited Cuba in 1924. The police became very active, and the houses where prostitution was carried on were reduced from 477 to 224. The incoming traffic, which had greatly increased since the war, was largely stopped in 1925 by a decree making it an offence to assist immigration for the purpose of prostitution and providing for the deportation of foreign women and keepers of prostitutes. The number of women so engaged in Havana was stated to be 700, chiefly French, Spanish and Italian. Except for the deportations the outgoing traffic was small. Cuba is a party to all the conventions.

The Argentine Republic.—South America has become the main objective of the traffic from Europe. The Argentine is a party to none of the conventions. Prostitution is there regulated by the municipalities. Houses are licensed and prostitutes are registered and medically examined. In Buenos Aires there were 585 licensed houses in 1923, showing a considerable increase. The women are chiefly French, Poles, Italians and Spaniards, but "there is a constant flow of foreign prostitutes from every corner of Europe to the Argentine around all barriers devised to check it. . . . It is clear that the traffickers manage to evade every restriction, and the evidence discloses an elaborate system for running the business of prostitution and securing girls therefor to the great profit of third parties." (*Report* of committee.)

Brazil.—Brazil is a party to the conventions of 1904 and 1910 and has signed the convention of 1921. There are no laws regulating prostitution and no licensed houses. The penal code, as modified in 1915, makes procuration and brothel-keeping an offence; but brothels, and ostentatious ones, abound in Rio de Janeiro. With regard to the traffic Brazil is a country of demand and prostitutes come there from everywhere. A memorandum prepared by the medical officer of health of Rio de Janeiro gave the nationality of 1,683 prostitutes; of these 987 were Brazilians, 158 Russian, 148 French, 144 Poles and 69 Portuguese.

It is hoped that the foregoing notes will sufficiently indicate the general position in the Western world. There are two main differences between the treatment of prostitution in the several countries. The first difference is the licensed house, which generally exists on the Continent but not in Great Britain and her dominions or in the United States. There is, however, a tendency to follow the example of Germany or, at least, of Berlin and

abolish them. This has been done in Switzerland, Holland, Czechoslovakia and the Scandinavian States. It is largely a geographical and racial question, but the tendency is in that direction. The second difference lies in the registration and examination of prostitutes. There is none in Great Britain, Holland, Switzerland and the United States; the institution of venereal clinics does something to protect the public health in its place, and does it better. The great object of the police in regard to prostitution is the maintenance of public order, which is undoubtedly assisted by licensing. But to-day prostitution is essentially an urban problem, and the vast size of modern cities makes clandestine prostitution so easy that the licensed houses hold only a small proportion of the total number. What proportion it is impossible to say; the estimates freely made are mere guesses.

Another modern problem is the international traffic, maintained by *souteneurs* and capitalist principals. The fact that this question has been taken up by the League of Nations is highly significant. No nation can wish to retain the traffic, with its abominable accessories, and the new immigration laws and, to a lesser extent, the greater protection afforded to girls going abroad, show that the action of the League is having a marked effect. But more than that, it has stirred the Governments to look into an unsavoury subject and has affected the whole anti-prostitution movement, which began in Great Britain with the campaign against the Contagious Diseases Acts.

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PROSTYLE, in architecture, a portico projecting in front of a building, or a building with such a portico.

PROTACTINIUM. The metallic element protactinium has the symbol Pa, atomic number 91, atomic weight 231, is predominantly pentavalent and characterized by low solubility in aqueous solution and is the second member of the actinide transition series of heaviest elements. It is radioactive, the third member of the natural, $4n + 3$, radioactive family and occurs in uranium ores. (*See* RADIOACTIVITY, NATURAL.) (G. T. Sg.)

PROTAGORAS (*c.* 481–411 B.C.), Greek philosopher, was born at Abdera. He is known as the first of the Sophists (*q.v.*), *i.e.*, he was the first to teach for payment. It is said that he received nearly £400 from a single pupil. He learned philosophy in the Ionian school, and was perhaps a pupil of Democritus, though this is doubtful on chronological grounds. He was an older contemporary of Socrates. Pericles entrusted him with the task of framing laws for the new colony of Thurii (Plut. *Pericles,* 36). At the age of 70, having been accused by Pythodorus, and convicted of atheism, Protagoras fled from Athens, and on his way to Sicily was lost at sea. Besides *Truth,* and the book *Of the Gods* which caused his condemnation at Athens, Diogenes Laërtius attributes to him treatises on political, ethical, educational and rhetorical subjects. Protagoras was the first to systematize grammar, distinguishing the parts of speech, the tenses and the moods.

PROTEACEAE, a family of dicotyledonous plants comprising about 50 genera and some 960 species, of which about 600 are Australian, including the silky oak (*Grevillea robusta*) introduced into Ceylon for shade and timber, the Queensland nut (*Macadamia ternifolia*), cultivated in Hawaii, California, and Florida, and the Australian honeysuckles (*Banksia*); there are about 260 species in southwestern Cape of Good Hope, including the silver tree (*Leucadendron argenteum*); the remaining species have a wide but irregular distribution in Asia, Africa, America and Australasia. Most of the species are trees or shrubs, and the majority are xerophytic (*i.e.*, inhabit arid country).

PROTECTION. By protection in the restricted sense is meant the use by the Government of special forms of regulation or restraint, particularly import duties and analogous fiscal expedients, in order to encourage or to maintain essential industries which are endangered by foreign competition. What industries are essential must be determined by the requirements of public policy. Protection is one phase of national policy, and its ultimate object is national security. The free trade theory assumed that every man knew his own interest better than anyone else did; that everyone would follow his own interest rather than the interest of anybody else, and thirdly that the interest of the individual coincided with the interest of the community. On these assumptions rested the whole doctrine of *laisser faire* (*q.v.*), that economic movements should be left to follow what was called their natural course under free competition. Society was an aggregate of individuals assumed to be equal to one another in the competitive struggle, and all individuals consciously or unconsciously pursued their own interests. Protection on the other hand involved a different conception. There was the interest of the individual, the interest of trade, and the interest of the commonwealth. The last was the most important. On the free trade theory the government should not interfere by tariff or other regulations in order to foster trades which did not make their own way in the competitive struggle, or to direct existing trades into channels in which they did not flow under purely individualist conditions. In so far as such attempts were successful they involved loss to the whole body.

The country practising free trade was realising "natural" conditions; tariffs or other regulations which interfered with such conditions, were artificial, imposing obstacles in the way of free movement associated with the "natural" state. Protection was therefore prejudicial to the realization of the greatest prosperity. A reversion to protection as a policy involves not merely the sporadic use of tariffs in order to safeguard particular industries, but a conception of the State, its constitution, its functions and its ultimate aims, different from the underlying conceptions of the free traders. To the free trader wealth is the end in view; to the protectionist wealth is the means. The real end governing the policy of protection may not be economic at all in the narrow sense, but may be national or imperial solidarity and power, though undoubtedly a protectionist holds that while the free trade policy may lead to the greater wealth of individuals, the protectionist policy properly administered, will bring about a balance of economic activities, involving a higher maximum of efficiency to the community as a whole and a more equitable distribution between the economic groups.

If agricultural enterprise under free competition and free trade cannot be made to pay, the free trader would abandon it and concentrate on those industrial lines of activity which under such conditions are at the time more profitable. The protectionist on the other hand would argue that this is a shortsighted view. In the first place agriculture is necessary to the State for its security, the maintenance of a healthy population and many other purposes not directly and immediately economic. But more than that, the protectionist would say that it is absurd from the economic point of view for a country to sacrifice its agriculture, for agriculture is the guarantee of a large home market for the country's manufactures, and the large and expanding home market is the best security for the successful exportation of manufactures. Given the home market, continuous running of the manufactories and the proportionate reduction of the burden of standing charges, cheapens cost of production and makes possible easier entry into markets abroad and a higher remuneration for the workers at home. The free trader would say that if an industry does not pay its way under a policy of free importation, it is better that the capital employed in that industry should be invested in some other branch of economic activity which is remunerative; that the artificial maintenance of such an industry by the imposition of protective tariffs is an economic loss to

the community. The protectionist would point out that the capital of such a depressed industry cannot be transferred to another industry, that capital is in the concrete form of factories and workshops and machines and many other forms which cannot be realised if the industry has fallen. It may indeed be desirable in certain circumstances to abandon it, but such a question cannot be decided without weighing carefully the number of persons employed, the possibility of their finding employment in other industries, the place of the industry in the national life, its relation to other industries in the scale of production, the possibility of obtaining its products in a suitable manner from other sources, its bearing on national security, and many other considerations of the highest importance. The free trader would not use tariffs or other artificial means for establishing in a country a new industry not hitherto practised. If such an industry were not likely to develop as the result of the unaided efforts of individuals, the free trader would not use government aid to promote it. The protectionist would consider the resources available in the form of raw materials, the possibility of acquiring the necessary skilled labour, the available organising ability, the demand for the products of such an industry at home and the accessibility of markets, and if the prospects were favourable would not hesitate to impose a definitely protective tariff with the intention to encourage the industry in view, even though for a few years it might involve higher prices to consumers at home, and he would do that all the more readily if there was plenty of capital for investment in the country for which he was responsible. Doctrinaire views on the question of protection have greatly declined in recent years, especially as a result of World War I. There are very few people who have influence in public affairs at the present time who would not be prepared to admit important exceptions to the free trade view and be willing to adopt a protectionist policy in particular cases, especially in regard to industries which are essential for the national security.

The justification of protection is to be found not in its conformity or its departure from an abstract theory, but in the conditions which govern the development of actual states and the laws of their development. It does not really belong to the domain of abstract economics, but to statecraft and practical organisation. The range of philosophical and other assumptions underlying the pure theory of economics is neither wide nor accurate enough to cover the varied motives and activities of an organic community, and men may at the same time accept and make use of the theory of economics so far as it goes, and yet be strong protectionists in action. In the article on ECONOMICS it has been shown how to use economic theory in investigation in opening up the relations between different series of economic facts and in suggesting approximations for the solution of practical problems. But the world we live in is a world of realities and of varying policies. We are dealing with nations, communities, human beings and concrete things, and it can never be assumed that the world does or ought to conform to the requirements of a purely theoretical system. The objections to protection in a hypothetical world where there is complete mobility of labour and capital, and time is an abstraction, are not relevant when we have to consider the great industries and the lines of commerce of the actual world, the tangled relations of the groups of human beings, their different histories and environment, and the divergent interests with which statesmen have to deal. If we keep in view the wide gulf between the world of pure theory and the conditions of actual life, we shall not hastily come to the conclusion that the states which have practised a protective policy have achieved success in spite of the measures they have adopted to secure it.

The Fall of the Old Policy.—In the middle ages the source of England's wealth was the exportation of raw materials, with which she purchased the manufactures and the luxuries of other countries. In those ages many of the regulations adopted were not, as they have been regarded by free trade writers, restraints upon liberty, but the conditions of its exercise. Freedom is only possible where there is security. Before the close of the middle ages manufactures were greatly extended as a result of encouragement, by the native aptitude of the people, and by the immigration of skilled artisans. Movements analogous to those of modern times took place on a small scale, and there were signs of a growing nationalism long before the close of the middle ages. Action taken by the trading companies, especially the great Merchant Adventurers Company, encouraged foreign trade, and we can trace in numerous statutes the foundations of what was subsequently called the mercantilist system. Then took place a development not dissimilar to that in continental countries in modern times. Internal barriers were removed. England and Scotland were united. Great Britain and Ireland became one economic area. By that time the United Kingdom, under the policy which was so widely condemned later on by economists, achieved economic supremacy. With apparently illimitable supplies of coal and other requisites of production, her industries growing by leaps and bounds from the use of new inventions, the whole organisation and structure of great industries rapidly changing, the old laws and methods of regulation became obsolete, and the tariffs worked out to suit the more primitive stages of industrial development were simply embarrassing or irrelevant in the new conditions. Attempts to adapt them failed and the old duties were swept away, not so much in obedience to a theory but because the necessary adaptations could not be made. It might have been more statesmanlike and prudent to keep at least the framework of the old system, but with wealth as the supreme end in life and with the opportunities which the new industrialism gave, this was the accepted course of contemporary statesmen. By 1860 free importation was the established policy of the country and the methods by which English statesmen had built up the economic power of the country were remembered simply as the economic fallacies of a former generation.

The Mercantile System in England.—In order to bring out the character of protection in its modern form we must make some further historical contrasts in British policy. The older policy was not protection in the narrow sense in which the word has been used in modern controversy. The idea of building up a great industrial commercial state by that policy ran through most of the economic measures which were adopted, affecting agriculture, trade and commerce, commercial treaties, finance, labour legislation, the poor laws, and colonial policy for several generations, and discriminating duties were imposed not from logical necessity or through loyalty to some theoretical system, but as practical expedients like any other form of regulation to deal with problems as they were at the time understood. Whole trades and branches of trades were left free. The mercantilism of England was always different in important respects from the Colbertism of France, and the tariff systems, generally, of continental states. Adam Smith comments on the "liberality" of English policy as contrasted with that of other states. It was a "free trade" system in (1) its extension of the powers of the central government over the trade and industry of the country at the expense of local and sectional bodies, close corporations, etc.: (2) the consequent equalising of opportunities and development of free enterprise, (3) the "nationalising" of great trades such as the East India trade, the trade of the Levant, etc., (4) the removal of internal restrictions, such, for example, as those on the corn trade, (5) the introduction of free trade first between England and Scotland and then between Great Britain and Ireland.

The term "free trade" was used in many different senses in contemporary literature and practice, but scarcely at all in its modern sense. It was applied to the freedom of intercourse between states as secured by treaty, to privileges granted to alien traders by which they were put on equal terms with the denizens of the country. It sometimes suggested illegality, piracy and unfair avoidance of established regulations; it was applied to the "interlopers" who carried on free trade with no regard to the regulations of the chartered companies, and to the smugglers who escaped the payment of duties levied by the state. In modern times free trade does not necessarily involve the meaning applied to it in England, but the policy of free exchange, and the levelling up of conditions by means of a tariff or other regulations to secure equality of competition between the countries concerned. Free importation in the modern English sense is peculiar to Eng-

land, just as in England the term protection has come to be restricted in its application to the imposition of duties. It is also to be noted that the rôle played by the colonies under the mercantile system was roughly that which Cobden and his followers expected both colonies and foreign countries to play when the United Kingdom adopted free importation, and if the mercantilists sometimes imposed special regulations to direct colonial trade into channels considered favourable for the development of the mother country, the adherents of the Manchester school not infrequently used the power and influence of England to keep the economic activities of neutral and eastern countries in a stage considered favourable to the interests of British industry and to prevent the due expansion of those countries on lines more in accordance with the wishes of the people and the national resources of those countries.

There is a further distinction between the older system and Cobdenism. Both were forms of "national" as distinct from "imperial" policy, but under the former the colonies had a great part to play. They were in a position entirely different from that of foreign countries, in relation to the United Kingdom; and the system of preferences which then existed would have lent itself to the building up of the empire. Under the Cobdenite system the colonies had no part to play at all different from that of foreign countries, and the "interests of the consumer" took the place of the "interests of the commonwealth" as the basis of public policy. The older system looked forward, as it were, to the establishment of a great empire. Cobdenism was not really internationalism viewed from the point of view of British policy, but nationalism in a narrow, insular sense and the policy of England under its influence was based upon the economic monopoly secured by the rapid progress of invention. The influence of the new industrialism broke the cautious continuity of British policy. Walpole and Pitt revised the fiscal system by removing duties on raw material and reducing other duties with the view of increasing revenue. Huskisson revised the fiscal system in much the same spirit. The measures throughout this period were more in accordance with the cautious and statesmanlike line of Adam Smith's *Wealth of Nations* rather than with the later economists. If this movement had not been interrupted England would probably have retained the means of conducting international negotiations for consolidating the empire and providing a wide basis for revenue without any violent changes, but under later influences the policy of free importation was carried to extremes. People pursued the logical consequences of free trade rather than the practical interests of the country. The free traders on the one hand and the protectionists on the other were in violent and direct opposition on grounds of abstract theory rather than practical policy. But there is no important economist of the free trade school who does not admit important exceptions to the doctrine of free importation. The idea that all economists of that school were Cobdenites is without foundation. Reference has been made above to Adam Smith and his cautious attitude, but the great classical economists fairly generally admitted cases in which duties on imported manufactures might be desirable. Allowing therefore for the very different philosophical conceptions which were the basis of economics at that time as compared with our own, and the very different economic conditions which prevailed, there is not so much to distinguish the attitude of the writers of the early part of the nineteenth century from those of our own day in regard to practical policy as may be thought from manifestations of feeling during the fiscal controversy. The views of economists must be distinguished from the use made of them by political and social controversialists. The Ricardian theory of rent, the high prices and the practical difficulties of the times gave such people magnificent opportunity for working up a crusade against landlords, and the free trade movement which at first had been a most reasonable and proper effort to get rid of tiresome obsolete restrictions, became in the hands of extremists an instrument of social and political revolution. It is in England especially that the free trade movement was directed mainly against the landlord class and later on the capitalists, and it has grown by natural stages into the socialistic movement of modern times, while protectionism in all its branches has been more identified with methods of creating an industrial and commercial state of the modern type.

The qualifications of the free trade doctrine admitted by John Stuart Mill went far to undermine the whole basis of the doctrine. His famous admission in regard to infant industries of a new country could be made to cover a very large proportion of the protectionist expedients adopted in modern countries. The economic conditions and the rapid growth of the United States in the 19th century naturally made an immense impression. It was necessary to work out an explanation for such progress under an economic policy so different from that of England. But historically speaking, analogies to the development of the United States policy could be found all the world over. The word "new" in regard to industry cannot be confined in its application to the historic position of a country or an industry. It must apply to the stage of organisation of particular industries and if it is once admitted that a high tariff is justified from that point of view, the tariff policy of Europe during the nineteenth century finds much justification from the writings of the economists. But the admission could easily be extended to cover many other important steps of policy. The case may be taken of the country whose industries have been actually devastated by war or destroyed in the sense that the existing organisation for production had broken up, markets lost by the diversion of great works into activities for which they were not built and where vast works of reconstruction are required to bring them back to the peace efficiency which they once had. On Mills' admission it is difficult to deny the claim for protection while reorganisation is being carried out. The question becomes a matter of practical expediency, when we have to consider whether in given circumstances duties should or should not be imposed as an instrument of organisation. Obviously the policy to be pursued cannot be decided on purely abstract grounds.

The German Zollverein.—The most remarkable instance in modern times of the constructive use of a protective tariff in the building up of a great empire is to be found in the history of Germany. At the beginning of the 19th century Germany consisted of a number of small states each enjoying fiscal autonomy, separated from one another by customs frontiers, and after the era of the Napoleonic wars, German statesmen and economists saw that if national industries were to be established on a modern scale, these numerous areas would have to be unified. Standing alone and more or less isolated economically from their neighbours, they could not get the full advantages they could obtain in production by the development of their materials from their numerous population and from their mutual commercial relations. Germany had to choose between a large-state and a small-state policy, and Prussia began the work of organisation by the adoption of the tariff of 1818. Internal tariffs in the provinces of Prussia were swept away. Prussia as a whole was given protection against all external competitors, and other German States were invited to enter into union with her. The result of this movement was the formation of the Prusso-Hessian Zollverein. This was followed by the Zollverein between Wurtemberg and Bavaria and other combinations. These combinations were then brought into union and the first treaty of the Zollverein was adopted in 1834. The larger part of Germany thus became more or less a homogeneous economic area, except for a survival of a number of internal duties which it took many years to get rid of. The treaties were in the first instance for 12 years. By the end of the first period other states had acceded and so the process went on until the German Zollverein was completed. The Zollverein was not co-terminous with the German Empire, but it was the condition and the means by which the German Empire was created.

This movement was not understood in England, where it was regarded as protectionist in the narrow sense in which the word was used in English controversy. There were gloomy prophecies as to what would happen to Germany and what would happen to the trade of England with Germany. In fact the German movement was not dissimilar from that extending over a long period of time during which the economic union of England, Scotland and Ireland was effected, and many internal barriers were swept away.

The formation of the Zollverein brought about freedom of trade over a vast area, and its trade was protected against foreign competition by a carefully devised tariff round its external frontier. It is obvious that the internal union could not have been secured without the external protection. The German tariff and the internal organisation were necessary parts of the same movement, and the tariff organisation was supplemented by great schemes of reconstruction affecting every aspect of German life. The progress which followed the movement is without parallel, and the German empire became the most powerful competitor in the world with other countries. This feat of statesmanship was all the more remarkable as it was carried out in the teeth of British competition. When Great Britain entered upon her era of rapid commercial progress, she was first in the field with the inventions which revolutionised industrial processes, and she had the manufacturing monopoly of the world. Germany at the beginning was technically behind Great Britain, but she had one great help to her progress. Just when she was applying on a vast scale the principles of policy which had made Great Britain mistress of the world, that country turned her back on her own traditions and made a free present of her market to any country which could exploit it. The rapid industrial progress of Germany was undoubtedly partly due to the fact that German exporters had free entry into the English market for their goods. Before the World War, it was quite common for great German factories to be planned, erected and organised on the basis that they could always dispose of their surplus productions in the English markets to an advantage at any price they could fetch.

This illustration from Germany is given in order to show how misleading was and is the practice of abstract English free traders of grouping the commercial policies of the world under two categories, of free trade and protection. Actual policies as they have been carried out can never be described in that simple manner. It is not enough to say that the actual policies are a combination of both theories. They are not. The actual policies of countries are the expression of the living activities of great societies as they have been determined by their long history and the powers and functions which they have developed, and they never follow the lines of an abstract theory divorced from the facts of that development. All countries have followed or are following much the same general course of development as Great Britain up to the modern era, but no country in any part of the world has ever deliberately adopted the practice of free importation in modern times. Many German students for years before the war studied very carefully the course of events in England in order to avoid the mistakes which had been made.

We can see how the growth of the Zollverein brings into clear relief the mutual relations of the measures adopted in carrying out a great policy of economic nationalism, and the conditions under which such a policy can be achieved. Internal fiscal differences have to be swept away as far as possible, and that requires the provision of some alternative means for furnishing the revenue which in the first instance has to be sacrificed. So we get the organisation of a tariff against external countries and the development of means of direct taxation. The process further involved a policy for application to the means of communication, especially the railway system and transport by sea. In all these processes there was necessary some political reorganisation. The small States had to sacrifice their autonomous fiscal powers when they entered into the new union. The Zollverein on the German model could not be achieved without such sacrifice, a condition which could not be realised in the British empire where the dominions would certainly not give up their fiscal autonomy.

The German measures could not be carried through without social reorganisation and mainly under the influence of the German Centre Party and their arrangement with Bismarck a whole code of new social laws was evolved. To enlarge still further the economic borders and to bring fresh markets on the continent within their ambit, the Germany treaty system was developed. Later on in order to meet the economic pressure which followed from their rapid development, Germany pushed into a colonial policy and the exigencies of diplomacy, quite apart from the necessities of defence, forced Germany into a naval policy, and the German navy was established. Thus the German empire was gradually forced to adopt in a modern form all the leading characteristics of the old English national system, and the instrument by which these changes were brought about was the German tariff. This immense constructive movement, the greatest example we have of modern economic nationalism, obviously cannot be described as simple protection. It was a great scheme of organisation in which for one purpose or another the German tariff had to be used as an instrument.

Modern Attitude to Protection.—A certain practical attitude to the question of protection characterises the policy of all countries in modern times. It is recognised that every case has to be examined on its merits. No two tariff systems are the same, nor can it be decided which is more protectionist than another without the most careful examination not only for the actual rates of duty, but of all surrounding circumstances. (*See* TARIFFS.) French and German policies have been in their main features singularly permanent during the nineteenth century. The broad lines of policy have remained and are likely to remain as long as these countries subsist. There are no signs of any considerable modification. French policy, it may be said, is certain, since the acquisition of Alsace and Lorraine, to become more nationalist in character and the features which have marked successive tariffs for many years are more likely to be emphasised than abandoned. Italy is showing all the signs of a nationalist régime, and she will proceed along much the same path as Germany and France. The new states which have been formed since World War I all show the marks of strong nationalism and this has found expression in the high tariffs they have one and all imposed. Under the pressure of modern economic conditions which are unfavourable to the existence of small States, many of them, while they may retain their political independence, will be forced by circumstances into economic combination, and the course of development followed by the German empire will be repeated in the economic sphere.

In the Far East the same movement is making rapid progress. It is many years since Japan embarked upon her own national policy. The development there is not in the least likely to be checked, still less will there be any return to the stage from which it was the departure. The old economic régime in China is at an end. Whether politically that huge country settles down to internal peace or not, it is certain that there will be an effective tariff in China organised for the purpose of Chinese industrial development and not as it has been, a revenue tariff while the Chinese market provided the means of disposing of the produce of European states. India is pursuing the same course, a fact of the utmost significance to Great Britain, because the Indian market as the Lancashire exporter has known it, is diminishing in importance; and the effect of this development upon the cotton trade and all the other 40 industries bound up in the cotton trade is of the greatest political and economic importance to Great Britain and the whole of the British empire. Egypt is following the same course. Within three years the conventions come to an end. Egypt will then have ready a new tariff. Every one of the British dominions is following the same course of development on national lines, and there is no sign that any other course, preference within the empire excepted, will be seriously considered. Great Britain, no longer the economic mistress of the world, one amongst many great nations at least as well equipped as she is, all pursuing with conviction the policy which they believe made the British empire, has abandoned her free trade attitude. There are now thousands of import duties in the British tariff. There is nothing between the present piecemeal application of protection and the working out of a tariff on a scale suited to domestic and imperial needs except transitory influences and questions of immediate expediency.

It seems therefore that both protection and free trade in the academic sense of loyalty to a particular theory in which these words were used, have ceased to cover in any way the developments of policy in the world as we know it. There is a reversion all the world over to a conception of policy similar to that which

inspired the earlier national policy of England under which protective tariffs are used or not used on the grounds of pure expediency to assist the aims of modern nationalism or imperialism, and this modern nationalism or imperialism is not a policy based upon the exploitation of any country or race, but the due adjustment of the economic relations of countries in such a manner as to secure their autonomous development and the efficiency of production. (W. A. S. H.)

UNITED STATES

The Civil War divides the protection policy of the United States into two distinct periods of approximately equal length. During the first 70 years there was a quarter-century (1789–1816) during which tariff making was governed primarily by revenue considerations; this was followed by a period of vigorous protection to rising young manufactures (1816–32), a period which was succeeded in turn by a quarter-century of declining protective duties (1833–60). With the Civil War, new forces came into operation, and since 1862 the United States has followed a rigid and consistent protective policy, interrupted thus far only by the relatively moderate Wilson and Underwood tariffs of 1894 and 1913.

When Congress met under the Constitution, the first bill introduced in the House of Representatives was a measure to provide revenue by means of a customs tariff. Various States had protective duties before the Constitution was adopted, and the debates on the revenue bill show clearly a general willingness to use the tariff to encourage domestic industries. Yet the rates enacted were low (in general but 5%), with specific duties on certain articles selected for special encouragement. During the 20 years following, the European wars created a great foreign market for American raw products, and made ship-building and shipping highly profitable, notably in New England; so there was little growth of American manufactures, and no appreciable increase of protectionist sentiment, despite the strong argument for protection put forth in Hamilton's *Report on Manufactures* (1792). As more revenue came to be needed, tariff rates were raised from time to time, but no special attention was given to their protective aspects, and down to 1816 the actual operation of the customs duties was only remotely protective.

From 1808, however, the industrial situation changed abruptly. The Embargo act (Dec. 1807), followed by the Non-Intercourse act (1809) and the war with England, cut off a large part of the export and import trade. Small manufactures sprang up in various parts of the country to meet pressing needs. Financially weak, and often ill-equipped, they were in no position to meet the sharp competition of the more advanced British manufactures with which they were faced on the return of peace. Their cries of distress, together with the need for more revenue, in 1816 brought new tariff legislation. Though designed to aid the manufacturers, this measure embodied only moderate duties, running as high as 25% on textiles for three years only, with a provision for minimum valuation. Though bad crops in Europe for a time kept the price of farm products high, the farmers too found themselves in difficulty after the crisis of 1818–19, and their thoughts turned toward the possibility of a home as opposed to a foreign market. As a result of these conditions there sprang up after 1819 an agitation for internal improvements and a vigorous protective movement, which aimed to insure national self-sufficiency by encouraging young manufactures and affording the farmer a home market. This so-called "American system," popularly identified with the name of Henry Clay, its foremost spokesman, had its early strength in the middle and Western States, New England at first holding aloof because of its predominant shipping and commercial interests. As industrialization proceeded, however, New England swung over, and from the latter part of the '20s that section became a foremost advocate of the protective system, which Pennsylvania had favoured from the first.

In response to the demand for protection, Congress passed the Tariff act of 1824, raising the duties on textiles, and also on iron, wool, hemp and other articles of particular interest to the middle and Western States and to the farmers. Agitation was renewed after the crisis of 1825–26, culminating in the celebrated Harrisburg convention of 1827. In the following year, as a result of extraordinary political manoeuvres, a new law was enacted, the so-called "tariff of abominations," which brought further sharp increases of rates, particularly on wool and other goods whose protection was specially distasteful to the New England protectionists. Four years later this measure was superseded by another act, which put the tariff into a form satisfactory to its friends. Goods not produced in the United States paid low rates while textiles, iron and other articles which it was desired to protect, paid high ones. Woollens, for example, were taxed 50%, while the specific duty on rolled bar-iron at 1832 prices was equal to 95%.

The Southern States were unable, because of slavery, to develop manufactures, and they were interested chiefly in a good market for their raw cotton. Rightly judging that protection was bound to work directly to their disadvantage, they had from the beginning sharply opposed protection. The opposition became so fierce that South Carolina undertook to nullify the Act of 1832, but the firmness of President Jackson maintained the Federal authority. As a consequence of Southern opposition, however, the compromise tariff of 1833 was enacted, providing for a slow reduction of duties over a period of 10 years, until in 1842 no rate should exceed 20%. Manufactures had in fact by 1832 become settled on a firm basis, and interest in the tariff waned, while other questions, like internal improvements and slavery, came to occupy public attention. The final low rates of the act of 1833, it so happened, were in effect but two months, as the Whig Party in 1842, for political rather than economic reasons, passed a new high-tariff measure, which remained on the statute books for four years. The protective movement had largely lost force, however, so this measure was without much difficulty replaced in 1846 by the so-called Walker tariff, a moderate measure under which the most important protected articles paid 30% except cottons, which paid 25%. There was little interest in the tariff, and in 1857 a redundancy of revenue led to further reductions, the 30% rate going down to 24%. Often called a free-trade tariff, the act of 1857 in fact marked the lowest level of protective rates since the beginning of active protection. Under the circumstances then existing, the reduction of duties commanded general approval, even among the manufacturers. The protective movement of the '20s, the period in which manufactures were becoming firmly established, had gradually lost fervour after 1832, leaving the way clear for the fixed opposition of the Southern States to make itself effectively felt. The interest of farmers and manufacturers alike turned to other methods than tariff legislation as a means of insuring prosperity, and no real or supposed national interest was successfully invoked to stay the growing movement toward greater freedom of international trade. A revenue shortage following the crisis of 1857 occasioned the enactment of the Morrill tariff of 1861, framed to attract protectionist votes to the Republican Party in the campaign of 1860. Undertaking only to restore the rates of 1846, its authors yet sought to give added protection to Pennsylvania and the Western States by changing *ad valorem* to higher specific duties and by raising rates on iron and wool. Even so, the measure belongs essentially to the period of tariff liberalization beginning in 1833.

The Civil War brought profound industrial changes, and gave a new direction to tariff policy. Hitherto, customs duties had been practically the sole source of government revenue, and tariff legislation had therefore been dictated to no small extent by the condition of the Treasury. The war, with its insatiable demands for revenue, called into existence an elaborate system of internal-revenue taxes, of which the imposts on liquor and tobacco remained as a permanent and highly important part of the revenue system, thus affording legislators somewhat more leeway to deal with customs duties without primary consideration of their effects on the revenue. The internal-revenue acts of 1862 and 1864 laid heavy taxes on the production of commodities of all sorts, taxes which were naturally accompanied by corresponding increases of duties on imports. As those who framed the laws were protectionists, they were eager to see that no domestic producer was injured; accordingly, almost any duty asked for was granted. A

tariff structure, "in many ways crude and ill-considered," establishing "protective duties more extreme than had been ventured on in any previous tariff act," to quote the leading authority, was thus suddenly built up. Like the other hasty financial legislation of the period, it was originally designed to meet the war emergency. At the end of the war, however, the structure thus erected, instead of being rebuilt, was preserved practically intact, and with relatively minor modifications continued to serve as one of the two pillars of Federal finance down to 1913.

After the war, the internal-revenue taxes, except those on liquor and tobacco, were promptly swept away, but the protected interests successfully resisted the reduction of protective duties, thus retaining what had been granted during the war both as compensation for internal taxes and as protection. The demand for tax reduction and tariff reform was met in 1870 by a lowering of rates on revenue articles like tea, coffee, sugar and spices, but an actual raising of certain protective duties, including those on steel rails and nickel. Two years later it became necessary to do something more to reduce revenue. Fearing worse things, the protectionists consented to a horizontal 10% reduction of all duties, on condition of the entire repeal of the non-protective duties on tea and coffee. When more revenue was needed in 1875, the 10% was easily and quietly restored. On the other hand, the high war rates on wool and woollens had been in 1867 raised yet higher, at the instance of certain woollen manufacturers and sheep breeders represented in the Syracuse convention; and the elaborate scheme of classified duties on wool, together with compound specific and *ad valorem* compensating and protective duties on woollens, introduced in the Morrill act, had been further developed. Similarly, the Lake Superior copper producers succeeded in 1869 in getting Congress to raise the duties on copper ore and ingot copper. By this means a combination of copper producers for a decade obtained extra prices equal to a good part of the duty. In 1870 the 45% duty on steel rails was changed to a slightly higher specific duty of $28 a ton. Rail costs fell rapidly, and by 1877 this amounted to almost 100%. The small number of American companies owning the Bessemer patent made enormous profits and expanded their business rapidly. At the request of interested producers, though with less striking results, there was a similar raising of duties on marble and nickel.

No general revision of duties occurred until 1883, when a redundant revenue compelled a reconsideration of the entire situation. A tariff commission was appointed, made up of protectionists. Its recommendations looked, on the whole, towards reduction, but little attention was paid to them. The protectionist forces in control of Congress managed, by skilful parliamentary management, to get rates raised on goods which continued to be imported despite the existing protective duties—articles such as fine woollen cloths and dress goods, cotton hosiery, laces and embroideries, iron ore and various special manufactures of steel—while duties were lowered chiefly in cases where the new rates were no less prohibitory than the old, such as cheap cottons, steel rails and copper. The act made no fundamental change in the protective system. Tariff discussion continued, and President Cleveland's annual message to Congress in Dec. 1887, urging general tariff reduction, particularly on raw materials, made protection the outstanding issue of the presidential campaign of 1888. The Republicans were successful, and they proceeded accordingly to revise the tariff in order to make it more highly protective. By the McKinley act (1890) the duties on wool and woollens were raised, as were also those on such cottons as continued to be imported, particularly knit goods. Linens went up sharply, and velvets and plushes of all sorts, of which imports were heavy, were charged high rates in the effort to establish a new industry. With the same purpose, tin-plate, with which the United States had been supplied almost entirely by importation, was charged $2\frac{2}{10}$ cents a pound, but with the proviso that it should be admitted duty free after 1896 unless domestic production should equal $\frac{1}{3}$ of imports in some one year between 1890 and 1896. The existing duty of two cents a pound on sugar, which was practically a revenue duty, since only a tenth of the supply was produced at home, was repealed. and the domestic producer was given a two-cent bounty instead, the two measures together taking something like 60 millions a year out of the Treasury. The whole act was a bold attempt to extend the protective system distinctly farther.

In the two succeeding political campaigns the Republicans were overwhelmingly defeated, and the Democrats returned to power pledged to tariff reduction. Party quarrels over the silver question, however, together with the narrowness of the party majority in the Senate and the determination of certain Democratic senators to maintain protection for particular interests, resulted in the emasculation of the tariff measure passed by the House, and the Wilson act of 1894 was allowed to become law without the president's signature. Even so, it constituted a break in the series of increasingly protective measures enacted since the Civil War. First, and most important, wool was made free, and the complicated duties on woollens were replaced by simple *ad valorem* duties, which, however, afforded the manufacturers a protection equal to the full amount that they had nominally enjoyed under the McKinley act. Rates on the finer cottons were lowered somewhat. Iron and steel duties were lowered, though not in any significant manner, and the rate on tin-plate was cut in two. Coal and iron ore, as raw materials, were made free by the House, but the Senate restored both to the dutiable list, though at reduced rates. The great battle was waged over sugar; the outcome was a duty of 40% *ad valorem* on raw sugar, and of 40% plus one-eighth of a cent a pound, plus an extra tenth of a cent a pound on sugar coming from any country that gave an export bounty, on refined sugar. This result was commonly regarded as a victory for the "sugar trust" and a violation of party pledges. The measure as a whole was a great disappointment to the tariff reformers. It went into effect, moreover, in the early stages of a period of business depression.

The money question carried the Republicans back into power in 1897, but political conditions made monetary legislation impossible, and President McKinley called Congress in extra session for the sole purpose of tariff revision. A new bill was promptly reported, and the Dingley act was passed without delay, restoring essentially the system of 1890. The wool and woollens duties of that year were re-established, with some changes, mostly upward. Specific duties, even higher than the previous high *ad valorem* ones, were laid on silks, and linens were treated likewise. The farmer got a duty on flax, and the ranchman, for the first time in 25 years, a tax on hides. As the iron and steel industry was largely beyond reach of foreign competition, rates were left in good part where they had been put in 1894, but certain specialties, like razors and cutlery, which continued to be imported, were raised by changes in classification, while tin-plate, the manufacture of which in the United States had been greatly aided by the relative cheapening of American steel sheets in the years immediately preceding, was given rates little in advance of those of 1894. Rates on raw sugar were pushed above those of the Wilson act, thus at once increasing revenue and giving added protection to the beet-growing industry, and the refiners kept the $\frac{1}{8}$ cent differential of 1894. The Dingley act, it will thus be seen, gave up no part of the protective structure of 1890, and at a number of points extended it beyond its previous limits.

The rapid growth after 1898 of industrial combinations, popularly supposed to be special beneficiaries of the tariff, and the rise in the cost of living, led in time to increasing criticism of the protective system, and aided, along with the restiveness of the Middle-West farmers and the growth of manufactured exports, in putting the protectionists more or less on the defensive. The Republican Party, accordingly, in the campaign of 1908 enunciated the so called "true principle" of protection, that duties should equal the difference between cost of production at home and abroad, plus a reasonable profit to American industries. Theoretically and practically impossible as the principle is, it yet indicated the line of defense to be adopted in the tariff revision promised by Taft as a presidential candidate. The Payne-Aldrich act of 1909 was in fact written along the same lines as its predecessors, with little more than lip-service to the "true principle." The House committee proposed to admit coal, lumber, iron ore and hides free. Hides were freed in fact, bringing some reductions in leather and

shoes; the other materials continued to pay duties, though at reduced rates. As usual, practically important upward changes were made in the textile schedules, as in the rates on mercerized cotton, cheap hosiery and silks. The iron and steel duties, most of which had long since ceased to have practical significance, were generally reduced; but razors were given another upward turn, as were also pliers, cheap cotton gloves, asbestos fabrics, and other particular articles whose claims were effectively presented by their producers to the legislators. Figs, prunes and lemons were protected. The act brought no substantial modification of the protective system, but the whole tone of its supporters indicated inability or unwillingness to push much farther the aggressive protectionist policy of the '90s.

The back-handed reciprocity provisions of the acts of 1890 and 1897, authorizing the president by proclamation to impose duties on certain goods otherwise free, if coming from countries that discriminated against products of the United States, were omitted from the Act of 1909. Instead, the rates of 1909 were declared the minimum tariff and those rates plus 25% (of the value of the goods) the maximum. After March 31, 1910, the maximum rates were to go into effect automatically, except in the case of those countries where the president had satisfied himself that "no undue discrimination" was exercised against the United States. By strenuous exertions the administration managed to avoid the imposition of the maximum rates in any case, though tariff wars with France, Germany, and especially Canada, were narrowly averted. The president also construed a provision of the maximum and minimum clause as authorizing him to appoint a tariff board, which proceeded to make studies on the basis of the "true principle," the moderate protectionists believing that its findings might serve as a second line of defense against the reduction of genuinely protective duties. The same moderate group, under the leadership of President Taft, were eager to do something for the export manufacturers, whose eagerness for foreign markets had been recognized in the Act of 1909 only in the ill-judged maximum and minimum provisions. A measure was accordingly driven through Congress, against the bitter opposition of the extreme protectionists, approving a treaty for a moderate measure of reciprocity with Canada, and freeing wood-pulp irrespective of Canadian action. To the disappointment of the moderates, Canada rejected the treaty.

The year 1913 found the Democrats in control of the presidency and of both branches of Congress. President Wilson promptly called Congress in special session, and a new tariff measure was enacted which was widely hailed as marking the beginning of a new era in American tariff policy. Announcing the principle of a "competitive tariff," and declaring their intention to injure no "legitimate industry," the party in power yet proceeded to a downward revision looking to definitely moderate protection. Wool was admitted free; and woollens after Jan. 1, 1914, were to pay a straight *ad valorem* rate of 35%. Sugar, the duty on which, with the growth of the beet industry, had become a protective one, was to be free after May 1, 1916, by which time it was thought that the newly enacted income tax would be in running order and would be yielding income effectively. Cottons were sharply reduced; though most of the reductions were nominal the new rates meant the probability of increased imports of the finer goods. Silks were cut somewhat, though the general rate was still 45%. Coal and lumber were freed, and leather and boots and shoes followed hides to the free list. Iron ore and crude iron and steel products likewise were made free, and rates were cut to a maximum of 20% on the advanced products. To meet the farmers' wishes, agricultural implements, by a harmless gesture, were carried to the free list; but at the same time wheat, flour, cattle and meats were freed in response to the demand for a lowered cost of living, thus introducing the possibility of a less restricted border trade. The "jokers," special rates imposed at the behest of particular favoured producers, which had become so conspicuous and unpleasant a feature of protective acts, for the greater part disappeared. The act repealed the maximum and minimum provisions of 1909, and in 1916 a tariff commission was established. While many of the reductions of the Underwood act were politically rather than economically important, it represented a genuine though cautious attempt at a wider freedom of trade.

After the outbreak of World War I, for half a decade American industries, despite reduced duties, had no European competition whatever. Various of the so-called "war babies," notably the chemical industry, grew enormously to meet immediate needs. With the return of peace, some of them faced sharp foreign competition. The spectacular fall of prices in 1920 plunged agriculture into distress, and the farmers turned to protection as a supposed remedy. When the Republicans returned to power in 1921, they promptly laid high duties (quite incapable of raising prices under the circumstances) on various farm products that had been freed in 1913, notably wheat, corn and meat, as also wool and sugar. This "emergency" measure was followed by the Fordney-McCumber tariff of 1922, following the lines of the Act of 1909, but surpassing it in the application of protection. Agricultural rates were higher than in 1909. Generally without economic significance, they did in fact mean the probability of higher prices for such products as California fruits, wheat on occasion, and notably sugar. Wool was given increased protection, and the elaborate system of compensating and protective duties on woollen manufacture was restored. Textiles generally fared about as in 1897 and 1909. Iron alloys and specialties subject to foreign competition, like cutlery and firearms, were raised above the rates of 1909, as were china ware, jewellery, toys and laces, the last-named paying 90% *ad valorem*. Coal-tar products, dye-stuffs and chemicals, which had sought absolute prohibition, were granted extremely high rates.

The Act authorized the President, after investigation by the tariff commission, to raise or lower rates (within the limit of 50% of the prescribed duties) as might be necessary to equalize costs in the principal competing country. Under this provision the president raised rates in a number of cases, but lowered them in no important instance.

The farmers failed to share the prosperity of the twenties, and early in his administration President Hoover called Congress in extraordinary session to revise the tariff for their benefit. Congressional action promptly took the form of a general upward revision of duties, giving rise to a fierce legislative struggle. Export manufacturers urged moderation, financial experts pointed out the necessity of increasing imports in view of the creditor position of the United States, protests against threatened injuries came from forty foreign countries, and more than a thousand economists signed a memorial advocating the defeat or veto of the measure. Nevertheless it was enacted in 1930, after a notorious process of log-rolling. According to the calculations of the tariff commission, the Act raised the average rates in every schedule, the increase being greatest on agricultural products. Sugar, cattle, dairy products, grains, lemons and other California products, wool, woollen and silk goods, manganese and tungsten bearing ores, and pig iron all went up. Lumber, brick, cement, hides, sole leather, and boots and shoes, all of which had been free, were subjected to duties.

There were increases on many small manufactured products, like watch and clock movements, cheap toys and matches, unimportant to the United States, but highly important to certain foreign exporting countries.

The flexible tariff provision was retained. The raising of American duties at a time when international trade was already declining caused sharp resentment abroad, and was promptly followed by higher tariffs in many countries. From 1929 to 1933 the foreign trade of the world, according to League of Nations figures, fell by 25 per cent in quantity and 65 per cent in value.

In 1934 a reciprocity act was passed authorizing the President for three years to make trade agreements with other countries; this act was later extended to 1940. Under it 19 nations made reciprocal trade agreements with the United States up to Jan. 1, 1939.

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PROTECTIVE COLOURATION: *see* COLOURS OF ANIMALS, MIMICRY.

PROTECTORATE, in international law, now a common term to describe the relation between two States, one of which exercises control, great or small, direct or indirect, over the other. It is significant of the rare use of the term until recent times that the word does not occur in Sir G. C. Lewis's book on *The Government of Dependencies*. Yet the relation is very ancient. There have always been States which dominated their neighbours, but which did not think fit to annex them. Engelhardt (*Les Protectorats anciens et modernes*) and other writers on the subject have collected a large number of instances in antiquity in which a true protectorate existed, even though the name was not used. Thus the hegemony of Athens, as it existed about 467 B.C., was a form of protectorate; though the subject States were termed allies, the so-called "allies" in all important legal matters had to resort to Athens (Meyer, *Geschichte des Alterthums*, vol. iii. s. 274).

In dealing with dependent nations Rome used terms which veiled subjection (Gairal, *Les Protectorats internationaux*, p. 26). Thus the relationship of subject or dependent cities to the dominant power was described as that of *clientes* to the *patronus* (Marquardt, *Römische Staatsverwaltung*, 2nd ed., vol. i. p. 80). Such cities might also be described as *civitates foederatae* or *civitates liberae*. Another expression of the same fact was that certain communities had come under the power of the Roman people; *in deditionem* or *in fidem populi romani venire* (Marquardt, *Römische Staatsverwaltung*, i. 73, 81). The kingdoms of Numidia, Macedonia, Syria and Pergamum were examples of protected States, their rulers being termed *inservientes*. The Romans drew a distinction between *foedera aequa* and *foedera iniqua*. The latter created a form of protectorate. But the protected State remained free.

In mediaeval times this relation existed, and the term "protection" was in use. But the relation of subordination of one State to another was generally expressed in terms of feudal law. One State was deemed the vassal of another; the ruler of one did homage to the ruler of another. In his book *De la République* Bodin treats of *ceux qui sont en protection* (I. c. 7), or, as the Latin text has it, *de patrocinio et clientela*. In Bodin's view such States retain their sovereignty (I. c. 8). Discussing the question whether a prince who becomes a *cliens* of another loses his *majestas*, he concludes that, unlike the true vassal, the *cliens* is not deprived of sovereignty. Elsewhere he remarks, "le mot de protection est special et n'emporte aucune subjection de celuy qui est en protection." He distinguishes the relation of *seigneur* and *vassal* from that of *protecteur* and *adherent* (p. 549, ed. 1580). At times letters of protection were granted by a prince to a weak State, as *e.g.*, by Louis XIII. in 1641 to the prince of Monaco (Gairal, p. 81).

Reverting to the distinction in Roman law, Grotius and Pufendorf, with many others, treat protection as an instance of unequal treaties; that is, "when either the promises are unequal, or when either of the parties is obliged to harder conditions" (*De jure belli et pacis*, I. c. 13. 21; *De jure naturae*, 8. c. 9).

Definitions.—"The one common element in protectorates is the prohibition of all foreign relations except those permitted by the protecting State. What the idea of a protectorate excludes, and the idea of annexation, on the other hand, would include, is that absolute ownership which was signified by the word *dominium* in Roman law, and which, though not quite satisfactorily, is sometimes described as 'territorial sovereignty.' The protected country remains, in regard to the protecting State, a foreign country; and this being so, the inhabitants of the protectorate, whether native-born or immigrant settlers, do not by virtue of the relationship between the protecting and the protected State become subjects of the protecting State" (Lord Justice Kennedy, *Rex* v. *Crewe*, 1910, 2 K.B. 576).

The term is used very loosely. Often it designates a relation which is deemed politic to leave indefinite: a State desires to obtain the reality of conquest without the responsibilities attaching thereto. Protectorate may mean no more than what it says: "One State agrees to protect or guarantee the safety of another." The term is also employed to describe any relation of a political superior to an inferior State. It is also used as the equivalent of suzerainty. As appears from the article SUZERAINTY, the terms are distinguishable. But both imply a desire to carry out changes without friction and not to break up ancient forms; both proceed on the plan of securing to the stronger State the substance of power while allowing the weaker State a semblance of its old constitution.

Certain protectorates originate in treaties; others have been imposed by force. Some are accompanied by occupation, in which case it is difficult to distinguish them from annexation. Thus the treaty of May 1881, art. 2, between France and Tunis, provides for the occupation of strategical points by the protecting State (A. Devaulx, *Les Protectorats de la France*, p. 21).

Strictly speaking, a protectorate cannot exist over a domain uninhabited or ruled by no organized State; in such cases the elements of the true protectorates are wanting. But the distinction is not adhered to.

Indian Protectorates.—It has been the policy of the British Government in India to establish on the frontiers, as elsewhere, protectorates. The political advantages of the system are pointed out in Sir A. Lyall's *Rise and Expansion of the British Dominion in India*. It is a system "whereby the great conquering or commercial peoples masked, so to speak, their irresistible advance"; it was much practised by the Romans in Africa and Asia; it has been chiefly applied in modern times in India (p. 326). The Indian States are sometimes described as "Feudatory States," sometimes "Independent and Protected States" (Twiss), sometimes "Mediatized States" (Chesney), sometimes "Half-Sovereign," sometimes as in a position of "subordinate alliance" (Lord Salisbury, *Parliamentary Papers*, 1897 [c. 8700]. s. 27). The Interpretation Act 1889 refers to the Indian native princes as under the "suzerainty" of the British Crown. These States are really *sui generis*, and their precise position can be understood only by a private examination of the treaties affecting them. (*See* Ilbert, *Government of India*, and the article INDIAN LAW.)

There are two principal classes of protectorates; the first being those exercised generally by treaty over civilized countries. Of the first, Andorra, protected by Spain and France as successors of the counts of Foix, is an example (*see* ANDORRA). The second class of protectorates consists of those exercised by one civilized State over an uncivilized people, sometimes called a "Colonial Protectorate" or "pseudo-protectorate," and usually the preparatory step to annexation. These have become common, especially in Africa, since 1878. The second class may be subdivided into two groups: (*a*) protectorates exercised over countries with organized Governments and under recognized sovereigns, such as the Malay States; and (*b*) those exercised over countries possessing no stable or definite Governments and rulers. The territories of chartered companies, when not within the dominion of the protecting State, may also for some purposes be regarded as protectorates. For details, the specific treaties must be consulted.

Protectorates and International Law.—The legal position of protectorates is still somewhat undetermined; there is an old view and also a new view of their nature. The relation may be one of international law, two States having entered into obligations by treaty. Or the relation may be one of public law; one of two States has become subordinate to, and incorporated with, the other. The general rule is that the protected State does not cease to be a sovereign State, if such was its previous status. Its head is still entitled to the immunities and dignity of a sovereign ruler (see *Development Co.* v. *Kelantan* [*Government*] *and A. G.*, 1924, A.C. 797). Further, the establishment of a protectorate does not

necessarily rescind treaties made between the protected State and other States, at all events when it is not in reality conquest or cession, or when any modification would be to the injury of third parties (*Parl. Papers*, "Madagascar," 1897 [c. 8700]; Trione, 187). Nor does the new relation make any change as to the nationality of the subjects of the two States, though in some countries facilities are afforded to the subjects of the *Unterstaat* to transfer their allegiance; and they owe a certain ill-defined degree of obedience to the protecting State. Nor, speaking generally, does the territory of the protected State become part of the territory of the *Oberstaat;* in this respect is it unlike a colony, which may be regarded as an extension or outlying province of the country. At the same time, the question whether a particular protectorate forms part of the "dominion" or "territory" of the Crown for any purposes or within the meaning of any statute cannot be regarded as wholly free from doubt; its terms and intention must be examined. (*See* Hall, *International Law*, 8th ed., 150; Heilborn, *Das völkerrechtliche Protectorat* [1891], 535; Tupper, *Indian Protectorates*, 336; Laband, *Das Staatsrecht des deutschen Reiches* [1876–82], 2, s. 70; *Sub Luza II.* v. *Miller and Swaziland Corporation*, 1926, D.C. 518).

The older view of the position of a protectorate according to international law is contained in the decision of Dr. Lushington in the case of the "Leucade" (8 S.T., N.S., 432), to the effect that, the declaration of war by Great Britain against Russia notwithstanding, the Ionian islands, which were then under the protectorate of Great Britain, remained neutral. The king of Great Britain had the right of declaring peace and war. "Such a right is inseparable from protection." But the Ionian States did not become necessarily enemies of the State with which Great Britain was at war. According to one view, the protected State is implicated in the wars to which the protecting State is a party only when the latter has acquired a right of military occupation over the territory of the former. "Cette solution a été reconnue par la France en 1870, à propos de la guerre contre l'Allemagne pour les îles Taiti alors soumises à notre protectorat; elle s'imposerait pour la Tunisie, l'Annam et Tonkin, et pour le Cambodge, où les traités nous conférent le droit d'occupation militaire" (M. Despagnet). In the event of hostilities between the protecting and protected States, such hostilities would be regarded not as of the nature of an insurrection, but as a regular war (Trione, 149).

By the General Act of the Berlin Conference it was agreed that the acquisition of a protectorate should be notified to the signatories to the agreement (art. 34), and it has been the practice to give such notice.

Many writers adhere to the doctrine that there is no impairment of sovereignty of the weaker State by the establishment of a protectorate. They also allege that it is *res inter alios acta*, an arrangement which concerns only parties to it. But the trend of recent policy and purport of much recent legislation are against this view. The probability is that in such cases Governments and courts applying international law would probably be guided not by technical facts—such, to take the case of British possessions, as the fact that an order in council permitted appeals to the Judicial Committee—but would look to the facts of the case. "Any State which undertakes to protect another assumes towards the rest of the world responsibility for its good behaviour—the more complete protection the more extensive the responsibility—and this responsibility involves a duty to interfere if need be" (Coolidge, *United States as a World Power*, p. 167; and to the same effect Liszt, *Völkerrecht*, p. 31; and Zorn, *Völkerrecht*, p. 45). The tendency is for protecting States to assert jurisdiction over foreigners within the territories of the protected States (Westlake, 187; Jenkyns, p. 176; Ilbert, 3rd ed., ch. 6). Hall remarks (*International Law*, 8th ed., p. 150 n.) that "all the States represented at the Berlin Conference of 1884–85, with the exception of Great Britain, maintained that the normal jurisdiction of a protectorate includes the right of administering justice over the subjects of other civilized States." The General Act contemplated measures which are scarcely compatible with the exemption of European traders and adventurers from the local civilized jurisdiction. He points out that Great Britain—which until lately took the view that a protected State possesses only delegated powers, and that an Eastern State cannot grant jurisdiction over persons who are neither its own subjects nor subjects of the country to which the powers are delegated—had by the Pacific order in council of 1893 and the South African orders in council of 1891–94 asserted jurisdiction over natives and foreign subjects. "The Orders show a gradual increase of the assumption of internal sovereignty" (Jenkyns, 193). The fact is that in the case of protectorates over uncivilized or semi-civilized countries a development is inevitable: control quickly hardens into conquest, and international law more and more takes note of this fact. (*See* also MANDATE; SOVEREIGNTY; SPHERES OF INFLUENCE.)

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(J. MAC.)

PROTEINS are highly complex substances found in all living cells, in blood and in materials elaborated for the development of the young animal or plant, such as milk, eggs and seeds. The word is derived from the Greek πρῶτος, meaning first, because proteins are apparently of first importance in respect of the phenomena which we call life, which can only exist in association with a material called protoplasm, which consists very largely of proteins. The composition of proteins varies somewhat. They all contain carbon, hydrogen, oxygen and nitrogen; most of them contain sulphur, and some contain phosphorus. The average composition is, C 51%, O 25%, N 16%, H 7%, S 0·4%, P 0·4%. They are formed by the union of a certain number of substances called amino-acids, of which about 20 have been discovered.

Amino-acids.—The living cells of the plant are able to form the amino-acids from relatively simple compounds, such as nitrates or ammonium salts, obtained from the soil. These amino-acids are then built up into the characteristic proteins of the particular plant. Animal cells are unable to form amino-acids from simple inorganic substances; the amino-acids must consequently be supplied in the food, in the form of plant proteins in the case of herbivorous animals, and animal proteins in the case of the carnivora. By the processes of digestion these food proteins are broken down into their constituent amino-acids, which are absorbed into the blood and are then available for building up the proteins of the tissues. It is probable that certain of the amino-acids can be formed in the body from other amino-acids, but on the other hand some essential amino-acids cannot be formed thus, *i.e.*, they must pre-exist in the protein of the food. The essential amino-acids are tryptophane, lysine, histidine, cystine, and possibly tyrosine and arginine. It follows that the nature of the amino-acids of which a protein is composed determines, to a certain extent, its value as a foodstuff for animals. Protein is disintegrated into its constituent amino-acids by boiling with dilute mineral acid, which converts tryptophane into a black substance called humin. Some proteins can be broken down by the action of certain digestive ferments, notably trypsin.

The amino-acids isolated by breaking protein down into its constituents are substances which contain both an acid (carboxylic) group and a basic (amino-) group. They can be divided into classes depending on the number of these groups, as follows:—(a) neutral amino-acids, containing one acid and one amino-group, *e.g.*, glycine, alanine, leucine, tyrosine and cystine, (b) acid amino-acids, containing two acid and one amino-group, *e.g.*, aspartic and glutaminic acids; (c) basic amino-acids, containing one acid and two amino-groups, *e.g.*, arginine and lysine; (d) heterocyclic compounds, in which a ring compound of carbon and

nitrogen is united to an amino-acid group, the two most important members being histidine and tryptophane. The amino-acids are united to one another by a condensation (or subtraction of the elements of water) between the carboxylic group of one compound and the amino-group of its neighbour:

$H_2N{\cdot}CH(CH_3){\cdot}COOH + HHN{\cdot}CH_2{\cdot}COOH \longrightarrow H_2N{\cdot}CH(CH_3){\cdot}CO{\cdot}NH{\cdot}CH_2{\cdot}COOH$

Alanine Glycine Alanyl-glycine.

The compound formed by such an union (peptide linkage) is called a di-peptide.

Very long chains of amino-acids have been formed synthetically, and the resulting compounds, called polypeptides, closely resemble the proteins in many ways. These *peptides* are split up into their constituent amino-acids by prolonged boiling with dilute mineral acids, the elements of water being added. This splitting or hydrolysis is also effected by two of the digestive enzymes found in the body, viz., trypsin of the pancreatic juice and erepsin of the intestinal juice. It is almost certain that there is at least one other type of union between the amino-acids, for pepsin, the enzyme of the gastric juice which digests proteins, is unable to split the peptide linkage, yet can break the highly complex food proteins into relatively simple compounds.

Classification of Proteins.—The system of classification adopted by the American Society of Biochemists is in general use and is closely followed in Great Britain; where the British Physiological Society uses a different name this is indicated by (B). The three main groups are those of the simple, conjugated and derived proteins, as follows:—

I. Simple Proteins: naturally occurring proteins formed from amino-acids only.

Albumins. Coagulable by heat, soluble in water and dilute salt solutions; *e.g.*, serum albumin, egg albumin and lactalbumin.

Globulins. Coagulable by heat, soluble in dilute salt solutions and dilute solutions of acids and alkalis. Generally insoluble in water, but a few ("pseudo-globulins") are soluble in water; *e.g.*, serum globulin of the blood and myosin, the chief protein of meat.

Glutelins. Found in cereals. Heat coagulable, insoluble in neutral solvents, but soluble in dilute acids and alkalis.

Prolamines (Gliadins [B]). Also found in cereals, but distinguished from the glutelins by their solubility in 75% alcohol; *e.g.*, zein from Indian corn (*Zea mais*), and gliadin from wheat.

Albuminoids (Scleroproteins [B]). Found in the skeletal and connective tissues of animals. They are characterized by their insolubility in most reagents; *e.g.*, keratin of hoofs and hair, elastin of yellow elastic tissue, collagen (the anhydride of gelatin) from tendons and white connective tissue.

Protamines. Basic proteins which are formed from a few amino-acids only and these mainly the basic amino-acids. They are found in the heads of ripe spermatozoa and in ova.

Histones. Similar to the protamines, but less rich in the basic amino-acids. They are not so basic as the protamines. They are present in unripe spermatozoa, in the red blood corpuscles and in the lymphoid tissues of the body.

II. Conjugated Proteins: proteins joined to a non-protein or prosthetic group.

Chromo-proteins. The prosthetic group is coloured, *e.g.*, haemoglobins of vertebrate blood, and haemocyanin of invertebrate blood, both of which are connected with respiration.

Glycoproteins (Glucoproteins [B]). The prosthetic group contains a carbohydrate radical; *e.g.*, mucin and mucoids.

Nucleoproteins. The prosthetic group is nucleic acid, which contains phosphorus, purine bases, pyrimidine bases and a sugar group. They are widely distributed in animal and vegetable cells, especially in nuclei.

Phosphoproteins. The prosthetic group is phosphoric acid. They are distinguished from the nucleoproteins in that they do not contain purine or pyrimidine bases; *e.g.*, casein of milk and vitellin of egg-yolk.

III. Derived Proteins: these are the decomposition products of any of the above, produced by boiling in water or by hydrolysis with dilute acids, alkalis or by the action of enzymes; the artificially synthesized polypeptides are also included.

Metaproteins. Insoluble in water or dilute salt solutions. Soluble in dilute acids or alkalis. Coagulated by heat if they are in suspension.

Proteoses. Soluble in water, not coagulated by heat. Precipitated by saturation with ammonium sulphate.

Peptones. Similar to the proteoses, but not precipitated by saturation with ammonium sulphate. They are relatively simple proteins and are much more diffusible.

Peptides. Simple peptones, generally of known constitution.

Reactions and Properties.—In the foregoing scheme of classification physical properties are mainly used for the characterization of the proteins. Certain colour reactions can be obtained arising from the chemical structure of the protein molecule and due either to the presence of certain amino-groupings in the protein molecule or to the special linkages formed by their union with one another. The more important of these colour reactions are, (1) the xanthoproteic, indicating such aromatic groups as tyrosine and tryptophane; (2) the glyoxylic, due to the presence of tryptophane; (3) Millon's, due to tyrosine; (4) the sulphur test, due to cystine; and (5) Molisch's test for a carbohydrate complex. It follows that a protein like gelatin, which does not contain either tryptophane, tyrosine or cystine, fails to give the glyoxylic, Millon's or sulphur tests. Zein does not contain tryptophane, but does contain tyrosine; hence it gives Millon's test but not the glyoxylic reaction. The biuret colour reaction, however, is of a different character, in that it is not given by any amino-acid but is given by all proteins, owing to the particular way in which the amino-acids are linked together.

The proteins are precipitated by certain complex acids called the alkaloidal reagents because they were first used for the precipitation of alkaloids (*q.v.*). The more important of these acids are tannic, picric, phosphotungstic, phosphomolybdic, metaphosphoric, sulphosalicylic, tri-iodo-hydriodic and ferrocyanic. These reagents only precipitate in acid solutions, the precipitates being soluble in alkalis. The peptones and peptides are less readily precipitated than the more complex proteins. The proteins are also precipitated in neutral or slightly alkaline solution by the salts of certain metals, especially those of copper, lead, mercury, iron and gold.

Of considerable importance in connection with the general physical properties of the proteins is the fact that the solutions are usually in the colloidal state (*see* Colloids). The feature of this condition is that the material is suspended in the solvent (water, salt solution, etc.) in particles of a certain size. If they are larger than 0·0001 mm. (0·1μ) they can be retained by filter paper or porcelain and are visible with an ordinary high-power microscope, and constitute a "coarse suspension" or precipitate; if they are smaller than 1×10^{-6} mm. (1$\mu\mu$) they form a "molecular solution," and the substance will diffuse through parchment or collodion membranes. Between these limits we have the colloids, in which the particles are too large to pass through parchment membranes and too small to be removed by filter paper, or be seen with an ordinary microscope, but are large enough to interfere with the passage of light rays, being thus rendered "visible" by the ultramicroscope. The proteins, and particularly the complex natural proteins, exist in the colloidal state owing to the great size of the molecules. The length of the molecule of egg-albumin has been found to be 4·17$\mu\mu$, that of the molecule of serum albumin 4·41$\mu\mu$, whilst the molecules of serum globulin or of gelatin may be as large as 50–100$\mu\mu$.

The particles in suspension may in some cases exist in the form of single molecules, but a slight change in the conditions may cause these to coalesce to form larger clumps, even to the extent of providing visible aggregates, or a precipitate. This can sometimes be effected by altering the acidity or alkalinity of the fluid, sometimes by the addition of a small amount of a particular neutral salt. When the aggregates formed cannot be dispersed by reverting to the original conditions, the phenomenon is known as *coagulation.* The best known example is that of the coagulation of the albumins and globulins of the egg by boiling, an alteration ("denaturation") taking place in the native proteins. The altered protein is precipitated at a certain reaction, which is

generally on the acid side of strict neutrality. At the coagulating temperature the particles of protein in the precipitate adhere together to form an irreversible coagulum. To produce this coagulation, a given temperature and reaction and the presence of certain inorganic substances are necessary. The first two conditions vary somewhat with different proteins and have been used for the characterization of some of the albumins and globulins.

The use of strong solutions of neutral salts as a method for the precipitation of certain proteins is of considerable importance. The chief salts employed are magnesium sulphate, sodium sulphate and particularly ammonium sulphate. When a solution is fully saturated with the last substance all proteins with the exception of the peptones and peptides are completely precipitated. The addition of one part of a saturated aqueous solution of ammonium sulphate to one part of a fluid is called "half-saturation" and is used for the separation of globulins from albumins. The methods for the complete removal of proteins from a solution depend on the nature of the proteins present. In the case of the albumins and globulins, heat coagulation at the correct reaction may suffice. The most important precipitants are tungstic acid, metaphosphoric acid and colloidal iron, though tannic and mercuric and lead salts are sometimes employed.

Uses of Proteins.—The most important use of protein is that of a food-stuff for man and the domestic animals, since protein is the only form in which they can obtain a supply of the amino-acids that are essential for the building-up and maintenance of the protoplasmic tissues of the body. Some of the amino-acids are used for the formation in the tissues of certain derivatives (generally known as "internal secretions") without which it is impossible for the body as a whole to function properly. It will be seen therefore that the nature and balance of the various amino-acids in a particular protein will have a marked effect on what is known as the "biological value" of the protein as a food. Thus the chief protein of Indian corn is zein, which does not contain any tryptophane—one of the essential amino-acids—and consequently persons whose sole protein is that of Indian corn are apt to suffer from the disease known as Pellagra, which may be due to the deficiency of tryptophane.

Another function of protein in the diet is that of supplying energy by combustion in the body. The proteins also are concerned in promoting the oxidation of the carbohydrates and particularly of the fats in the body. Thus the inhabitants of very cold climates can withstand the low temperatures on a diet very rich in protein and fat, the high protein content enabling the fats to be oxidized more readily in the body. This action is known as the "specific dynamic action" of the proteins. The inhabitants of the tropics, on the other hand, subsist on a diet that contains a relatively small amount of protein, the energy requirements for the maintenance of body temperature being very low. It was at one time thought that the muscular energy of the body was obtained from the proteins alone, but it has been found that this is erroneous. Carbohydrates normally function in this way, but the requisite carbohydrates can be supplied from certain of the amino-acids in animals fed on a pure protein diet. Any excess of protein in the diet over the immediate needs of the body is usually oxidized in a few hours, the body being unable to store protein as it can fats or carbohydrates. But within certain limits it seems that if abundant protein is taken with regular muscular exercise, as in the training diet of some athletes, a small percentage of this protein can be stored for increase in the size of the protoplasmic masses of the individual muscle fibre. The utilization of proteins as food-stuffs is primarily dependent on their digestibility. Proteins like the keratins of hair and horn are not broken down into amino-acids by the enzymes of the alimentary canal and cannot serve as foods. The average amount of protein in the adequate diets of adult inhabitants of the temperate climes is about 100 grams per diem.

Industrial uses of proteins are dealt with in other articles (*see* CASEIN; GELATIN; GLUE; LEATHER; SILK MANUFACTURE; WOOL, etc.). Other uses are in the manufacture of water-resisting adhesives, distempers, small articles such as buttons, and in the special transparent preparation known as "galalyte" which is used for artificial amber.

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(S. W. C.)

PROTESILAUS, a Thessalian hero, son of Iphiclus, and husband of Laodameia. He was the first to spring ashore on Trojan soil, although he knew it meant instant death. His wife prayed that he might be permitted to return to earth for three hours. Her prayer was granted, and on the expiration of the time allotted she returned with him to the nether world. Hyginus gives (*Fab.*, 104) what seems to be a rationalistic version of this. It is curious that no surviving Greek author tells the story. In another account (Conon, *Narrationes*, 13) Protesilaus survived the fall of Troy and built the city of Scione. His tomb and temple were near Eleus in the Thracian Chersonese.

Iliad, ii. 698; Ovid, *Heroides*, xiii.; Lucian, *Dial mort.* xxiii., 1; Philostratus, *Heroica*, iii.

PROTESTANT, the generic name for an adherent of those Churches which base their teaching on the principles of the Reformation. The name is derived from the formal *Protestatio* handed in by the evangelical states of the empire, including some of the more important princes and imperial cities, against the *recess* of the diet of Spires (1529), which decreed that the religious *status quo* was to be preserved, that no innovations were to be introduced in those states which had not hitherto made them, and that the mass was everywhere to be tolerated. The name Protestant seems to have been first applied to the protesting princes by their opponents, and it soon came to be used indiscriminately of all the adherents of the reformed religion. Its use appears to have spread more rapidly outside Germany than in Germany itself, one cause of its popularity being that it was negative and colourless, and could thus be applied by adherents of the "old religion" to those of the "new religion," without giving offence, on occasions when it was expedient to avoid abusive language.

As the designation of a Church, "Protestant" was unknown during the Reformation period and for a long while after. In Germany the Reformers called themselves usually *evangelici*, and avoided special designations for their communities, which they conceived only as part of the true Catholic Church. It was not until the period of the Thirty Years' War that the two main schools of the reformed or evangelical Churches marked their definitive separation: the Calvinists describing themselves as the "Reformed Church," the Lutherans as the "Lutheran Church." In France, in England, in Holland the evangelicals continued to describe their churches as *ecclesiae reformatae*, without the *arrière pensée* which in Germany had confined the designation "Reformed" to the followers of a particular church order and doctrine. As to the word "Protestant," it was never applied to the Church of England or to any other, save unofficially and in the wide sense above indicated, until the style "Protestant Episcopal Church" was assumed by the Anglican communion in the United States.

PROTESTANTENVEREIN is the name of a society in Germany the general object of which was to promote the union (*Verein*) and progress of the various established Protestant Churches of the country in harmony with the advance of culture and on the basis of Christianity. It was founded at Frankfort-on-the-Main in 1863 by a number of distinguished clergymen and laymen of liberal tendencies, representing the freer parties of the Lutheran and Reformed Churches of the various German states, amongst whom were the statesmen Bluntschli and Von Bennigsen and the professors R. Rothe, H. Ewald, D. Schenkel, A. Hilgenfeld and F. Hitzig. The more special objects of the association were, beside the promotion of mutual toleration and respect among adherents of different creeds and of all Christian works necessary for the moral strength and prosperity of the nation, the assertion of the right of the clergy, laity and both lay and clerical professors to search for and proclaim freely the truth in independence of the creeds and the letter of Scripture.

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und seine Bedeutung für die Gegenwart (Wiesbaden, 1868; 2nd ed., 1871); *Der deutsche Protestantenverein in seinen Statuten und den Thesen seiner Hauptversammlungen 1865–1882* (Berlin, 1883); P. Wehlhorn in Herzog-Hauck's *Realencyklopädie;* H. Weinel, "Religious Life and Thought in Germany To-day," *Hibbert Journal* (July 1909).

PROTESTANT EPISCOPAL CHURCH in the United States of America is spiritually the direct descendant of the Church of England, and is a part of the Anglican Communion. From the Church of England the Protestant Episcopal Church inherits its faith, its liturgy and its spiritual traditions, though it is entirely independent in its own life and government. The preface of the American Prayer Book, officially set forth in 1789, affirms the substantial identity and continuity of the two churches in the following words "This Church is far from intending to depart from the Church of England in any essential point of doctrine, discipline or worship; or further than local circumstances require." The Protestant Episcopal Church is therefore in full fellowship with the Anglican Communion, while at the same time it is wholly free and independent in the ordering of its life and the fulfilment of its mission in the United States.

Although services were held in various parts of the country by the clergy who, as chaplains, accompanied groups engaged in exploration, the first permanent settlement of the church was at Jamestown, Va., in 1607. The church was legally established in Virginia from the start, and became established in Maryland after the Revolution of 1689. At the beginning of the American Revolution, it was established in all of the southern Colonies, and in five counties in New York. Trinity church, New York, was chartered by the crown in 1697. The Church of England obtained a foothold in Massachusetts in 1686, in Pennsylvania in 1695 and in Connecticut in 1706. By the end of the colonial period, it was represented in all of the Colonies, though its members were a small minority in some of them. Its growth during this period was fostered by the Society for the Propagation of the Gospel in Foreign Parts. Founded in 1701, through the efforts of the Rev. Thomas Bray, a missionary in Maryland, this body helped to support ministers and schoolmasters in communities where the local maintenance was inadequate. Through all this period, however, the church had no bishop in the American colonies. It was under the jurisdiction of the bishop of London, who naturally could do little for this far distant field. Without bishops, the Episcopal Church was in an anomalous position. Those desiring to be ordained to the ministry were compelled to make the long and perilous voyage to England. The people could not be brought to confirmation. Efforts to secure the consecration of bishops by the mother church in England were strongly opposed by the Nonconformist churches in the colonies, especially in New England.

Revolutionary Period.—The Revolution was a time of severe trial for the Church of England in the colonies. Many of the clergy felt called upon to give up their parishes and return to England, though others, especially in the south, remained at their posts and gave their support to the American cause. Of the laity a large majority was on the side of the Revolution, and many of them were among its most active leaders. Two-thirds of those whose names are signed to the Declaration of Independence were members of the Episcopal Church. William White, afterward the first bishop of Pennsylvania, was chaplain of the Continental congress. George Washington, himself a member of the church, went, accompanied by both houses of congress, to St. Paul's chapel, still standing on Broadway and Vesey street, New York city, for the religious service which completed the ceremonies of his inauguration as first president of the United States, and this service was conducted by Samuel Provoost, the first bishop of New York and rector of Trinity church.

At the close of the war, the church was left without bishops or a central organization. The first bishop was Samuel Seabury, elected by the clergy of Connecticut, who, impatient of delays in England, secured consecration from the nonjuring bishops of Scotland on Nov. 14, 1784. The development of a central organization resulted from a movement which centred in the middle states, under the leadership of the Rev. William White, rector of Christ church, Philadelphia, Pa. State conventions, including the clergy and representatives of the laity, were first formed, and these were united in a general convention which drew up a constitution, began a revision of the Prayer Book and secured the consecration of two bishops in England, William White of Pennsylvania and Samuel Provoost of New York, on Feb. 4, 1787.

The whole church was united in the General convention of 1789, when Bishop Seabury and delegates from New England joined the representatives from other states. This meeting revised the constitution to provide for a separate house of bishops in General convention, and completed the revision of the Prayer Book along more conservative lines than those originally proposed. Another bishop, James Madison of Virginia, was consecrated in England on Sept. 19, 1790. All four bishops united in the first consecration on American soil, that of Thomas John Claggett as bishop of Maryland in 1792.

The church was organized for its work, but the conditions which it faced were full of difficulties. As a result of the Revolutionary War there was much popular prejudice against any institution claiming connection with England, in the communities influenced by Puritanism there was strong opposition to the principles and teachings of the Episcopal Church and there were divisions within its own household. At the convention of 1811 only one of the six bishops attended, and there were few more clergy and laymen present than in 1789.

Period of New Vigour.—With the coming of a new generation, the church found more vigorous leaders, whose zeal and devotion were exemplified in the careers of three men, John Henry Hobart, Alexander Viets Griswold and Richard Channing Moore, consecrated bishops respectively of New York, the eastern diocese and Virginia. In Virginia, Bishop Moore's powerful preaching and strong personality roused the church to new life. Bishop Griswold's diocese included an immense region comprising the collapsed diocese of Massachusetts (which had already had two bishops, Edward Bass in 1797 and Samuel Parker in 1804), Maine, Rhode Island, New Hampshire and Vermont. His achievements were truly amazing; with only 16 clergy in all at the outset of his episcopate, he had the satisfaction of ending it with a fivefold increase in the number both of parishes and communicants, and with the redivision of his cumbersome territory into five separate dioceses.

Bishops Griswold and Moore were Evangelicals. Bishop Hobart, who had brilliant success in building up the church in New York state and founded a number of important church institutions, was a high churchman who anticipated some of the positions of the Oxford movement. An awakening interest in theological education led to the foundation of General Theological seminary in New York in 1819, and of the Theological seminary in Virginia in 1824.

The church was now aroused to meet the new conditions and opportunities of its reconstituted life. The Domestic and Foreign Missionary Society, founded in 1820, gave fresh impetus to the work of church extension. In 1835 its membership was made coextensive with the church. Philander Chase, the pioneer bishop of the west, did his great work in Ohio and founded Kenyon college, obtaining from churchmen in England funds for this undertaking; Jackson Kemper, the first officially designated missionary bishop, went further into the northwest where his arduous labours prepared the way for future dioceses; James Harvey Otey did noble missionary work in Tennessee and the southwest. James Lloyd Breck, priest and missionary, founded Nashotah hall, originally an associate mission, but later a theological seminary, in Wisconsin; he also started schools in Minnesota, at Faribault, and pushed on across the country, establishing new foundations as he went, until he reached the Pacific coast. During this period the Episcopal Church grew steadily from a proportion of 1 communicant to 400 of the population in 1830 to 1 communicant to 107 at the end of the century. With the growth and development of the country new dioceses and missionary districts were established. In 1853 Bishop William I. Kip began his labours as first bishop of California; in 1854 bishops were consecrated for Oregon and Iowa; in 1859 Bishop Henry B. Whipple was sent to Minnesota to take up his work among white people and Indians. Foreign missionary work was begun with

the opening of an educational mission in Greece in 1829, and expanded with the founding of missions in Liberia in 1835, China in 1840 and Japan in 1859.

The Oxford movement, whose influence began to be felt in the United States during the 1840s, though destined to enrich and broaden the life of the church, excited a bitter controversy which was interrupted but not ended by the Civil War. The Muhlenberg memorial, presented to the house of bishops in 1853, made an impassioned plea to the church to rise above partisanship and realize the full possibilities of its position. Its proposals were too daring for the time, but many of them were later adopted in modified forms. The spirit of controversy reached its peak at the General convention of 1874, but gradually subsided thereafter, through a growing realization that the church's nature was essentially comprehensive and that its Catholic and Protestant traditions could both make important contributions to its mission. The rise of the liberal movement aided in the growth of this realization.

Civil War and After.—The Civil War necessarily led to a separate administration of the church in the confederate states, but the whole body was quickly reunited at the close of the conflict. The war period saw the formation of two new seminaries, the Philadelphia Divinity school and the Episcopal Theological school at Cambridge, Mass. During the years following, the church-controlled University of the South was organized at Sewanee, Tenn.

After the period of the Civil War, the church made progress, its growth more than keeping pace with the increase in population. Its organization came to cover every part of the United States and its dependencies, and it continued to expand its missionary work in other lands, with bishops and organized missionary work in Alaska, Puerto Rico, the Panama Canal Zone, the Hawaiian Islands, the Republic of the Philippines, Cuba, Mexico, Brazil, China, Japan, Liberia, Haiti and the Dominican Republic. In 1867 and thereafter, bishops of the Episcopal Church participated periodically in conferences of the entire Anglican episcopate held at Lambeth, Eng.

Among the educational institutions of the church at mid-20th century were Trinity college at Hartford, Conn.; the University of the South at Sewanee, Tenn.; Hobart college at Geneva, N.Y.; Kenyon college at Gambier, O.; Bard college at Annandale, N.Y.; Canterbury college, Danville, Ind.; and the American Church institute for Negroes. The Theological schools, in addition to the General Theological seminary in New York (official institution of the whole church) and the Virginia seminary previously mentioned, were the Berkeley Divinity school at New Haven, Conn.; the Divinity school in Philadelphia; the Episcopal Theological school in Cambridge, Mass.; Nashotah house at Nashotah, Wis.; the Theological school at Sewanee, Tenn.; the Seabury–Western Theological seminary at Evanston, Ill.; the Church Divinity School of the Pacific, San Francisco, Calif.; the Bishop Payne Divinity school at Petersburg, Va.; Bexley hall, Gambier, O. The Church also had established, especially in the east, many important schools for boys and girls.

Church Development.—The life of the church continued to find expression in a great number of societies and organizations, such as the Women's auxiliary to the National council; the Brotherhood of St. Andrew; the Girls' Friendly society; the Church Association for Seamen's Work; the Social Service commissions; the church clubs of the various dioceses; the Episcopal Service for Youth; the American Church union; and the Church congress in the United States. Among the religious orders at mid-20th century were the Society of Mission Priests of St. John the Evangelist; the Order of the Holy Cross; St. Barnabas brotherhood; the Community of St. Mary; the Community of St. John the Baptist; the Society of St. Margaret; the All Saints Sisters of the Poor; the Sisterhood of the Holy Nativity; and others. The institutions for the training of deaconesses included the New York Training School for Deaconesses; the department of women of the Philadelphia Divinity school; and the School for Christian Service and Deaconess Training School of the Pacific at Berkeley, Calif.

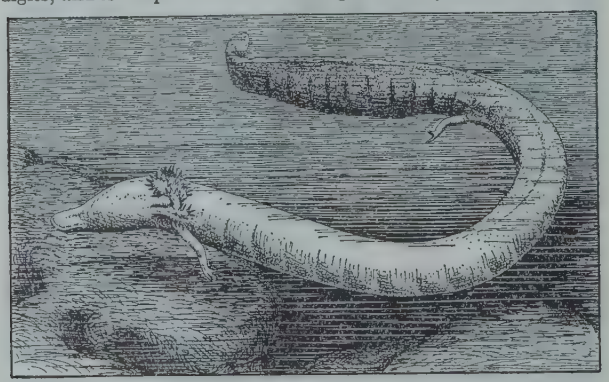
The governing body of the Protestant Episcopal Church is the General convention which meets every three years, and which consists of the house of bishops and the house of deputies, the two houses sitting and deliberating separately. The house of bishops has as its members all the bishops of the church. The house of deputies is composed of not more than four presbyters and four laymen elected by each diocese and not more than one presbyter and one layman elected by each missionary district. Either house may originate and propose legislation, and all acts of the convention must be adopted and authenticated by both houses. In the house of deputies the vote on any question may be taken by orders, the clerical and lay deputies voting separately and a concurrent vote of the two orders being required for the adoption of the resolution. The laity thus have their full share and responsibility in the legislative action of the church. No alteration in the Book of Common Prayer may be made unless this is proposed at one meeting of the General convention and adopted at the next succeeding triennial meeting. Each diocese holds its own annual convention, presided over by the bishop, in which both clergy and laity have their part. The diocese adopts its own constitution and canons for the regulation of its internal affairs, with the provision that these must not conflict with the constitution and canons of the General convention. A bishop is elected by the diocese, but the election must be confirmed by a majority of the bishops exercising jurisdiction within the United States, and by a majority of the standing committees of all the dioceses. Missionary bishops are elected by the house of bishops, the choice being subject to confirmation by the house of deputies if the General convention is in session, and at other times by a majority of the standing committees of the several dioceses. As regards the ministry, the Episcopal Church, in common with the Anglican Communion, holds to the historic threefold order of bishops, priests and deacons. The official pronouncements on this subject are contained in the Preface to the Ordinal. The constitution of the church (article viii) provides that no person shall be consecrated bishop, or ordained priest or deacon, until he shall have made in writing, in presence of the ordaining bishop or bishops, the following declaration: "I do believe the Holy Scriptures of the Old and New Testaments to be the Word of God and to contain all things necessary to salvation; and I do solemnly engage to conform to the Doctrine, Discipline, and Worship of the Protestant Episcopal Church in the United States of America." And every person before being baptized and received into membership in the church is required to answer affirmatively the question "Dost thou believe all the articles of the Christian Faith as contained in the Apostles' Creed?" Neither the clergy nor the laity are required to subscribe to the Thirty-Nine Articles.

Church Activities.—An important change in the organization of the church was made in 1919 by the establishment of a national council, with the presiding bishop at its head, to act as the executive body of the General convention between its sessions, and to have charge of the general missionary, social and educational work of the church; with the provision that, for the future, the presiding bishop should be elected instead of succeeding to this office by seniority of consecration. The national council gave new impetus to the work of the church and strengthened its corporate life. The revision of the Book of Common Prayer, undertaken in 1913, was completed in 1928. A statistical report at mid-century gave the following figures: dioceses and missionary districts, 102; communicants, 1,671,366; clergy, 6,547; candidates for Holy Orders, 394; lay readers, 5,537; enrolled in Sunday schools, 546,064; total contributions for the year 1949, $69,311,977. Clergy and people desired that the Protestant Episcopal Church in the United States should serve the cause of Christian reunion. At the General convention in 1910 a movement was initiated to bring about a world conference on faith and order. After 17 years of preparation and effort, the conference was held in 1927 at Lausanne, Switz., and was attended by representatives of all the major churches of Christendom with the exception of the Roman Catholic Church. Similar conferences were held in Oxford in 1937 and in Amsterdam, Neth., in 1947. The Episcopal Church joined the Federal Council of the Churches

of Christ in America in 1940. Missionary work in Asia was disrupted by World War II but was renewed with fresh vigour afterward.

BIBLIOGRAPHY.—*See* W. S. Perry, *Historical Collections Relating to the Episcopal Colonial Church* (1870), and *History of the American Episcopal Church* (1885); Bishop William White, *Memoirs of the Protestant Episcopal Church* (1880); W. W. Manross, *History of the American Episcopal Church* (1935); E. C. Chorley, *Men and Movements in the American Episcopal Church* (1946). *See* also references under ENGLAND, CHURCH OF. (W. T. M.; W. W. MS.)

PROTEUS or OLM, a blind, water-breathing, tailed amphibian (*Proteus anguinus*) inhabiting the limestone caves to the east of the Adriatic. It is a small eel-like salamander, with minute limbs, the anterior pair having three toes on each, the posterior two, a narrow head, with flat truncate snout, minute vestigial eyes hidden under the skin which is pale flesh-coloured, with the short, plumelike external gills blood-red. *Proteus* forms with the American *Necturus* the family Proteidae. The second genus is more generalized in structure, with better developed limbs, with four digits, and is adapted to live in the light. Its thyroid gland is very



CAVE SALAMANDER OF EUROPE CALLED THE "OLM" (AFTER BREHM)

much reduced, but, unlike the axolotl it cannot be transformed into a terrestrial form by feeding with thyroid. Exposure to white light causes the skin to become black, even over the eyes; however, in red light, no blackening occurs, and the eyes grow large and functional.

See H. Gadow, *Amphibia and Reptiles* (*Cambridge Natural Hist.*)

PROTEUS, a Greek sea-daimon, shepherd of the flocks of the sea (seals, etc.) and a great prophet. According to Homer, his dwelling place was the island of Pharos, near the mouth of the Nile; in Virgil his home is the island of Carpathus, between Crete and Rhodes. He knew all things, past, present and future, but disliked telling what he knew. Those who wished to consult him had first to surprise and bind him during his noonday slumber in a cave by the sea, where he spent his time during the heat of the day surrounded by his seals. Even when caught he would try to escape by assuming all sorts of shapes, that of a lion, a serpent, a leopard, a boar, a tree, fire, water. But if his captor held him fast the god at last returned to his proper shape, gave the wished-for answer and plunged into the sea. He was subject to Poseidon.

In post-Homeric times the story (invented by Stesichorus?) ran that Proteus was the son of Poseidon and a king of Egypt, to whose court Helen was taken by Hermes after she had been carried off, Paris being accompanied to Troy by a phantom substituted for her. This is the story followed by Herodotus, who got it from Egyptian priests, and by Euripides in the *Helena*. From his power of assuming whatever shape he pleased, Proteus came to be regarded, especially by the Orphic mystics, as a symbol of the original matter from which the world was created.

See Homer, *Od.* iv; Virgil, *Georg.* iv; Stesichorus, p. 26 (44) ed. Bergk, with his notes; Euripides, *Helena;* Herodotus, ii, 112, 118.

PROTHERO, SIR GEORGE WALTER (1848–1922), British historian, was born in Wiltshire Oct. 14, 1848, being the eldest son of the Rev. G. Prothero, Canon of Westminster Abbey. Educated at Eton, he went from there to King's college, Cambridge, where he became a fellow. For a time a master at Eton, he soon returned to Cambridge as lecturer and tutor at King's college, where he was senior tutor from 1881. In 1884 he was appointed university lecturer in history; in 1894 he went to Edinburgh as professor of history; and in 1899 he succeeded his brother Rowland, afterwards Lord Ernle (*q.v.*) as editor of *The Quarterly Review*. During World War I he was director of the historical section of the Foreign Office and in that capacity he attended the Peace conference in Paris. He was created K.B.E. in 1920 and died in London July 10, 1922.

Prothero's chief historical works are *The Life and Times of Simon de Montfort* and the collection of authorities entitled *Select Statutes and other Constitutional Documents Bearing on the Reigns of Elizabeth and James I.* He also wrote a *Memoir of Henry Bradshaw,* a *School History of Great Britain and Ireland* (to 1910) and *German Policy Before the War*. He edited Voltaire's *Louis Quatorze* and J. R. Seeley's *Growth of British Policy* as well as the Cambridge "historical series," and he was one of the editors of *The Cambridge Modern History*.

PROTHESIS, in the liturgy of the Orthodox Eastern Church, the name given to the act of "setting forth" the oblation, *i.e.* the arranging of the bread on the paten, the signing of the cross (σφραγίζειν) on the bread with the sacred spear, the mixing of the chalice, and the veiling of the paten and chalice (*see* F. E. Brightman, *Liturgies Eastern and Western,* 1896). (Gr. πρόθεσις a setting forth). The term is also used, architecturally, for the place in which this ceremony is enacted, a chamber on the north side of the central apse in a Greek church, with a small table. During the reign of Justin II (565–574) this chamber was located in an apse and another apse was added on the south side for the diaconicon (*q.v.*), so that from his time the Greek church was triapsal. In the churches in central Syria both prothesis and diaconia are generally rectangular, and the former, according to de Vogué, constitutes a chamber for the deposit of offerings by the faithful. Consequently it was sometimes placed on the south side, if when so placed it was more accessible to the pilgrims. There is always a much wider doorway to the prothesis than to the diaconicon, and there are cases where a side doorway from the central apse leads direct to the diaconicon, but never to the prothesis.

PROTIĆ, STOJAN (1857–1923), Yugoslav statesman, was born at Krusšvak Jan. 29, 1857, and at first entered the government service. He soon came into conflict with the repressive régime of King Milan and in 1882 became editor of *Samouprava* and a leader of the new Radical party. He was imprisoned for a press offence in 1883 and again in 1885. He held subordinate posts in the Radical cabinet of 1887. In 1899 an attempt on King Milan's life was used by the government to rid itself of its Radical rivals. Protić was sentenced to 20 years' hard labour, although, in fact, he had no connection with the crime. Pardoned nine months later, he became director of the National library. After the revolution of 1903 he represented the Radicals in the first provisional cabinet under King Peter and remained minister of the interior in most of the succeeding cabinets down to 1907. He was finance minister during the Bosnian crisis and again became minister of the interior during the period of the Balkan Wars and the European crisis of 1914. In 1914, when leaders of the secret "Black Hand" organization were implicated in the murder of Serajevo, this organization was actually at daggers drawn with the Serbian government owing to a quarrel with Protić.

Protić remained out of office during the period of coalition government from Dec. 1914 to June 1917, but continued to exercise great influence in the background. He was returned to office in 1917 and played an active part in the negotiations leading to the Corfu agreement between the Serbian government and the Yugoslav committee.

He showed more comprehension for the Croat and Slovene standpoint than his colleague Pašić, and when the conflict between Pašić and Trumbić in 1918 delayed the recognition of Yugoslavia by the Allies and created an awkward situation with Italy, Protić was appointed the first premier of the new Yugoslav state. He was keenly interested in the constitutional prob-

lem, and after his resignation in Aug. 1919 published his own draft project.

Disagreeing with the exaggerated centralism of Pašić, he declined office in 1921 and drifted steadily away from his old colleague.

Protić died in Belgrade in Nov. 1923.

His publications include *The Aspirations of Bulgaria* (1916) and *Le problème Albanais,* etc. (1913), issued under the pseudonym of "Balkanicus."

PROTISTA: *see* PROTOZOA.

PROTOCOL, in diplomacy, the name given to a variety of written instruments.

The French word *protocole* is derived from the late Latin *protocollum,* from the Greek πρῶτος first, and κολλᾶν to glue, *i.e.,* originally the first sheet of a papyrus roll. The *protocollum* under the late Roman empire was a volume of leaves, bound together with glue, in which public acts were recorded, so as to guard against fraud or error on the part of those responsible for preparing them; and in later usage it came to be applied to the original drafts of such acts. Thus, too, the word *prothocollare* was devised for the process of drawing up public acts in authentic form.

In diplomacy the name of "protocol" is given to the minutes (*procès-verbaux*) of the several sittings of a conference or congress; these, though signed by the plenipotentiaries present, have only the force of verbal engagements (*see* CONGRESS). It is also given to certain diplomatic instruments in which, without the form of a treaty or convention being adopted, are recorded the principles or the matters of detail on which an agreement has been reached, *e.g.,* making special arrangements for carrying out the objects of previous treaties, defining these objects more clearly, interpreting the exact sense of a doubtful clause in a treaty (*protocoles interpretatifs*) and the like.

Occasionally also an agreement between two or more powers takes the form of a protocol, rather than a treaty, when the intention is to proclaim a community of views or aims without binding them to eventual common action in support of those views or aims.

Finally, "the protocol" (*protocole diplomatique, protocole de chancellerie*) is the body of ceremonial rules to be observed in all written or personal official intercourse between the heads of different states or their ministers. It lays down the styles and titles of states, their heads and public ministers, and indicates the forms and customary courtesies to be observed in all international acts. "It is," says M. Pradier-Fodéré, "the code of international politeness."

See P. Pradier-Fodéré, *Cours de droit diplomatique* (1899), ii, 499; E. Satow, *Diplomatic Practice.*

PROTOGENES, a Greek painter, born in Caunus, on the coast of Caria, but resident in Rhodes during the latter half of the 4th century B.C. He was celebrated for the minute and laborious finish which he bestowed on his pictures, both in drawing and in colour. Apelles, his great rival, standing amazed in the presence of one of these works, could only console himself by saying that it was wanting in charm. On one picture, the "Ialysus," he spent seven years; on another, the "Satyr," he worked continuously during the siege of Rhodes by Demetrius Poliorcetes (305–304 B.C.) notwithstanding that the garden in which he painted was in the middle of the enemy's camp. Demetrius, unsolicited, took measures for his safety; more than that, when told that the "Ialysus" just mentioned was in a part of the town exposed to assault, Demetrius changed his plan of operations. Ialysus was a local hero, the founder of the town of the same name in the island of Rhodes, and probably he was represented as a huntsman. This picture was still in Rhodes in the time of Cicero, but was afterwards removed to Rome, where it perished in the burning of the Temple of Peace.

The picture painted during the siege of Rhodes consisted of a satyr leaning idly against a pillar on which was a figure of a partridge, so life-like that ordinary spectators saw nothing but it. Enraged on this account, the painter wiped out the partridge. The "Satyr" must have been one of his last works. He would then be about 70 years of age, and had enjoyed for about 20 years a reputation next only to that of Apelles, his friend and benefactor. Both were finished colourists so far as the fresco painting of their day permitted, and both were laborious in the practice of drawing, doubtless with the view to obtaining bold effects of perspective as well as fineness of outline. It was an illustration of this practice when Apelles, finding in the house of Protogenes a large panel ready prepared for a picture, drew upon it with a brush a very fine line which he said would tell sufficiently who had called. Protogenes on his return home took a brush with a different colour and drew a still finer line along that of Apelles, dividing it in two. Apelles called again, and thus challenged, drew with a third colour another line within that of Protogenes, who then admitted himself surpassed. This panel was seen by Pliny (*N.H.* xxxv, 83) in Rome, where it was much admired, and where it was destroyed by fire.

In the Propylaea at Athens was a painting by Protogenes representing personifications of the coast of Attica, Paralus and Hammonias. For the council chamber at Athens he painted figures of the Thesmothetae, but in what form or character is not known. Probably these works were executed in Athens, and it may have been then that he met Aristotle, who recommended him to take for subjects the deeds of Alexander the Great. In his "Alexander and Pan" he may have followed that advice in the idealizing spirit to which he was accustomed. To this spirit must be traced also his "Cydippe" and "Tlepolemus," legendary personages of Rhodes. Among his portraits are mentioned those of the mother of Aristotle, Philiscus, the tragic poet, and King Antigonus. But Protogenes was also a sculptor to some extent, and made several bronze statues of athletes, armed figures, huntsmen and persons in the act of offering sacrifices.

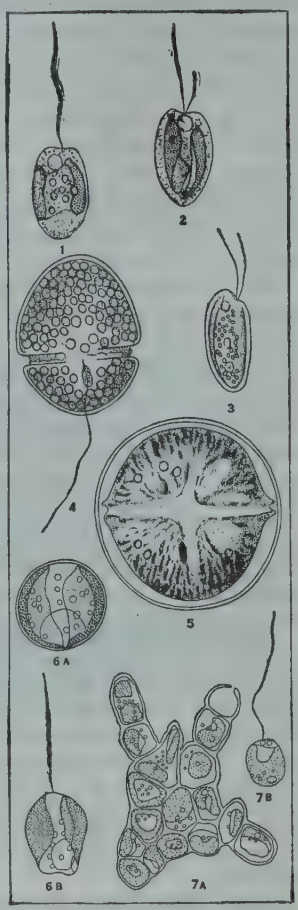
PROTOGUEROFF, ALEXANDER NICHOLOFF (1867–1928), Macedonian revolutionary leader, was born at Ochrida, Macedonia, in 1867. He went to the military school of Sofia, and, after some military service in Bulgaria, joined the Macedonian movement in 1895 and commanded a band of insurgents. He was a moderate member of the Superior Macedonian committee in Sofia, a rival of the Secret committee which was responsible for the rising of 1903. From 1908 to 1911 Protogueroff served in the army, and after a period in retirement, was elected in 1912 president of the Executive committee of the Macedonian societies.

When World War I broke out he organized the 11th Macedonian division, and commanded the 3rd brigade, later becoming assistant to the Bulgarian governor of Macedonia. In Sept. 1918 he was made commandant of Sofia, and maintained order when the Bulgarians were driven back. Later he left the army and entered politics, being arrested on Nov. 4, 1919, with Radoslavoff's cabinet. He escaped, and after two years in hiding, reached Macedonia in Oct. 1921, where he joined Todor Alexandrov, the Macedonian leader, and his chief lieutenant Peter Chaüleff.

On Aug. 31, 1924, Alexandrov was assassinated by Chaüleff's friends, as a result, it is supposed, of an agreement between Chaüleff and the Communists. Protogueroff in his turn arranged for the assassination of four of the persons responsible for Alexandrov's death. Chaüleff himself was assassinated on Dec. 23, 1924, and two more of his followers in the following year. During the later years of his life Gen. Protogueroff retired from active participation in the revolutionary movement, and became interested in spiritualism.

PROTOPHYTA. The designation Protophyta ("first plants") is applied to all simple one- and several-celled organisms that obtain their nourishment after the manner of a plant. Such forms probably afford a fairly accurate picture of what the early stages in the evolution of the vegetable kingdom were like. The simpler Algae (*q.v.*) are of course embraced in the Protophyta. Together with Protozoa (*q.v.*) the latter constitute the Protista, which comprise all the most elementary forms of life. There are many classes of Protista, some definitely holophytic (*i.e.,* feeding like a plant), others definitely holozoic (*i.e.,* taking in solid food like an animal), while still others exhibit a min-

gling of plant and animal characteristics, so that it depends to some extent on personal bias whether they be referred to Protozoa or Protophyta. A rigid definition is impossible and undesirable. The Protophyta may, however, justifiably be taken to include all simple organisms carrying on photosynthesis. In this process organic compounds are built up from carbon dioxide and water with the help of solar energy absorbed by pigments which are held within the cells in special protoplasmic bodies, the *chromatophores*. The latter always contain green chlorophyll which predominates in the green Algae (Chlorophyta), but in many classes is associated with other pigments (yellow, brown, red, etc.) which give a distinctive colouration to their respective members. Moreover, the carbon-compounds, that accumulate in the cells after active photosynthesis, vary in the different classes (starch, fat, leucosin, etc.), an indication that distinct metabolic processes are associated with the diverse types of pigmentation. The various classes can thus be distinguished on a physiological basis by their special mechanisms for nutrition.



FROM "SUSSWASSERFLORA," AND HARTMAN & PASCHER, "ARCHIVES FÜR PROTISTENKUNDE" (GUSTAV FISCHER)

TYPES OF PROTOPHYTA

1. Chromulina, motile cell (Chrysophyceae). 2. Ochromonas, motile cell. 3. Cryptomonas, motile cell. 4. Glenodinium, motile cell (Dinophyceae) 5. Hypnodinium, motionless cell (same). 6a. Chrysosphaera, motionless cell (Chrysophyceae). 6b. Chrysosphaera, Zoospore (same). 7a. Thallochrysis, branched filament (same). 7b. Thallochrysis, Zoospore (same)

Motile and Stationary Forms.—Many of the simplest unicellular Protophyta are actively motile with the help of delicate protoplasmic threads, the cilia or flagella, whose number and arrangement is usually distinctive for each class (figs. 1–4). Every class, however, also includes motionless organisms of varied type, partly unicellular (figs. 5, 6a) and partly multicellular (fig. 7a). Many of these reproduce themselves by means of naked swarmers (zoospores), which are essentially similar to the motile unicellular individuals of their class and which, after a period of movement, lose their cilia and give rise to the stationary organism. This fact has led to the assumption—now generally accepted—that such sedentary forms have evolved from motile unicells in much the same way as they arise from their zoospores during their individual life-history. It is, however, probable that in some series of Protophyta (*e.g.*, Myxophyceae) no motile organisms were ever evolved, even the unicellular individuals being motionless from the first.

In certain classes of Protophyta (Chlorophyceae, Xanthophyceae, Myxophyceae) the majority of the known genera are stationary, *i.e.*, they exhibit the essentially plant-like characteristic of immobility. These are usually grouped under the name of Algae (*q.v.*) which also comprise some series that have evolved beyond the level of the Protophyta and in which no simple forms are known. In other classes of Protophyta, however, the majority of the species are motile and, for this reason, and also because the simpler individuals are ordinarily not clothed by a cell-wall, they have been regarded as something apart from the Algae more nearly related to Protozoa and grouped as Flagellata. But in several of these classes (Dinophyceae, Chrysophyceae) motionless unicellular and filamentous types corresponding to those found in Chlorophyceae, Xanthophyceae, etc. (*see* ALGAE) have been discovered in recent times, and there is thus no valid reason for separating them from those Protophyta that are grouped as Algae.

A number of colourless Protista resemble plants, since they feed mainly by absorbing (organic) solutions and not by ingesting solid particles, *i.e.*, they are saprophytes or parasites. Such forms are probably in part descended from holophytic types which have lost their chromatophores, while others may have been devoid of them from the first. From such primitively colourless Protophyta various series of fungi may have originated, although some fungi may have been derived from pigmented types by loss of chromatophores.

(For classification *see* ALGAE.)

Range of Form.—Most classes exhibit a more or less extensive range from simple unicells to branched multicellular filaments. One can distinguish motile and motionless unicells, colonies of motile and motionless individuals, palmelloid forms with numerous cells embedded in mucilage, simple and branched filaments, etc. Analogous forms, often almost identical in shape though with the differences in pigmentation, etc., characteristic of the relevant groups are met with in most classes of holophytic Flagellata. Thus, *Chrysosphaera* (fig. 6) is a spherical unicell, similar to *Chlorococcum* (Chlorophyceae) or *Halosphaera* (Xanthophyceae), but it possesses the orange chromatophores and leucosin of Chrysophyceae and reproduces by zoospores closely resembling a *Chromulina*, one of the motile unicells of that class; similarly *Hypnodinium* (fig. 5) is such a motionless member of Dinophyceae, whose protoplasmic body before dividing during reproduction acquires temporarily the typical transverse and longitudinal furrows. Palmelloid forms, analogous to *Tetraspora* (Chlorophyceae), are seen in *Phaeosphaera* (Chrysophyceae) and *Phaeococcus* (Cryptophyceae), while filamentous types are represented by *Phaeothamnion* or *Thallochrysis* (fig. 7) (Chrysophyceae) and *Dinothrix* (Dinophyceae), all reproducing by zoospores resembling closely the motile unicells of their particular classes. Further details cannot be given in the confines of a short article, but it will be clear that there is a far-going parallelism in the evolution of the different classes of Protophyta.

Reproduction.—The reproductive processes are of the simplest kind, most commonly consisting in a mere division of the individual into two parts, which in the motile forms may even take place during movement. Reproduction by zoospores, as already mentioned, is frequent in the more advanced stationary forms (figs. 6, 7). Sexuality, altogether lacking in the Myxophyceae, is rare and restricted to the higher forms in most classes. Oogamy (*see* ALGAE) is encountered alone in the Chlorophyceae, where altogether the reproductive methods show a greater elaboration than among other Protophyta.

Relation to Other Groups.—The definite range from simple to complex implies an upgrade evolution which is recognizable also in the reproductive processes. As far as present knowledge goes, however, the multicellular filamentous types are of the simplest kind in most Protophyta. Even when branching occurs, there is no differentiation among the cells and the formation of reproductive units takes place in the simplest possible way. In other words these classes have ended blindly without developing far in the direction of the multicellular plant and it is only in Chlorophyceae (as well as in Phaeophyta and Rhodophyta which, as explained above, must have had a Protophyte ancestry) that a considerably greater specialization is found; and this is accompanied by more complex reproductive methods and the development of an oogamous sexual process. While in the two classes of seaweeds massive and complex bodies have been evolved, this is not the case in the green Algae, although in other respects their advanced forms are almost as highly specialized as those of seaweeds. The absence of more elaborate types in Chlorophyceae is probably due to their further evolution into land-plants in the far past, just as the simpler (extinct) Phaeophyta and Rhodophyta evolved into the seaweeds of the present day. In the same way other classes of Protophyta must have given rise to the various groups of fungi. There is little evidence of relationship between the known classes of Protophyta; most, if not all,

seem to represent separate attempts at the evolution of a holophytic organism. The occasional resemblances to classes of Protozoa are no doubt due to the fact that plant and animal tendencies were not clearly segregated in all the different evolutionary series.

BIBLIOGRAPHY.—For a general account of Protophyta, *see* F. E. Fritsch, *Presidential Address to Section K, British Association* (1927).

(F. E. F.; X.)

PROTOPLASM is a highly organized system endowed with properties, the sum total of which is life. The term was introduced long after the discovery of the microscope and not until investigators began to be aware of a visible substance enclosed within what had been known as cells of plants and animals. It was probably first coined in 1839 by Johannes Evangelista Purkinje (1787–1869) of Prague, who adopted it from Protoplastus, a liturgical term having reference to Adam. Shortly thereafter, Hugo von Mohl (1805–72), a German botanist, applied the same term, as meaning "first plasma," to the slimelike, granule-filled material which he observed undergoing circulatory movements within plant cells. In 1835, Felix Dujardin (1801–60), a French protozoologist, had introduced the term, sarcode, for the material he saw in protozoa which had been called a living jelly. He described it as "a substance, viscid, translucent, homogeneous, elastic and contractile."

In 1861, Max Schulze (1825–74) called attention to the similarity of the protoplasm of plants and animals and of the sarcode of protozoa and proposed the term protoplasm for the physical basis of all life. Thus, the unification of biological science was begun by the recognition of the cell and of its protoplasm as the physical basis of all living beings.

The multifarious activities of protoplasm within the dimensions of a living cell require a complexity of constitution and structure. The earlier investigators sought for this in the fibrils (Walter Flemming, 1843–1905), granules (Richard Altmann, 1852–1901) and alveoles (Otto Bütschli, 1843–1920) familiar to the cytologist (*see* CYTOLOGY). William B. Hardy (1864–1933) emphasized the *colloidal state* as being essential for the manifestations of life (*see* COLLOIDS).

According to the present concept, protoplasm possesses an ultramicroscopic, labile system of structural proteins offering large internal surfaces for the promotion of heterogeneous catalyses, the interstices of the system being filled with a liquid. This interstitial liquid is generally regarded as aqueous, and the protein fabric as capable of imbibing water.

The characteristic properties of protoplasm are *irritability, motility, metabolism, growth* and *reproduction. Adaptability* must also be included to account for the evolutionary changes. The ovum, from which an organism springs, possesses potentialities for changes, but these changes ordinarily lie within the limits of the organization of a particular species. Occasionally, mutations occur spontaneously and have even been induced experimentally. The surprising feature is that, with the complexity of the protoplasmic constitution and the variety of environmental conditions, there should be such an extraordinary stability of protoplasm as we find it in nature.

The properties of protoplasm which are most readily observable through a microscope are *motility, irritability, reproduction* and *growth. Motility* is expressed in two types of motion, the amoeboid locomotion of entire cells and the currents of flow within the protoplasm of a cell. Both vary greatly in rate. It is of interest to note that the apparent inertia of most plants and the constant activity of animals are in striking contrast to what is observed within their cells. The protoplasm of most plant cells generally exhibits a marked streaming which is barely perceptible in most animal cells. The property of *irritability* may be easily observed by the cessation or, conversely, the acceleration of protoplasmic flow when mechanical or electrical stimuli are applied. The phenomena of *reproduction* and *growth* can be observed readily in young root hairs, in yeast and in cells of tissue culture (*q.v.*) by the cleavage of parent into daughter cells and the increase in size of the latter.

The three most prominent constituents of the protoplasmic unit of a cell are the *nucleus*, the *cytoplasm* and the *protoplasmic surface film*. This *surface film*, called plasma membrane by Wilhelm Pfeffer (1845–1920) who first recognized its existence, maintains the integrity of the protoplasmic unit. If, in the normal, aqueous medium of cells, it is torn and does not repair itself quickly, the protoplasm undergoes progressive disintegration or cytolysis. The *nucleus* is usually a spheroidal body first described in plant cells by Robert Brown (1773–1858). It contains specific nuclear structures, chromosomes and the so-called nucleoplasm. The *cytoplasm* constitutes the remainder of the protoplasmic unit and usually contains granules and vacuoles of various sizes, mitochondria, etc.

The discovery of the virus, which is beyond the visibility of the light microscope, has posed a question as to the size-limits of a viable unit of structure. Some viruses, *e.g.*, the tobacco mosaic virus, are regarded as consisting of no more than one or a few thousand molecules of nucleoprotein. This is much smaller than the structural elements or particles generally seen in protoplasm. Structural elements of protoplasm may have a higher degree of autonomy than is generally assumed, and their survival, when removed from protoplasm, may become possible when a medium is found which is compatible with their environment. There is no evidence of spontaneous generation. But a beginning must be inferred. There must have been a time when existing conditions brought about syntheses of compounds containing asymmetric carbons which led to the formation of proteins as prerequisites for the creation of living matter. The present era seems to be one in which protoplasm persists and perpetuates its properties of individuality, adaptability, growth and reproduction.

METHODS OF STUDY

Cytochemical Methods.—The technique involves primarily the analysis of extracts of disintegrated cells and tissues. Our knowledge of the chemistry of protoplasm has been greatly enhanced by developments of physicochemical techniques and improved methods of extraction and isolation of various constituents of these extracts, *e.g.*, by electrophoresis and by ultracentrifugation. Specific proteins have thus been isolated and studied. In particular, various important enzymes have been isolated, and a study *in vitro* of their activities, separately and combined, is helping to explain many of the mechanisms by means of which living cells maintain and perform their functions (*see* BIOCHEMISTRY).

An important corollary to the above is the mechanical isolation of morphologically visible cell components from freshly disintegrated cells. Cell nuclei, cytoplasmic granules, mitochondria and even nuclear chromosomes can be separated by virtue of their different size and density and isolated by micro-needles or by differential high-speed centrifugation or by exposure to certain salt solutions which dissolve some and not others. Chemical analyses and enzyme-activity tests are then performed on the separated fractions. A limitation to this type of study, which involves crushing of protoplasm, is the injury inflicted on many of the components.

In some cytochemical techniques the cells are not destroyed but are subjected to various physical and chemical treatments while intact. In the *incineration* method, thin layers of cells and of cellular tissues are placed on transparent sheets of mica and exposed rapidly to high temperatures. The morphological contours of the ashed cells persist and, through the microscope, the distribution of mineral constituents may be mapped by chemical and electron-optical means.

Other cytochemical methods employ specific colour reactions to demonstrate the distribution, *e.g.*, of enzymes, of nucleic acids and of arginine-rich proteins. Use has also been made of purified enzymes to determine the structural importance of substances such as lipids, proteins and nucleic acids in the framework of certain cell constituents (chromosomes, etc.).

Information on important biocatalysts has been gathered by studying the effect on living cells of specific enzyme-inhibitors (carbon monoxide, cyanide, azide, etc.). Thus, the haemin nature of the respiratory ferment and of the Pasteur enzyme has been elucidated by determining the effect of monochromatic light

of different wave lengths on the carbon monoxide inhibition of cell respiration or the Pasteur reaction (Warburg's photochemical method).

Still another method is to explore living tissues with the aid of heavy and radioactive *isotopes, e.g.,* deuterium, heavy nitrogen, radioactive carbon, etc. These become incorporated and serve as "tracer" atoms to determine the origin and fate of protoplasmic constituents, *e.g.,* proteins, also the movements of certain chemical elements into and out of living cells.

Physical Methods.—The *light microscope* (*see* MICROSCOPE) is of prime necessity for observing protoplasmic structures. The unaided eye, at a distance of 10 in., can discern objects 0.1 mm. (1/250 in.) apart. This is the resolving power of the unaided eye. The light microscope increases the resolving power 400 times; in other words, it can discriminate objects 0.00025 mm. or 0.25 of a micron apart. The resolution is limited by the wave length of the light illuminating the object. An increase of resolving power can be obtained by utilizing radiations of wave lengths shorter than those of visible light. This has been achieved by means of the *ultra-violet microscope,* with which objects 0.1 of a micron apart may be photographically recorded. Visibility to the eye is made possible by the use of fluorescent screens and fluorescent dyes. The usefulness of this instrument is not so much in its resolving power, which is only about twice that of visible light, but more as a means for detecting cell components which specifically absorb ultra-violet radiations, *e.g.,* nucleoproteins. The *phase-contrast microscope* accentuates minute, refractive index differences with the aid of artificially created interference phenomena. Photoelasticity, form and flow birefringence may be studied with the *polarizing microscope.* When the exact shape of particles is less important than their detection or behaviour (*e.g.,* Brownian motion), the *dark field* and the so-called *ultra-microscope* are used. Particles, down to 5 millimicra (0.000005 mm.) appear as luminous diffraction disks (*see* LIGHT: *The Scattering of Light*).

A further extension of the range of observability is accomplished by the *electron microscope* (*q.v.*). This is essentially a vacuum tube with accessories for utilizing electrons in the same manner that light waves are utilized in a light microscope. A stream of electrons, after passing through an object, is focused in magnetic or electrostatic fields which act as condenser lenses analogous to the glass lenses of a light microscope. The resulting magnified image of the object is projected on a photographic plate, or on a fluorescent screen for direct observation. Electron-optical magnifications as high as 50,000 diameters have become possible; the resolving power of the present electron microscopes under optimum conditions is estimated at 15Å (Ångstrom units), or 1.5 millimicrons. By means of this microscope, viruses and even single protein molecules have been photographed. A limitation to its use is the necessity of working with dried films of extreme thinness and in a high vacuum. The visibility of the dried objects, *e.g.,* tendon fibrils, has been enhanced by impregnating them with multivalent, heavy metal acids (electron stains), also by coating objects, such as viruses and protein molecules, with noble metal films placed under oblique angles of incidence (shadow casting). The *centrifuge microscope* permits observation of the effect of intense gravitational fields on living cells. This and the centrifuge method, in general, has been used to determine the relative mass and density of particles, also to study differences in rigidity of certain regions in protoplasm.

Electromagnets, mounted on the microscope stage, have been used to measure protoplasmic viscosity by observing the rate of travel of minute particles of iron or nickel introduced into cells. *Hydraulic pressure chambers* mounted on the microscope stage have been devised for directly observing the reversible liquefaction of gelated protoplasm under high pressure. The *microspectroscope* is an attachment to an ordinary microscope which facilitates the identification, through their absorption spectra, of pigments contained in living cells.

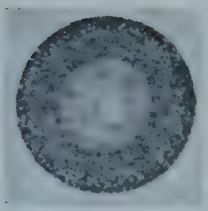
The thickness of films, such as cell envelopes and nuclear membranes, may be determined with the aid of the *leptoscope,* which enables comparison of the intensity of the light reflected from the object with that reflected from a barium stearate film of known dimensions. The fine structure of living systems, *i.e.,* their molecular organization, can be studied by the *X-ray and the electron diffraction method.* The application of X-ray analysis to fibrils, virus-protein crystals, and similar objects has thrown light on their molecular pattern and has yielded quantitative information on backbone and side-chain spacings of regularly built units and molecules. The irradiation of living cells with intense *monochromatic ultra-violet radiation* or with *X-rays,* as well as their bombardment with gamma-rays (from radium) and with neutrons (by the use of the cyclotron), produces lesions and mutations which have been of value in the study of chromosome structure, mitosis and gene action. Electrophoresis (migration of particles in electrical fields), produced by the application of *electric currents,* has been used for determining the electrical charge on cell granules and on intact cells. Microrespirometers of the constant volume (manometric) and constant pressure (volumetric) type, *e.g.,* the Warburg manometric apparatus and the Cartesian diver, are used for making quantitative measurements of the rate of energy-yielding reactions of intact cells, of cell extracts and of formed elements isolated from cells. *Micrurgy,* or the micromanipulation technique, employs mechanical devices for operating on living cells in the field of the compound microscope (*see* MICROMANIPULATION OR MICRURGY). The method makes possible microscopic observations on differences in the relative stiffness or viscosity of visible constituents of protoplasm, effects of mechanical injury in various regions of single cells and the reparability of these regions under experimental conditions, etc. The tensile strength and torsional resistance of protoplasmic strands have also been studied. The microinjection of various chemical solutions and the application to the surface and to the interior of protoplasm, of oil drops differing in interfacial tensions have afforded new insight into the physical and chemical state of living protoplasm. The importance of this technique is appreciated since protoplasm exists only within microscopic dimensions. There is no way of securing a sizeable mass of protoplasm for gross handling. In most instances it exists as microscopic units. In macroscopic cells, *e.g.,* some plant cells, plasmodia of myxomycetes and the avian yolk cell the contained protoplasm is microscopic in at least one of its dimensions. Apparent exceptions are the fruiting masses of some moulds, but here also the actual protoplasm does not occupy more than a microscopic fraction of the mass.

Maintenance of Environmental Conditions for Living Cells.—A usual way of observing or operating on protoplasm is to secure cells which either occur singly or can be isolated from tissues. Examples of such cells are the relatively yolk-free, microscopic egg cells of many marine organisms, protozoa, plant hairs, teased out or finely sectioned layers of plant and animal tissues, and cells present in blood and body fluids.

Marine eggs and protozoa are best studied in their natural aqueous environment, while tissues and single cells from higher organisms are usually suspended in body fluids (serum) or in synthetic media—such as Ringer's solution—which contain salts in the concentration of their normal medium. An important adjunct is the use of the *tissue-culture technique* by means of which fragments of tissue from plants or animals are grown in suitable media outside the organism (*see* TISSUE CULTURE).

Constitution of a Physiological Medium.—The natural environment of all living cells, plant and animal, is aqueous and contains electrolytes, the indispensable ions of which are sodium, potassium and calcium. Of evolutionary significance is the fact that these electrolytes are present in body fluids in the same relative proportions as in the ocean. The total concentration of these salts, within well-defined groups of living organisms, is constant but varies greatly among different groups.

Water freely penetrates most cells, and special provisions exist to prevent what otherwise would result in an excessive osmotic swelling of the protoplasmic unit and an eventual bursting of the cell. Among plant cells the provision is partly mechanical through the presence of rigid cell walls. Many unicellular fresh-water organisms are similarly protected, while others have devices for the periodic elimination of excess water. Unicellular organisms



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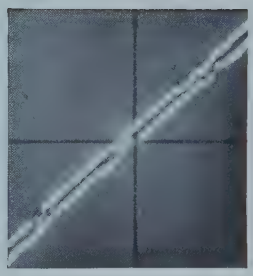

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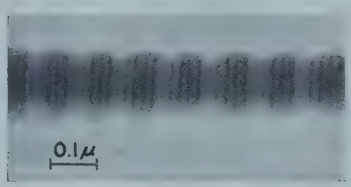

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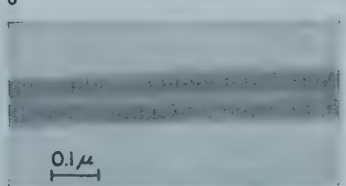

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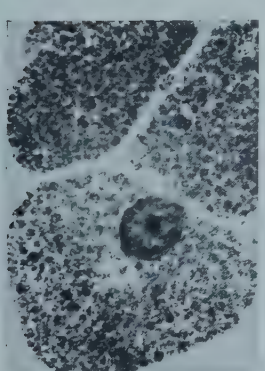

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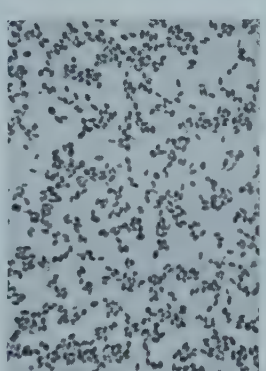

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BY COURTESY OF (1) E. B. HARVEY, PRINCETON UNIVERSITY, (2) G. I. LAVIN, (3, 5-7) F. O. SCHMIDT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, (4) R. S. BEAR, (8) K. R. PORTER, (9-11) ALBERT CLAUDE, ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

PHOTOMICROGRAPHS OF VARIOUS BIOLOGICAL SPECIMENS EXAMINED WITH DIFFERENT TYPES OF RADIATION

1. *Light microscope.* Living, immature egg (70 microns in diameter) of sea urchin, magnified 300 x. Cytoplasm, with dispersed, brown pigment-granules which appear dark, and nucleus which is translucent and contains a hyaline nucleolus

2. *Ultra-violet light microscope.* Similar specimen, same magnification, exhibiting opaque regions because of the presence of nucleic acids which strongly absorb ultra-violet light of 2,600 Ångstrom units

3. *Polarizing microscope.* Side view of a myelinated nerve fibre freshly removed from the sciatic nerve (frog), magnified 460 x and viewed between crossed nicol-prisms showing the bi-refringent bright myelin-sheath against a dark background

4. *X-ray diffraction pattern* of a tendon (kangaroo) taken with a pin-hole camera. Fibre axis is vertical to the X-ray beam. Inset, to right, shows the central portion of a pattern more highly magnified and taken with a slit camera. It indicates a repeating period of 145 Ångstrom units along the fibre axis

5. *Electron microscope.* Side view of a fibril from a guinea pig tendon (dried in vacuo). Width of fibril is slightly greater than 0.1 of a micron, therefore, barely within limit of resolution by the light microscope. Here it appears as a relatively broad structure with cross-bands of alternating light and dark material

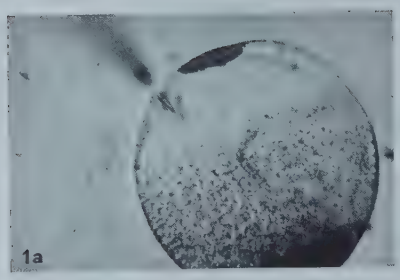
6. *Electron microscope.* Fibril of fig. 5, impregnated with phosphotungstic acid. This electron stain enhances the resolution of the finer, cross-band elements within spacings of 0.01-0.02 of a micron

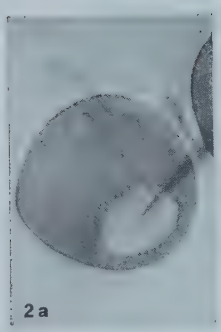
7. *Electron microscope.* Paramyosin fibril (from a clam), impregnated with phosphotungstic acid. The resolving power is so great that cross-bands of 145 Ångstrom units (0.0145 microns) apart can be distinguished

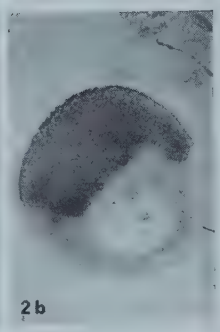
8. *Electron microscope.* Detail of much flattened part of a cell (macrophage) in tissue culture, showing filamentous mitochondria (fixed with osmic acid, magnification 4,000 x)

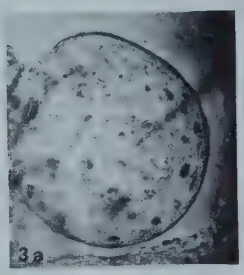
9, 10, 11. Photomicrographs to compare magnifications obtained with the visible light and those with the electron microscope. 9. *Light microscope.* Section of liver (*Amphiuma*) fixed and stained. Three liver cells are shown in which the nucleus of one is evident. The cytoplasm contains many granules, among which the melanin granules (0.5 microns in diameter) are clearly seen as small, black dots (magnification 1,000 x). 10. *Light microscope.* A cluster of melanin granules from the *Amphiuma* liver, obtained by crushing the cells and collecting the melanin granules by centrifugation (magnification 2,000 x). 11. *Electron microscope.* The same melanin granules magnified 20,000 times

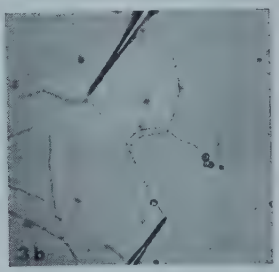
PROTOPLASM

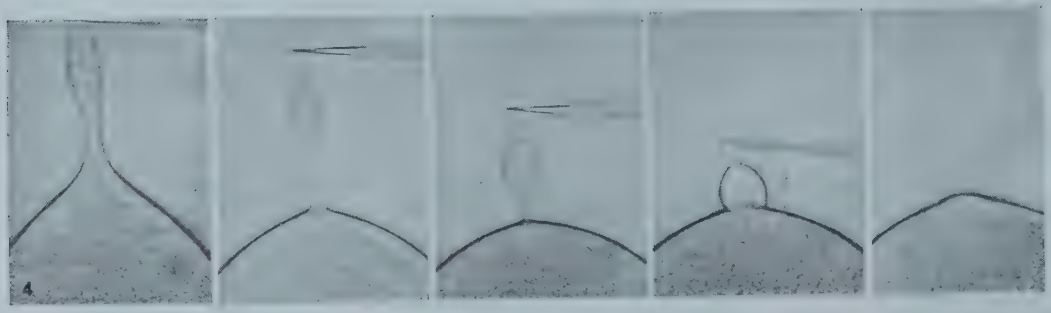


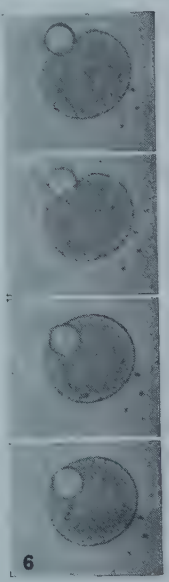


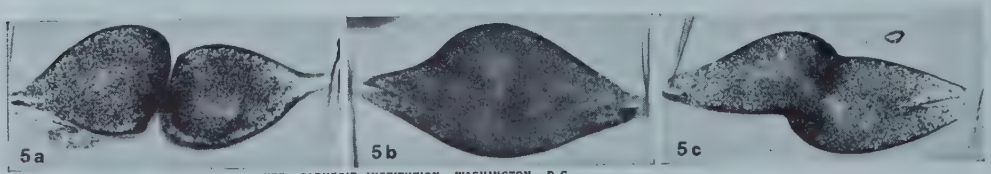












BY COURTESY OF (3) DR. WM. R. DURYEE, CARNEGIE INSTITUTION, WASHINGTON, D.C.

ALL THE FIGURES ARE FROM PHOTOMICROGRAPHS OF MICRURGICAL OPERATIONS ON LIVING OVA UNDER THE LIGHT MICROSCOPE TO DEMONSTRATE FEATURES OF THE PHYSICAL STATE AND STRUCTURE OF PROTOPLASM

1a. Living sea-urchin egg (70 microns in diameter) after having been centrifuged so as to sediment its visible components into several zones according to their relative weights. The tip of a microneedle has been inserted into the fluid, hyaline zone, above which is a dark mass of fat droplets. Just below can be seen a clear spherical body, the nucleus. Below the hyaline is a granular zone, the lowest layer of which consists of dark-brown pigment-granules

1b, c. Two successive micrographs, one and two seconds after tearing the surface layer of the egg. They show the escape of fluid and the outward dispersal of the various granules. In 1c the extruded nucleus can be barely seen in advance of the out-streaming fat globules

2a, b, c. Three successive micrographs of a starfish egg after tearing the nuclear membrane. They show the destructive effect of suddenly mixing nuclear and cytoplasmic material

3a. Ovarian egg of an amphibian with centrally located nucleus

3b. Highly magnified view of a filamentous chromosome being stretched after it had been removed from the nucleus. The chromosome appears to consist of an elastic thread of cohering granules

4. A strand of protoplasm drawn out with a microneedle from the surface of a starfish egg. The strand behaves as a viscous fluid since, on causing the needle-tip to approach the egg's surface, the release of tension results in a shortening and beading of the strand until finally the strand flows back and disappears in the protoplasm of the egg

5a. A sea-urchin egg which underwent successful cleavage after it had been stretched along the polar axis into the shape of a ribbon. b. A sea-urchin egg which did not cleave after being stretched at right angles to its polar axis. c. A sea-urchin egg which cleaved after having been stretched diagonally to its polar axis. The cleavage persisted in the plane at right angles to the original, polar axis. On each side of the cleavage furrow can be seen bulges which are not to be expected if the consistency of the stretched mass of the egg were uniform. The bulges are caused by the gelated regions which resist the pull exerted by the microneedles

6. Four photomicrographs of a sea-urchin egg, taken at intervals of one-twentieth of a second, showing the rapid penetration of an oil drop applied to the surface of the egg with no evidence of rupturing the surface

which live in the sea are in osmotic equilibrium with their environment (*see* PHYSICS IN MEDICINE: *Osmotic Pressure*). The cells of the more highly organized animals are in osmotic equilibrium with their body fluids; this equilibrium is maintained independently of external variations.

Temperature.—Raising the temperature only a few degrees above the optimum destroys protoplasm. This may be explained by the effect of the temperature on the rate of enzymatic reactions and on the native configuration of proteins which undergo irreversible denaturation. On the other hand, lowering the temperature slows down chemical reactions and thus tends to prolong vital activities without irreversibly affecting them. Many cells survive subcooling to several degrees below 0° C. Even when the extra-cellular fluids are frozen solid, the fine capillarity of the fluid spaces within living cells prevents internal freezing. Death may eventually occur through irreversible dehydration. Furthermore, death occurs if, at any time, ice crystals form intracellularly. This can be induced either by sudden agitation of the cooled tissue or by introducing an ice crystal into the cell by means of a micropipette.

Hydrogen-ion Concentration.—The maintenance of an acid base equilibrium of the medium is essential for most cells. Physiologically, the hydrogen-ion concentration is chiefly regulated by bicarbonate in equilibrium with gaseous carbon dioxide. This may occur with the participation of proteins in the body fluids of higher animals.

THE NATURE OF PROTOPLASM

Physical State and Morphology of Protoplasm.—To appreciate the implications involved in a study of protoplasm it is advisable to begin with results obtained on its physical state and that of its structural components. Protoplasm is to be regarded as a microheterogeneous system in which particles and molecules of varying solubility are dispersed in an aqueous phase. The state of the protoplasm of many cells is such that the cells round up into spheres when freed of their extraneous envelopes. This is also true for the protoplasts of plant cells removed from their rigid cell walls.

The protoplasmic surface film is a tenuous structure usually interposed between an external envelope of varying rigidity and an internal layer of gel-like, cortical material of the protoplasm. The external material which serves as a supporting envelope is an excretion product of the protoplasmic body. It is extraneous to the protoplasm, since it can be removed without interfering with the viable properties of the latter. This envelope depends for its rigidity upon the presence of calcium in the surrounding medium. In multicellular tissues the envelope of contiguous cells serves as intercellular cement for binding the cells together. When calcium is deficient or absent from the medium the cement loses its cohesiveness and the cells become separated. The protoplasmic surface-film beneath the extraneous envelope also depends for its maintenance on the electrolytes of the medium but, in this case, the chief ions responsible are sodium and potassium. Thus, of the three electrolytes, sodium, potassium and calcium present in the aqueous environment of living cells, calcium is essential for the external cell envelopes and hence for the intercellular cement of multicellular forms, while sodium and potassium are required for the protoplasmic surface film. The older literature which stressed the importance of calcium, to the extent of introducing the phrase "calcium is essential for life," arises chiefly from observations on multicellular organisms. Plant and animal tissues, immersed in nutrient media lacking calcium, break down into isolated cells but, as long as sodium and potassium are present, maintain their individual vitality.

Theoretical considerations, supported by certain experimental observations, lead to the concept that the surface layer of protoplasm consists of a palisadelike arrangement of lipoproteins, the more water-soluble groups of which are directed outward. It is suggested that the extraneous envelopes of animal cells are produced by the continual casting off of denatured, proteinaceous material. Experimental tearing of the protoplasmic surface results in the outflow of the fluid parts of the interior, provided that calcium has been removed from the environment. Otherwise, irreversible clotting of the exuding material occurs and spreads into the interior. The protoplasmic surface layer disappears in a wave spreading from the torn region, as if the palisade arrangement forming the boundary were disrupting or breaking down. Repairs from such injuries, if not too extensive, have been observed. Minute vacuoles appear in the cytoplasm of the torn region. These break open and the linings of the vacuoles spread out and join until a sufficient area of film separates the disintegrating from the intact cytoplasm underneath.

The *formed elements* of protoplasm are of two general types: well-defined inclusion bodies and regions of gelation, the latter being transitory and serving special purposes. Of the inclusion bodies, some in highly differentiated cells, are specific organellae such as the elastic, contractile trichocysts of paramecia (*see* PROTOZOA; PARAMECIUM). Other inclusion bodies are fat and yolk globules, pigment-containing and colourless vacuoles some of which may be very large (especially in plant cells), rod-shaped or spherical mitochondria and microsomes, the last being barely within the limits of vision. These bodies mostly float freely in the cytoplasm, and their constant movements reveal the existence of currents flowing in various directions in the cell. The function of many of these bodies is unknown. Some are doubtless reservoirs of foodstuffs, while for others there is suggestive evidence that they carry enzymes and are concerned with oxidation-reduction activities and various anabolic and catabolic processes.

The so-called *ground substance* of protoplasm exhibits at one time the properties of a fluid (sol) and at another, those of a deformable solid (gel).

It is known that many colloidal substances, *e.g.*, certain proteins, bentonite or vanadium pentoxide, in solution readily pass from the sol to the gel state and vice versa. This phenomenon, called *thixotropy*, is exhibited by these systems upon shaking, application of pressure, temperature changes or the action of chemical agents. Protoplasm thus may be regarded as a *thixotropic* colloid.

The nucleoplasm of the cell nucleus varies widely in viscosity. In some cells it behaves like a stiff gel. In others it is so fluid that the nucleolus suspended in it is readily affected by gravity. Within the nucleoplasm are slender chromatin strands of an elastic consistency. During cell division these filaments shorten into the chromosomes, which are considered to be the carriers of hereditary characters (genes).

It is well recognized that the life of the cell depends upon its nucleus. A case in point is given in fig. 1, which illustrates a binucleated cell in tissue culture. It shows the damage caused by puncturing one of the nuclei and the subsequent repair because of the presence of the second, unharmed nucleus. If the cell had been mononucleated, the initial damage would have destroyed the cell.

A micro-needle (*see* MICROMANIPULATION OR MICRURGY), when inserted into a gland cell or a starfish egg and rapidly agitated, generally produces cytolytic reactions involving the liberation of acid and the progressive breakdown of the vacuoles, mitochondria, etc. A cloud of microsomes is generated which tend to convert the translucent protoplasm into an opaque mass. On the other hand, the gradual insertion and cautious manipulation of the needle in the cytoplasm produces no appreciable effect.

Theories on Ultrastructure of Protoplasm.—According to A. Frey-Wyssling, the cytoplasm forms a network of fibrils having the dimensions of a single polypeptide chain of a protein molecule. These chains are considered to be angular in shape and periodically branched. The side chains interact through points of attachment which may be of various types. This creates a finely meshed, three-dimensional net or molecular sponge the interstices of which are occupied by aqueous solutions of salts and also by lipids. The entire assembly is well ordered through the hydrophilic and lipophilic groups present in the protein network. Such a spongy fine structure would explain many properties of protoplasm, such as reversible swelling by imbibition of fluid or dehydration by constriction of the interstitial spaces. The salient feature of this concept is the presence of an organization of the

materials constituting a scaffold, so as to ensure an orderly progression of the reactions over the surfaces of the structure, presumably through the alternate adsorption and desorption of substrate molecules on the stationary centres of enzymatic, active proteins. Obviously, any detailed picture of protoplasmic fine structure must be based largely on our knowledge of the structure of proteins.

Work on *proteins* has indicated the inadequacy of the original concept by Emil Fischer of their molecular structure, viz., of long, straight polypeptide chains of different amino acids. A more complex structure is required to explain such important features as specificity, biological activity, and the phenomena encountered in the denaturation of proteins. Some (*e.g.*, W. T. Astbury) assume that the polypeptide chains in the globular and fibrous protein molecules are folded or contracted in varying degrees and are kept so by hydrogen bonds and similar forces. According to this view, protein denaturation would consist in the unfolding of compact units similar to the opening up of the bellows of an accordion or to the unravelling of a spool of thread. Others (*e.g.*, D. M. Wrinch) postulate more elaborate structures, such as the so-called cyclol fabric involving the formation of six-membered carbon rings through secondary valencies. Whatever the true picture of a protein molecule may be, it can no longer be doubted that these large molecules possess a high degree of geometrical symmetry. This is already indicated by the well-defined X-ray diffraction patterns exhibited by a variety of proteins (Astbury, J. D. Bernal, I. Fankuchen and D. Crawfoot).

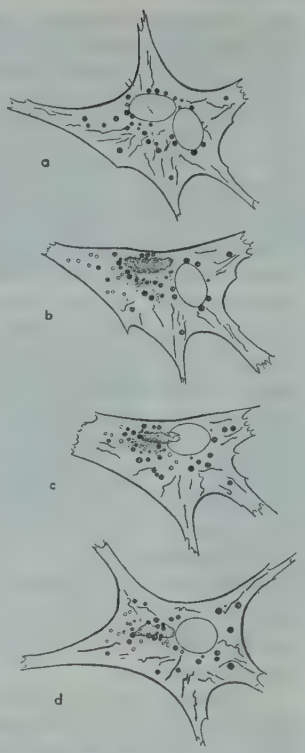


FIG. 1.—SUCCESSIVE STAGES OF A CELL WITH TWO NUCLEI (FIBROCYTE) IN TISSUE CULTURE, SHOWING THE EFFECT OF PUNCTURING ONE OF THE NUCLEI

(a) The cell showing extended pseudopodia before the microoperation. The tip of a micro-needle is about to puncture one of the nuclei. In the cytoplasm can be seen the mitochondria as slender filaments and the fat droplets as highly refractive spheres. (b) The same cell, four seconds after the nuclear puncture. The punctured nucleus has been changed into an opaque mass of material. The cytoplasm near the damaged nucleus is abnormally granular and the mitochondria in the vicinity have changed into pale, spherical bodies. The fat droplets are unaffected. (c) Six seconds later. The damaged nucleus is fading and the cytoplasm surrounding it is becoming less granular. (d) Twenty seconds later. The cell has recovered because of the presence of the second, undamaged nucleus

A striking phenomenon is the *streaming* of the cytoplasm. This is accompanied by a greater or smaller degree of flow birefringence to be explained by the alignment, through shearing stresses, of asymmetric, rod- or plate-like particles. When observed in the Tyndall beam of the slit ultramicroscope or with dark-field illumination, the cytoplasm reveals the presence of immense numbers of particles, as small as 50 Å, which are in active Brownian motion. These may represent the basic building blocks of protoplasm of which the larger particles, ranging up to 5,000 Å, are aggregates.

There appears to be a close correlation between the submicroscopic and the visible structure of cellular components. A fibril, for instance, has its special form and properties, *e.g.*, elasticity, because the protein molecules which it contains are themselves fibrous and contractile. Experimental observations have also indicated that cilia, flagella, sperm tails and linear chromosomes consist of interlinked bundles of submicroscopic fibrous protein particles which are oriented with their long axes parallel to the fibre axis. Likewise, membranes and films seem to be built up of submicroscopic layers or lamellae of single molecules. It is of interest to note that the plasma or protoplasmic surface film appears to contain also lipid molecules, with their long axes perpendicular to the surface. On the other hand, the nuclear membrane seems to contain little or no oriented lipid material. The most highly organized protein-lipid system thus far encountered is the myelin sheath of nerve fibres. The sheath appears to consist of concentric lipid-protein layers, each layer about 180 Å thick, containing one or two thin protein leaflets of about 25 Å lying between two double molecular sheets of mixed lipids. Water molecules seem to be distributed over the polar interfaces of this highly organized structure which is irreversibly destroyed by dehydration.

These complex, fine structures of protoplasmic organization constitute a reversible, dynamic system, continually being built up and broken down during the course of normal cell metabolism. This has been demonstrated through the use of isotopic tracer elements, carbon, nitrogen, etc., which, when fed to animals or cells, rapidly replace the corresponding elements forming essential parts of the molecular structure (R. Schönheimer).

Chemistry of Protoplasm.—From a quantitative point of view, *water* represents the major component: Animal tissues contain up to about 80% water while the plasmodia of myxomycetes (slime moulds) may contain as much as 94%. The water may be a basic constituent additional to serving as the solvent or suspension medium of many components of protoplasm.

The chemical composition of the protoplasmic solids may be deduced from the analysis of such animal tissues as lung, muscle, brain or liver. They contain about 20% solids. The protein content is, on the average, about 10%, that of muscle about 16.5%. The total lipid content of brain and liver is about 4%, that of lung 2.7%. The mineral content of tissues in general is approximately 1.5%. In addition to these there is a series of minor substances, such as reserve carbohydrates (glycogen), organic acids, creatine and creatinine, free amino acids, pigments, urea, etc. Some of these minor constituents vary in amount, depending on the functional state of the tissue; they may be classified as metabolites and excretion products rather than as essential constituents of protoplasm.

The compounds classed under the general terms of "protein" or "lipid" may be subdivided into conjugated and straight proteins, or neutral fats, cholesterol, cephalin, etc. The conjugated proteins comprise such different complexes as nucleoproteins, lipoproteins, mucoproteins, iron proteins, etc.

The *nucleoproteins* are of signal importance: Those containing desoxyribose (thymonucleoproteins) appear to occur exclusively in the *nucleus*, while those containing pentose (yeast or ribose nucleoproteins) are found predominantly in the *cytoplasm* and in the nucleolus. The desoxyribose nucleoproteins are integral components of the *chromosomes* and are considered by many to be the carriers of the inherited characters of the organism (genes). The ribose nucleoproteins of the cytoplasm appear to be related functionally to the mitotic cycle, which involves the chromosomal nucleoproteins, and to the synthesis of proteins and protoplasmic substance of the cell in general. The functional aspects of the nucleoprotein problem, of great importance for the genesis and maintenance of protoplasmic structures, as still largely inferential and speculative. Nucleoproteins within the cell may be detected and quantitatively estimated with the aid of ultra-violet microscopy and microphotometry. This method utilizes the strong absorption of nucleic acids in the ultra-violet region (near 2,600 Å) where ordinary proteins and other cellular constituents are fairly transparent. It should be pointed out, however, that this technique does not differentiate between the two basic types of nucleic acids which can be detected by certain staining and colour reactions (Feulgen and Dische reactions).

The *lipoproteins* constitute an important group of conjugated proteins. They appear to be secondary valence complexes in which various proteins and lipids, *e.g.*, lecithin, cephalin, or sphingomyelin, are held together by forces of the Van Der Waals type. The lipoproteins appear to be contained chiefly in the cell or plasma membrane, in the mitochondria, microsomes and other

cytoplasmic inclusions. The lipoprotein "mosaic," present in the plasma membrane, plays an important role in determining its permeability.

The components just enumerated represent either building blocks or metabolites of protoplasm. There are also many catalysts, *i.e.*, substances capable of accelerating and promoting reactions which, in their absence, would take place only at negligible rates (*see* CATALYSIS and ENZYMES). The catalysts are either enzymatic or nonenzymatic. The *enzymes* (or thermolabile, colloidal catalysts) are classified as hydrolytic or as oxidative, according to their action on suitable *substrates*. The hydrolytic enzymes split lipids and proteins by introducing the elements of water. The oxidative enzymes are the oxidases which cause substrates to combine with molecular oxygen and the dehydrogenases which serve as hydrogen acceptors, thereby removing hydrogen atoms from the substrate. The action of many of these enzymes has been shown to be reversible, thus indicating that they not only promote the breakdown but also the synthesis of protoplasmic constituents. Another important group of intracellular enzymes are the phosphorylases which store energy by forming energy-rich phosphate bonds and also, by splitting the same phosphate esters, *e.g.*, adenosine triphosphate, yield readily available energy for vital processes. Examples of intracellular enzymes are catalase, which splits hydrogen peroxide into oxygen and water; cathepsin, a proteinase which attacks the peptide bonds in native proteins at the hydrogen-ion concentrations prevailing in the cell; and cytochrome oxidase (or respiratory ferment), which through the intermediary catalyst, cytochrome, induces molecular oxygen to oxidize suitable substrates, such as paraphenylene diamine. Cytochrome is an example of a nonenzymatic or intermediary catalyst. The oxidative enzymes, together with nonenzymatic catalysts, play an important role in the energy metabolism (respiration and fermentation) of the cell, while the hydrolytic enzymes are mainly concerned with the breakdown of foodstuffs and the rebuilding of protoplasm from the split products. The distribution of the various enzymes and other catalysts between the different formed elements of the cell and the cytoplasm has as yet not been completely elucidated. However, it would seem as if all important enzymes occur both in the nucleus and in the cytoplasm. It would appear that the mitochondria are particularly rich in enzyme content. The control of the orderly flow of the reactions in protoplasm is accomplished by various devices, such as the mechanical separation of catalysts and substrates and the regulation of the hydrogen-ion concentration which, in turn, affects the rate of enzymatic processes. The orderly progress of reactions of these various catalysts and their substrates, all within the confines of a single protoplasmic unit, postulates the existence of regulatory mechanisms. For example, the rate of enzymatic processes is markedly affected by changes in the hydrogen-ion concentration of the medium. Spatial separation may also be assumed to play a role since there is evidence that some of the enzymes concerned with the terminal oxidation of metabolites are anchored, in a definite pattern, to the surface of macromolecular particles within the living cell.

Protoplasmic Reactions.—*Cell Respiration and Energy Production.*—Perhaps the most valid criterion of life is *metabolism*, a term which covers the intricate processes concerned in the breakdown of foodstuffs (substrates or metabolites) and the utilization of the reactions to release energy required for the proper functioning as well as for the repair and growth of protoplasm. Energy-yielding reactions are of two types: *respiration* and *fermentation*. Respiration utilizes the molecular oxygen of the air. Fermentation, on the other hand, proceeds in the absence of air and, in many instances, is adversely affected by the presence of oxygen (Pasteur effect). In the metabolism of the most primitive types of cells, represented by certain strictly anaerobic micro-organisms, the primary requisite of life appears to be the ability to ferment carbohydrate, yielding end products such as lactic acid, butyric acid, carbon dioxide or hydrogen. From an energetic point of view, fermentation is not very economical since it releases only a small fraction of the energy available in foodstuffs. In contrast to this the respiratory or oxidative process releases all the available energy from a given substrate by burning it to carbon dioxide and water. Aerobic cells possess both types of mechanism. Fermentation is an indispensable prerequisite for respiration, since the latter utilizes chiefly products made available by anaerobic splitting of foodstuffs. The Pasteur effect allows only that portion of fermentation to persist in the presence of air which is required for the production of the substrates needed by the respiratory system.

It had been assumed that the ability to respire was restricted to intact and complete cells. It is now known that neither the cell membrane nor the nucleus is indispensable for this process and that the ability to utilize oxygen for the combustion of suitable substrates resides in the smallest particles which can be obtained from the protoplasm by mechanical means. Cell-free extracts retain the ability to ferment sugar but lose the ability to respire normally. It appears that the mechanical methods which break up the architecture of the protoplasm destroy the intricate correlations which are necessary for normal cell respiration. The same is true for the Pasteur reaction. However, it has been possible to demonstrate in cell-free solutions the presence of many of the enzymatic components of the respiratory system. This shows that the steps catalyzed by single enzymes do not depend upon the co-ordinated, vital activities of protoplasm (*see* ENZYMES).

Chemical energy is required for all of the so-called "vital" functions of the cell, such as the maintenance of membrane potentials, selective permeability, the maintenance of optimal hydrogen-ion concentration, of oxidation-reduction potentials, as well as cell division and protoplasmic movements. While primarily this energy can be made available only by fermentation or respiration processes, it is becoming increasingly clear that the immediate source of readily-available energy for these diverse functions is to be found in energy-rich phosphate bonds. The energy released from the foodstuffs by the metabolic activity may be stored up by the synthesis of compounds of the type of adenosine triphosphate and creatine phosphate. The energy can then be released for such processes as the contraction of a muscle fibre or the excitation of a nerve fibre with the aid of specific enzymes which split the energy-rich phosphate bonds.

Oxidation-Reduction Potentials in Living Cells.—Oxidation-reduction systems are classified as *reversible* or *irreversible*. However, there exist many intermediate types such as the fully electroactive, the sluggish and the semireversible systems, depending on the ease with which the state of oxidation of the system may be reversed or with which electrons may be exchanged with other systems. A cell can not be regarded as a system endowed with a uniform degree of oxidation-reduction intensity. It is possible that certain materials of a suitable reduction intensity are being continuously depleted by irreversible oxidation and are as continuously being replenished by the formation of fresh amounts. The physiological function of the reversible systems would then lie in their continual oscillation between the oxidized and reduced state, thus enabling the systems to play the role of nonenzymatic, intermediary catalysts. Systems composed of certain oxidative enzymes and their substrates, in the presence of suitable, electroactive dyestuffs (mediators) have been shown to constitute truly reversible oxidation-reduction systems, the potential of which is determined by the ratio of the oxidized and the reduced form of the substrate. In the living cell, we do not encounter such a state of thermodynamic equilibrium but rather a steady state resulting from the incessant and simultaneous flow of oxidative and reductive reactions in both directions; this balance has been designated as *"aerobic"* and *"anaerobic"* potential. It is evident that any disturbance of this steady state by changing the oxygen tension of the medium or by the addition of strongly reducing or oxidizing agents will profoundly affect the physiological activity of the cell, provided they break through the defensive mechanism which may be described as the oxidation-reduction buffering capacity of protoplasm.

Hydrogen-ion Concentration.—Attempts at determining the intracellular hydrogen-ion concentration or pH (*see* PHYSICAL CHEMISTRY) have been made in various ways. The earliest was to crush a mass of cellular tissue and determine the pH of the extract electrometrically and also by means of colorimetric pH indicator-solutions. Considerable variations were found to occur, not only with different tissues but with the same tissue at different times. It was later observed that the damage produced in crushing the protoplasm of cells causes the appearance of what has been termed an "acid of injury" which upsets the evaluations. The only method to prevent this is to obtain values in single cells while the cells are known to be still alive. Such a method has been made possible by means of microinjection (*see* MICROMANIPULATION OR MICRURGY). Colorimetric indicators in aqueous solution can be injected into living cells and have produced results on which this section is based. In the determinations it is necessary to realize that the values obtained refer to the aqueous portion of the protoplasm.

The two chief constituents of protoplasm are protein and water. The water is continuous throughout the protoplasmic matrix and serves as a dispersing medium for granules of various sorts, fatty droplets and vacuoles, also as a solvent for electrolytes and the ionizable portions of the other main constituent, viz., protein. The nature and degree of the ionization depend upon the hydrogen-ion concentration, which is a conditioning factor for the metabolic activities of protoplasm. For the cytoplasm the pH value has been found to be 6.9 ± 0.2 where pH 7.0 represents neutrality. For the nucleus the value is 7.7 ± 0.2 indicating that the aqueous phase or portion of the nucleus is definitely more alkaline than that of the cytoplasm. It is significant that these values have been found to be constant in a large variety of animal and plant cells, both of unicellular and multicellular organisms. This constancy is maintained by the so-called buffers, *e.g.*, the bicarbonate-carbonic acid system and the amphoteric proteins. Otherwise, the normal functional state of the protoplasm would be

seriously disturbed by the acids which are produced during the various metabolic reactions occurring in the cell. For example, such metabolic end products as lactic and carbonic acid are immediately neutralized. The resulting neutral compounds are carried to the surface of the cell where their acid components are released to the outside.

The cytoplasmic vacuoles are liquid-filled sacs. Their enveloping membranes consist of a nonaqueous material and serve as mechanical and selectively permeable barriers to keep the vacuolar contents separated from the surrounding cytoplasm. The membranes of the vacuoles may allow certain solutes to enter but not to leave. In other words, these membranes exhibit the remarkable property of a one-way permeability, a property which has caused considerable speculation as to their physicochemical structure. The vacuolar contents are usually more acid and, in some instances, more alkaline than the cytoplasm. They are only slightly if at all buffered. Because of this the pH of the vacuoles may vary considerably with the nature of the environment. On the other hand, the pH of the cytoplasm and of the nucleus is independent of the environment as long as the cell is alive. This constancy of the protoplasmic pH is of great significance for the maintenance of the normal physiological state of the protoplasm and of its metabolic activities. Therefore, when one speaks of intracellular pH, it is necessary to discriminate between the pH of the protoplasm and of the contained vacuoles.

Gel-Sol Reversal.—The peculiar property of protoplasm to maintain or to change its physical state occurs generally in such a way that one part of the protoplasm is gelated while another remains in the sol state. These changes, together with protoplasmic streaming, are related to various protoplasmic activities such as amoeboid movement, cell division and possibly the periodic torsion observed in extended strands of myxomycete plasmodia. The gelated regions are more or less transient in character and revert to the sol state either spontaneously or when subjected to certain experimental conditions.

Amoeboid Movements.—An amoeba or a leucocyte is unable to advance were it not for the ability of its protoplasm to undergo gel-sol reversals. While at rest, most of the body of the amoeba is extended into several, long-tapering pseudopodia. Its protoplasm is in the state of a gel except for the innermost region which is in the sol state and exhibits a slow, shifting flow of the granules suspended in it. When an amoeba begins to advance, the action is initiated by a return, at some spot on its periphery, of the gel into the sol state. There follows a streaming from within the amoeba into this region, which bulges outward. The streaming progressively develops into a "fountain flow," *i.e.*, an axial forward and a peripheral return flow (fig. 2). When the peripherally returning fluid reaches the base of the bulge, it gelates. A pseudopodium thus develops by the formation of a progressive lengthening of a cylinder, the walls of which are in the gel and the interior in the sol state. The interior is flowing forward to the tip where the "fountain flow" continues. Retrogression of the pseudopodium occurs by a change in direction of the flow, accompanied by a liquefaction of the walls of the cylinder progressing backward from the tip. Mechanical agitation accelerates the reversal to the state of a sol.

FIG. 2.—FORMATION OF AN AMOEBOID PSEUDOPODIUM

(a) Initial solation of the peripherally gelated protoplasm accompanied by a "fountain flow" in that region. (b) Extension of the pseudopodium by means of forward, axial streaming of the protoplasm in the sol state and a progressively lengthening, hollow column of gelated protoplasm being added to by peripheral back flow at the tip

Cell Division.—This process also exhibits sol-gel reversal. The first step in cell division is the disappearance of the nuclear membrane, followed by a mixing of the nucleoplasm with the cytoplasm. At this time the mitotic spindle appears and the chromosomes collect at its equator (*see* CYTOLOGY). During this period two regions of the protoplasm, one at each pole of the cell, progressively undergo gelation. This phenomenon is accompanied at the equator by a streaming which is directed toward the centre of the cell. The stream, as it approaches the centre, separates into two currents to the two opposite poles of the cell. The inward streaming produces a depression at the surface around the equator of the cell. This depression forms an ever-deepening furrow which ultimately divides the cell in two. As it advances, the walls of the furrow become gelated. In brief, there are two principal phenomena which accompany the process of cell division. One is a specifically directed protoplasmic flow and the other is a localized sol-gel reversal.

Selective Permeability of Protoplasm.—Ever since the cell was discovered as the structural unit of protoplasm, it has been abundantly proven that protoplasm exhibits a unique selectivity in the incorporation of certain materials and not of others from the surrounding medium. Water and dissolved gases readily pass in and out; so do certain ions, but not others. Nonionized molecules, *e.g.*, of weak acids and bases, appear to penetrate readily, while water-insoluble fatty acids do not. The penetration of particles in suspension and of nonelectrolytes appear to be a matter of size.

Electric charges play an important role with ion-valency as a determining factor. Most cells appear to be readily permeable to monovalent and distinctly less so to polyvalent cations. Some types, *e.g.*, blood cells, have been found to be permeable to anions and not to cations; but this is not true for all species of red cells. The fact that, in general, weak acids and weak bases penetrate more readily the less they are dissociated, has been used as an argument for a predominantly lipoid nature of the protoplasmic surface.

Paul Ehrlich (*q.v.*) and Charles E. Overton (1865–1933) made extensive use of a great variety of dyestuffs, especially coal-tar products, dissolved in the normal, aqueous environment of living cells. They found that the predominating condition for penetration is that the dye be the salt of a basic dye, the colour base of which is fat-soluble. Overton used this fact as the chief argument for his theory that the superficial layer of protoplasm is a lipoid membrane. Later, H. A. Bethe pointed out that the normal environment of cells is relatively alkaline and that protein, which is the chief constituent of protoplasm, should exist on the alkaline side of its isoelectric point and, therefore, react as an acid. Bethe opposed the Overton theory by concluding that the observed staining with basic dyes is explained more simply on the basis of chemical affinity, namely the basic dye-radical combining with the acid-radical of the intracellular protein. Unfortunately for Bethe's assumption, chemical combinations of foreign compounds with the proteins in living cells are often toxic.

The following three types of processes may be mentioned, using dyestuffs as examples.

Penetration of Particles by Virtue of Size.—Most of the vital acid dyes are salts of weak acids which, at the pH of the normal cell environment, tend to be dispersed either molecularly or in aggregates of molecules. The diffusibility of many of these dyes into living cells has been shown to be a property of particle size, the size varying between 5 or 6 Å to 10 or 11 Å for different types of cells.

Penetration of Solubility.—Vital basic dyes, such as neutral red (an amino-azin), are salts of a weak, coloured base. It tends to be both fat-and-water soluble and is also more soluble in acid, aqueous media while it becomes increasingly nonionized and tends to precipitate in more alkaline media. The environment of cells is usually more basic than the aqueous phase of the protoplasmic interior. The dye diffuses readily into the cell where its accumulation predominates in the still more acidic, cytoplasmic vacuoles giving them a bright red colour. Moreover, by virtue of its lipid solubility, neutral-red also colours lipid granules.

Penetration Depending upon Metabolic Activities.—This phenomenon, recognized as a so-called secretory process, may be illustrated by referring to the cells of the wall of the kidney tubule. It can be demonstrated on living fragments of kidney tubules immersed in solutions of highly dissociated salts of coloured acids, such as phenolsulphonphthalein, which do not penetrate cells generally.

There is evidence that this type of penetration is caused by some type of a metabolic process. Optimum temperature and oxidation-reduction conditions are obligatory, conditions which are not needed with the usual vital dyes, such as neutral red. A significant feature to be pointed out is that the cells do not exhibit this phenomenon during the period when they are undergoing reproduction by division. Evidently, the metabolic functions for the performance of "secretion" and of division do not occur simultaneously.

There is no generally accepted opinion regarding the nature of the protoplasmic surface to explain its selective permeability. Some have claimed the surface layer to be a mosaic of water and lipoid soluble regions, both of which may be present simultaneously or may alternate in appearance with time. Others adhere to Overton's theory, according to which the passage of ions is explained by their conversion into lipoid soluble compounds at the time of their passage. Still others lay stress on the role played by electric charges on the surface. The selective permeability of the protoplasmic surface layer also may be conditioned by the interstices of the molecules constituting it, and by the chemical affinity for cations or for anions, according to whether carboxyl or amino groups predominate in the surface layer.

CONCLUSION

Protoplasm is an organized entity in which structure and chemical reactions are closely integrated. It possesses the physical properties of a plastic, deformable material. Although a major part of its substance is water, dispersed through it as a continuous phase, protoplasm contrives to maintain its structural integrity in an aqueous environment. It follows that water-insoluble materials, such as lipids and fibrous proteins, must predominate at its surface. The physicochemical nature of this surface film largely conditions the interchange of materials with the environment. The mechanical rigidity of a living cell is a function of the nature of its envelope, of the water-imbibing property of its protoplasm, and of the ability of protoplasm to undergo reversible sol-gel transformations.

The kinetics of the catalytic and other chemical reactions of protoplasm are aided by the ultrastructure of its ground substance with its large multiplicity of surfaces. Mechanisms which regulate these reactions involve the control of hydrogen-ion concentration and of levels of oxidation-reduction intensities. Of particular importance are the enzymes which, by means of reversible, coupled reactions, make energy available for the functioning of the cell. It is an interesting fact that cells are built up of the same kind of materials that are used as substrates for their energy-yielding reactions.

In summary, protoplasm, as the physical basis of life, is a dynamic system of organized matter constantly absorbing and expending energy. Its uniqueness is due to the fact that part of the absorbed energy it utilizes for its own regeneration and growth, the remainder being largely expended as work and heat.

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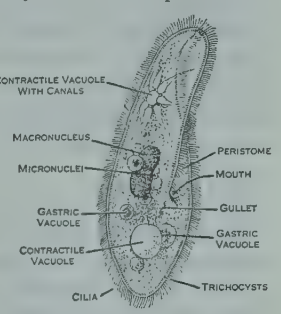
PROTOPOPOV, ALEXANDER DMITRIEVICH (1864–1918), Russian statesman, was born in 1864 and educated in a military school. He served for some time in the army before going into business. As a big landowner of the Simbirsk province, he took an active part in the Zemstvo life, and was elected member of the executive board of the Simbirsk Zemstvo and marshal of the nobility of the Simbirsk province. He was elected member of the third (1907) and of the fourth State Duma, where he joined the left wing of the Octobrist (Moderate Liberal) party. Later he became vice-president of the State Duma. In March 1916 he visited the capitals of western Europe as one of the leaders of the Russian parliamentary delegation. At the beginning of Oct. 1916 he was appointed minister of the interior in the Stürmer cabinet, proving to be now the strongest upholder of reaction. He enforced the censorship, and interfered dangerously with the food-supply work of the Zemstvos and Towns union. At a stormy meeting held at the Duma he was asked to resign his post, and when he refused his name was struck off the list of members of the party. Hated by the Liberal circles and by the Duma, Protopopov not only supported the reactionary policy of Stürmer and Prince Galitzin, but he is said also to have been one of the secret organizers of the disturbances of Feb. 1917, which he proposed to suppress by military force, and which, unexpectedly for him, resulted in the overthrow of the empire and of himself. He was arrested by the provisional government and committed for trial. He remained for many months in the Peter and Paul fortress and was executed by order of the extraordinary commission in Sept. 1918.

PROTOZOA. The Protozoa are usually defined as unicellular animals in contrast with the higher animals, or Metazoa, in which the body is composed of many structural and physiological units, or cells, differentiated to perform the various functions of life. Under the influence of the "cell theory," this interpretation was definitely suggested in 1843 by M. Barry and formally made in 1845 by T. H. von Siebold, the latter establishing the term Protozoa, previously used in a general sense for primitive animals, for the basic phylum of the animal kingdom. However, in view of the fact that each protozoon is a complete independently-living organism, a few zoologists, under the impetus of C. Dobell (1911), prefer to regard the Protozoa as "noncellular" and to restrict the term cell to the units of the tissues of the Metazoa. But this unduly minimizes, for instance, the significance of the fundamentally similar structure and method of division of the Protozoa and the cells of Metazoa and also the highly probable, and generally accepted, view that the Metazoa have evolved from the Protozoa by the aggregation and specialization of these units to allow tissue differentiation. The Protozoa apparently have accomplished all that is possible within the confines of a cell, and have endowed the Metazoa with potentialities that are essentially unlimited. (Fig. 1.)

The Protozoa are the simplest but by no means simple animals. Most species are too small to be seen with the naked eye, so their discovery awaited the advent of microscopes in biological studies during the 17th century. In 1674 the Dutch microscopist, Antony van Leeuwenhoek, focused his lenses on pond water, vegetable infusions, etc., to reveal a new and prolific microcosm of "animalcules," and became the founder of protozoology and bacteriology.



FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)

FIG. 1.—PARAMECIUM AURELIA. MAGNIFIED ABOUT 350 TIMES

Significance of Protozoology.—When the Protozoa were discovered they naturally provoked amazement by their small size, stupendous numbers and enormous powers of multiplication, and were seized upon as support for the current views on spontaneous generation which were being undermined, in particular by the work of Francesco Redi on the propagation of flies in 1668. The spontaneous origin of "animalcules" appeared highly plausible, but it was believed by Leeuwenhoek to be fallacious. This was definitely indicated as early as 1718 by the experiments of Louis Joblot, who found that boiled infusions, thoroughly sealed, remained devoid of life.

Although the problem of the origin of the tiny animals long persisted, interest gradually centred on their description and classification. Thus, John Hill in 1752 formally assigned to them the basic position in the animal kingdom, under the title Animalcules, but the first great contributions to their taxonomy were made by O. F. Mueller, chiefly in his monograph published in 1786. This broad survey naturally led to intensive studies on protozoan structure. Is it essentially a tiny replica of the body of higher animals with somewhat similar organs and organ systems, or is it unique? C. G. Ehrenberg presented the culmination of the former view in 1838 and F. Dujardin of the latter in 1841. Dujardin's ideas prevailed during the ensuing decade with the recognition that the protozoan body is relatively simple, being composed of a unit mass of sarcode, now called protoplasm, which is the physical basis of life common to all animals and plants. Then came the realization, as already indicated, that the individual protozoon is comparable to the cellular unit of structure and function in higher organisms. So it appeared that the Protozoa present animal life in primitive form—isolated cells in which the answers to some of the fundamental life problems can be sought more readily than in multicellular animals with tissue differentiation. This viewpoint led to a wealth of important investigations begun shortly after the middle of the 19th century and still continuing unabated, but now with the full realization that the intricacies of protozoan morphology and physiology within the cell—the *multum in parvo* plan of structure—does not necessarily spell simplicity. Indeed, one wonders whether the performance of all the functions of an individual's life within the confines of one cell, instead of in myriads of differentiated cells, is the more simple. Be that as it may, the fact remains that these primitive animals have served as an important approach to many basic questions such as the structure of protoplasm, the intricacies of growth and regeneration, the significance of fertilization, and the factors underlying senility—to cite only a few of many. All told, these studies have contributed greatly

to the grasp of general biological problems, even though it may be admitted that the little animals have divulged their secrets somewhat more grudgingly than the earlier workers anticipated in their enthusiasm.

It should be emphasized that much of our information in regard to the Protozoa has been derived from investigations conducted with no immediate object in view other than to broaden the horizon of knowledge. But the facts secured have proved a necessary foundation for other studies of medical and economic importance. It has become increasingly apparent that many Protozoa are disease-producing parasites of man and beast. Although Leeuwenhoek observed some protozoon parasites, it was not until about the start of the 20th century that the causal relation of Protozoa to certain diseases, notably malaria, amoebic dysentery and African sleeping sickness, attracted wide attention. This aspect of protozoology came to form a large and important part of parasitology, and so from the practical as well as the theoretical standpoint studies on the Protozoa afford invaluable information.

Types of Protozoa.—Broadly speaking, all Protozoa are aquatic organisms since they demand a fluid environment for active life. They abound in pools and puddles, lakes and seas, and the soil, as well as in the bodies of higher animals and plants —essentially everywhere that moisture is available and elsewhere when they are in a dormant state. Nearly every animal that has been carefully studied has revealed one or more species especially adapted to live in its body, and therefore it seems probable that there are actually more kinds of Protozoa than there are of all the rest of the animal world, although by 1945 only about 20,000 species had been described.

Active phases of the Protozoa are provided with suitable locomotor organs, and it is on the type of these organs that three of the four great classes of the phylum are chiefly based. The Mastigophora or Flagellata (*e.g., Euglena*) move by flagella, the Sarcodina or Rhizopoda (*e.g., Amoeba*) by pseudopodia and the Ciliophora or Ciliata (*e.g., Paramecium*) by cilia. The remaining class, the Sporozoa (*e.g., Plasmodium*), comprises solely parasites which possess no diagnostic locomotor organs though all species are motile at some stage in their life history. It might appear, then, that the separation of the Protozoa into clearly defined classes should be relatively easy, but since some species exhibit, for example, both flagella and pseudopodia at different phases in their life history as well as other intermediate characters, their relationships must be appraised on the ensemble of characters presented. Comparable difficulties arise in the taxonomy of the various subdivisions of the classes. (Figs. 1–4.)

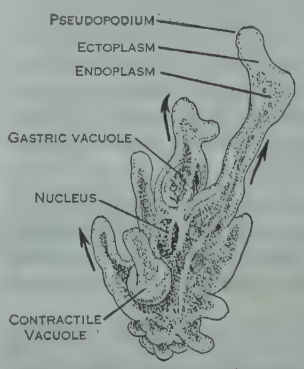
Although the class Mastigophora comprises the most primitive animals, no hard and fast line can be drawn between the plant and animal kingdoms—one merges into the other when their simplest forms are approached. In fact botanists claim, with considerable justice, some of the flagellates, chiefly because they possess chlorophyll and are able to synthesize food by the energy of sunlight as do typical green plants. But in the absence of light, many of these forms with chloroplasts or chromatophores, such as *Euglena*, are able to use relatively complex food material in solution, and are similar in structure to other species without chlorophyll that are typically holozoic, *i.e.*, engulf solid food. Accordingly, it is to a considerable extent a matter of emphasis on one or another of the various aspects of flagellate physiology and structure which determines whether certain species are regarded as unicellular Algae or Protozoa—a condition recognized by zoologists who stress the animal nature of the flagellates but divide the class into two major divisions, the Phytomastigophora and Zoomastigophora.

Form.—Protozoa in general exhibit a definite "adult" form characteristic of the species, although many of the rhizopods, in particular, readily change their shape by protoplasmic flowing, known as amoeboid movement from the name of the common genus, *Amoeba*. Furthermore, many species have complicated life cycles in which the individual cells at various stages are quite different in appearance so that more than one and often many stages are necessary for identification. Indeed, polymorphic life cycles in which a series of forms follow one another in a definite sequence complicate the concept of "individuality" in the Protozoa just as they do in many higher animals and plants. (Fig. 4.)

The protozoan body form is so exceedingly diverse that nearly every possibility seems to be realized. For instance, the range is from homaxonic or spherical types, typically seen in various floating rhizopods such as most of the fresh-water Heliozoa and marine Radiolaria, to monoaxonic types in which a mouth, or cytostome, is at or near the anterior end of the long axis, resulting usually in imperfect bilateral symmetry as in many flagellates and ciliates. Some of the latter in particular show a marked dorsoventral differentiation with the cytostome on the ventral aspect.

Although the vast majority of the Protozoa are microscopic in size, the lower limit being about 2/1000 of a millimetre, there are giants among the rhizopods; a few of the Foraminifera approximate 15 cm. in diameter and are exceeded by the plasmodia of some Mycetozoa. Well-known species such as *Amoeba proteus* and *Paramecium aurelia* are barely visible to the naked eye under the most favourable conditions. While a fairly definite size characterizes each species, as well as the various stages of polymorphic species, many are composed of races showing size differences, and all are especially susceptible to nutritional and other changes in their environment. Accordingly, size alone is a precarious specific character. (Figs. 1, 2.)

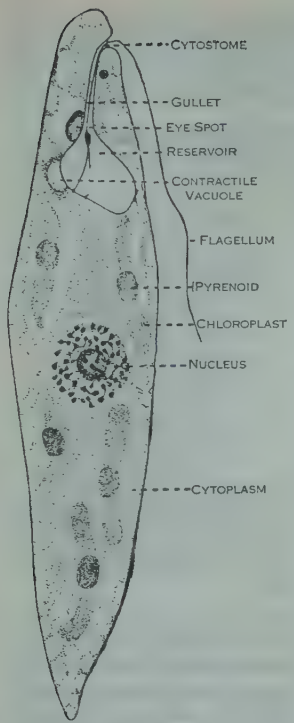
Shells and Skeletons.—External and internal protective and supporting structures, usually permanent but sometimes temporary and restricted to certain stages, are widespread. In some instances the secreted substance is solely organic in nature, such as gelatinous material, tectin or cellulose. In other types there are added to this basis various inorganic elements, in particular calcium and silicon, and also foreign bodies, such as diatom tests and sand grains. The protective covering may be closely applied to the cell surface or separated by a space. In many of the Foraminifera elaborate shells of calcium carbonate are largely internal structures, becoming permeated and surrounded by the protoplasm of the animal. In other species the cell may be supported by a skeleton, often both external and internal, reaching the climax of complexity in many of the Radiolaria. So again, as in the case of form to which they contribute, nearly every shape of protective and supporting structure that can be imagined in a unicellular animal has been attained, and even the most elaborate of these are necessarily formed anew during reproduction and often repaired after mutilation. An example of the complexity of the process of shell-building is afforded by certain common freshwater rhizopods. Thus in *Difflugia*, with a simple shell composed of siliceous particles embedded in an organic matrix, the foreign material is gathered before fission and passed to the offspring during the process; while in the closely related *Euglypha*, plates and spines are secreted by the parent cell and later become arranged on the surface of the young animal. (Fig. 5.)



FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)

FIG. 2.—AMOEBA PROTEUS. MAGNIFIED ABOUT 100 TIMES

Cell Body.—The cytoplasm of the protozoan body usually exhibits two general regions: an outer, clear, relatively homogeneous layer, or ectoplasm, and an inner, granular mass, or endoplasm, forming the bulk of the cell. The ectoplasm proper is physiologically delimited from its surrounding by an altered surface, or plasma membrane, which by virtue of selective permeability controls the diffusion of materials into and from the cell. Usually there is also a definite skin, or pellicle, that may either appear structureless or show striations, grooves, ridges or sculpturing in various ways,



FROM MACDOUGALL & HEGNER, "BIOLOGY: THE SCIENCE OF LIFE" (MCGRAW-HILL BOOK CO.), AFTER BAKER

FIG. 3.—EUGLENA AGILIS, A GREEN FLAGELLATE. MAGNIFIED ABOUT 1,500 TIMES

sometimes in relation to the protrusion of cilia or flagella. Also in the ectoplasm there may be skeletogenous material in the form of rods, plates and fibrils, and contractile fibres or myonemes, as well as specialized organelles serving other functions, particularly those which are in direct relation to the environment of the cell.

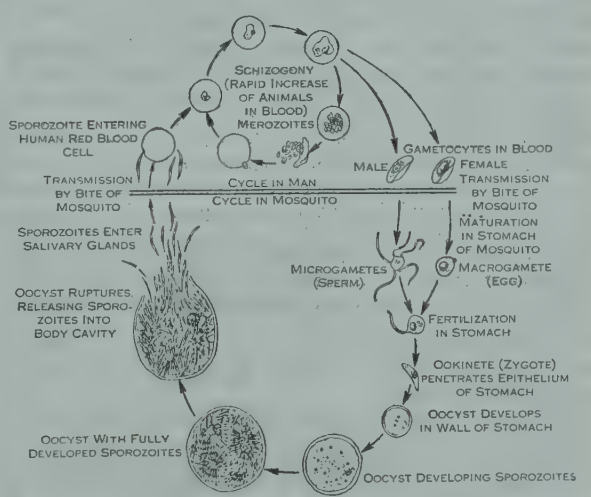
The endoplasm, in contrast with the ectoplasm, is relatively fluid, markedly granular and vacuolated; the last character giving the impetus to O. Buetschli's well-known "alveolar theory" (1878, 1892) of the finer structure of protoplasm. Within the endoplasm is the nuclear apparatus, comprising one or more nuclei, and most of the organelles, such as gastric vacuoles, contractile vacuoles and chromatophores, as well as stored proteins, carbohydrates and fats, and crystals and other metaplasmic bodies. Chondriosomes and Golgi bodies have been described in many species and probably are always present.

Motor Organelles.—Motor organelles—pseudopodia, flagella and cilia—have served from the time of Felix Dujardin (1841) to demark three of the great groups of Protozoa. Pseudopodia are temporary extensions of the body which range in complexity from mere outflowings of the protoplasm of the cell, as seen in *Amoeba proteus* and its allies, to more definitely formed structures as found in the Heliozoa and many Radiolaria. All pseudopodia function to some extent in locomotion and prehension of food, but the latter use predominates in many species. Four general types of pseudopodia may be distinguished, each of which is characteristic of certain species, though subject to considerable modification under varying surroundings. Lobopodia are relatively broad and usually blunt outflowings of both ectoplasm and endoplasm (*e.g.*, in common Amoebae); filopodia are long, slender, pointed threads of ectoplasm (*e.g.*, in *Euglypha*); myxopodia are threadlike and tend to branch and fuse to form large meshworks (*e.g.*, in the Foraminifera); and axopodia are relatively stiff raylike processes, each consisting of an axial filament arising from a basal body in the cell and enclosed by a layer of flowing protoplasm (*e.g.*, in the Heliozoa). Axopodia in certain species approach the structure of flagella and have been regarded as evidence of a close relationship between the Heliozoa and Mastigophora. (Figs. 2, 6.)

Flagella are long, vibratile threads of protoplasm which extend from the surface of the cell and function chiefly as locomotor organs, but also may serve to waft food-bearing currents toward the animal or to explore the immediate surroundings in a sensory capacity. The number of flagella varies in different species from one to hundreds, but usually does not exceed four. Typically they arise at the anterior end of the cell and project forward, but in many common species with two flagella (*e.g.*, *Bodo* sp.) one flagellum trails posteriorly, acting as a gliding organ or rudder. There may be considerable variations in length and also in form of the flagella in the same and different species. Most flagella are circular in cross section, but some are flattened or form the edge of an undulating membrane as in certain parasitic flagellates (*e.g.*, Trypanosomes). The finer structure of flagella is extremely difficult to determine, but from the study of favourable examples it evidently consists of two parts—an elastic sheath which envelopes an axial vibratile filament, the latter being an outgrowth of a basal body, or blepharoplast. The mechanism of flagellar movement is apparently inherent in the flagellum itself because it retains activity when isolated with its basal body. The basal body is a centriole, or a derivative of a centriole, which is usually situated just under the cell surface near the point of exit of the axial filament but may lie deeper and be closely associated with the nucleus. In many species the kinetic system is complicated by multiple basal bodies, parabasal bodies, axostyles, rhizoplasts and other elements of unknown function too diverse to be briefly summarized. (Figs. 3, 16, 19.)

Cilia are relatively short protoplasmic threads which arise from basal bodies in the ectoplasm of all species of the Ciliophora. They are usually exceedingly numerous and form longitudinal rows that may be evenly distributed over the surface of the cell or restricted to certain regions and differentiated for special functions. Thus the union of the cilia in a row or the union of rows of cilia, or both, form such complexes as undulating membranes and membranelles in the oral region for wafting food into the peristome, while the fusion of tufts of cilia constitutes bristlelike cirri for crawling and tactile purposes. The basic structure and mechanism of movement of cilia appear to be similar to that of flagella, but the effectiveness of ciliary action is caused by waves of contraction passing along the rows, each composed of a multitude of cilia coordinated by underlying fibres that connect the basal bodies. (Figs. 1, 14.)

Nucleus.—The nuclei of the Protozoa have the same basic structure and function as in metazoan cells: a nuclear membrane encloses the karyolymph in which are embedded achromatic and chromatic elements; the latter constitutes the definitive chromosomes. However, the nuclei show much more variation in general structure than do those of the Metazoa, and in many cases kinetic bodies are intranuclear. All attempts to arrange a satisfactory evolutionary series of nuclear types have failed, largely because diverse types may occur in obviously closely related species. It is customary to classify protozoan nuclei in a broad way as either vesicular or massive. In the former type


SCHIZOGONY (RAPID INCREASE OF ANIMALS IN BLOOD) MEROZOITES
SPOROZOITE ENTERING HUMAN RED BLOOD CELL
GAMETOCYTES IN BLOOD
MALE
FEMALE
TRANSMISSION BY BITE OF MOSQUITO
CYCLE IN MAN
CYCLE IN MOSQUITO
TRANSMISSION BY BITE OF MOSQUITO
MATURATION IN STOMACH OF MOSQUITO
SPOROZOITES ENTER SALIVARY GLANDS
MICROGAMETES (SPERM)
MACROGAMETE (EGG)
OOCYST RUPTURES, RELEASING SPOROZOITES INTO BODY CAVITY
FERTILIZATION IN STOMACH
OOKINETE (ZYGOTE) PENETRATES EPITHELIUM OF STOMACH
OOCYST DEVELOPS IN WALL OF STOMACH
OOCYST WITH FULLY DEVELOPED SPOROZOITES
OOCYST DEVELOPING SPOROZOITES

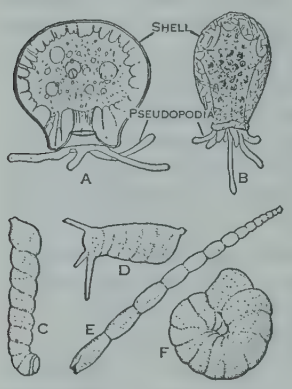
FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)

FIG. 4.—GENERAL SCHEME OF THE LIFE HISTORY OF A HUMAN MALARIAL PARASITE, PLASMODIUM

the chromatin is concentrated in a centrally located body, the endosome, surrounded by a zone of clear karyolymph; but there are many gradations between this condition and the massive type in which the chromatin is distributed evenly throughout so that the nucleus presents a comparatively homogeneous appearance. Both nuclear types may be found in the same genus: the micronuclei are typically vesicular in some species of *Paramecium* and approach the massive in others.

The majority of Protozoa contain a single nucleus, but there are many species with two or more nuclei, and some with hundreds. Common forms with many nuclei are represented by the large freshwater rhizopod, *Pelomyxa,* certain stages of the Mycetozoa and some of the parasitic ciliates of the frog, such as *Opalina.* Multiple nuclei may be present during nearly the whole life of a species, or only in stages preparatory to reproduction by multiple division.

A unique and characteristic condition prevails in nearly all of the ciliates, where the typical nuclear apparatus comprises two structurally differentiated parts: usually one relatively large macronucleus and one or more micronuclei. Both types divide during cell division, but the macronucleus is apparently a composite nucleus which as a whole divides amitotically in distributing its component elements which may individually divide mitotically. The micronuclei divide by typical mitosis and on them depends the origin of gametic nuclei, and the formation of a new macronucleus after fertilization as well as in a nuclear reorganization process known as endomixis (fig. 1).



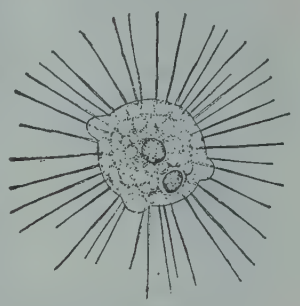
FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN), AFTER SEVERAL AUTHORS.

FIG. 5.—(A.) ARCELLA SHOWING THE PROTOPLASM THROUGH THE TRANSPARENT SHELL AND ALSO PROTRUDING AS PSEUDOPODIA; (B.) DIFFLUGIA SHOWING THE SAME; (C-F.) SHELLS OF FOUR SPECIES OF FORAMINIFERA. VARIOUSLY MAGNIFIED

In addition to the formed nuclei, sometimes there are granules distributed in the cytoplasm that have been released from the nucleus. Many of these take nuclear stains and are undoubtedly chromatin, but the chromatin nature of others is highly questionable. The chromatin granules, or chromidia, gave rise to elaborate theories, by R. Hertwig and his school, in regard to their cell function, particularly in reference to the nucleo-cytoplasmic relationship and to the origin of the nuclei of gametes. It is generally accepted that a delicately balanced proportionality normally exists between the volume of nucleus and cytoplasm of a cell, a relationship which, however, varies within limits during different phases of cellular activity. Granting this, it is assumed that the nucleo-cytoplasmic ratio is under certain conditions maintained by the elimination of chromatin from the nucleus. This may well be true, though crucial evidence that chromidia function in this way is lacking. But the aspect of the "chromidial hypothesis" which is of most interest assumes that formed nuclei, especially of the gametes, arise from chromidia in certain species. A number of categorical descriptions of such an origin have been given, but more recent observations demonstrate beyond peradventure in all cases that have been critically re-examined (*e.g.,* in the Foraminifera) that the nuclei of the gametes are formed by a continuous series of mitotic divisions involving definite chromosome distribution.

It is clear then that nuclear division, long believed to be amitotic in many Protozoa, is really mitotic since it involves the exact distribution of chromosomes or elements comparable with chromosomes in metazoan cells. This has been demonstrated by observations on dividing nuclei in certain species, and also by the results derived from genetic studies that can be interpreted only from the standpoint of a segregating mechanism as in Metazoa. It is true that the macronucleus of ciliates divides as a whole amitotically but, significantly, is replaced periodically from mitotically dividing micronuclei. Although in many species of Protozoa definitive chromosomes have not actually been seen, in others specific chromosomes have been unequivocally identified in both the haploid and diploid state; *e.g.,* the diploid number in the sporozoan, *Aggregata eberthi,* is 12, and in the foraminifer, *Patellina corrugata,* is 24. In most cases the chromosome number is within the usual range of that found in metazoan cells, say less than 50, although polyploidy may greatly increase the number, as in certain races of *Paramecium bursaria.* Again the number may mount to more than a thousand, as in the so-called polyenergid nuclei of some of the Radiolaria that may be essentially aggregates of nuclei.

In contrast with metazoan nuclei, the protozoan nuclear membrane usually persists during mitosis, and the centrioles or comparable kinetic agents, as well as the spindle, are intranuclear. However, variations are very numerous and range from cases where part of the mitotic apparatus is outside the membrane to those in which the whole mitotic figure arises in the adjacent cytoplasm (figs. 8, 9).



FROM KUDO'S "PROTOZOOLOGY," 3RD ED., P. 357, FIG. 163 (1946). COURTESY CHARLES C. THOMAS, PUBLISHER, SPRINGFIELD, ILL.

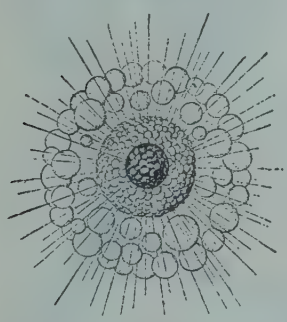
FIG. 6.—A HELIOZOAN, ACTINOPHRYS SOL. MAGNIFIED ABOUT 400 TIMES

Nutrition.—Various methods of nutrition occur in the Protozoa and, in general, these are characteristic of particular groups. Autotrophic, or holophytic, nutrition is found in the chlorophyll-bearing species, particularly in the phytoflagellates, and involves photosynthesis as in green plants, but some of these species, even in the light, require nitrogen in organic combinations, such as amino acids. In the absence of light most autotrophic forms (*e.g., Euglena*) can absorb organic substances dissolved in the medium and so live by the saprozoic method, whereas many of the free-living flagellates without chlorophyll and nearly all parasitic Protozoa are solely saprozoic. But variations in details of nutrition are legion. For example, it appears that some of the free-living, colourless flagellates can be cultivated on a remarkably simple inorganic medium to which acetate has been added as a carbon source. Indeed, it is becoming increasingly clear from extensive studies on pure cultures of various species and races of flagellates, rhizopods and ciliates in controlled media, where the significance of vitamins, trace elements, and so on may be determined, that there are many intermediate gradations between typical autotrophic and saprozoic nutrition and between the latter and holozoic nutrition in which particulate food is required. To define this nutritional versatility a highly elaborate but unsettled terminology has been developed.

The majority of the free-living species are holozoic, ingesting solid food, usually micro-organisms, such as bacteria and yeasts, and other Protozoa. This involves the development of a wide variety of methods for securing and ingesting the food. In most rhizopods the mere contact of the nutrient material with nearly any point on the exposed surface of the protoplasm is followed by its gradual engulfment by pseudopodial action; in other species a special receptive point for ingestion is provided. This may consist, as in some flagellates, merely of an exposed region at the anterior end near the base of the flagellum, or, as in many ciliates, of a definite cytostome leading into the endoplasm. The cytostome may be terminal but more often in the ciliates it is situated laterally and ventrally in a funnel-like depression of the surface, the peristome, and opens into a tubular gullet extending into the endoplasm. Ciliary action in the peristome wafts the food particles in a vortex toward the mouth and accordingly it is in this region that special groups of cilia, such as undulating membranes and membranelles, are present. Species so provided feed continually if food is available because the mouth is permanently open. It has been conservatively estimated that a *Paramecium* may ingest as many as 5,000,000 bacteria in 24 hours. In various other species the mouth is open only when occasion demands. This is particularly true in the case of carnivorous forms which capture prey when chance brings it within reach, as is well illustrated by ciliates such as *Didinium,* whose sole diet consists of *Paramecium,* and *Spathidium,* which feeds on *Colpidium* and closely similar small ciliates. In such cases the food is "selected" by limitations imposed by the character

of the oral apparatus. Thus the seizing organ of *Didinium* is in some way adapted so that it adheres to the pellicle of *Paramecium* and not to that of other organisms with which it happens to come in contact. Quite a different method of food capture is employed by the free-living Suctoria, which in the adult state are devoid of cilia but are provided with tentacles. Prey, such as a small ciliate, coming in contact with the tentacles is paralyzed, presumably by some poisonous secretion, and thereupon its endoplasm is sucked out until there is merely a collapsed remnant. (Figs. 10, 11).

In some species the ingested food appears to lie directly in contact with the endoplasm, but more often it is in a droplet of water, taken in at the same time, that constitutes a gastric vacuole. In most ciliates, such as *Paramecium*, the vacuole passes from the gullet into the endoplasm, where it is carried along a more or less definite course through the cell by cyclosis. During this passage digestive enzymes, etc., are secreted into the vacuole. The reaction of the vacuolar content varies from acid to alkaline, and the presence of proteinases and amylases has been demonstrated, but in very few Protozoa is there definite evidence of the digestion of fats, although this undoubtedly occurs. However, the details of digestion are largely undetermined, not only because of the delicacy of the technique involved in the study but also because the process varies in different species and in the same species with the nature of the available food. In any event the digestible contents of the vacuole gradually disappear as it circulates through the endoplasm and then the useless residue passes out of the cell, usually at a definite point, the cytoproct. It appears that gastric vacuoles containing material of no food value are rejected after a relatively short course in the cell. (Fig. 1.)



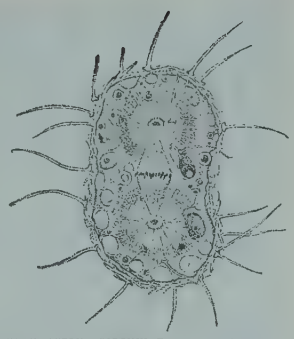
FROM KUDO'S "PROTOZOOLOGY," 3RD ED., P. 372, FIG. 169B (1946). COURTESY CHARLES C. THOMAS, PUBLISHER, SPRINGFIELD, ILL., AFTER HUTH

FIG. 7.—A RADIOLARIAN, THALASSICOLLA NUCLEATA. MAGNIFIED ABOUT 15 TIMES

Respiration.—With the wide distribution of Protozoa in nearly every ecological niche of nature, it is not strange that their respiratory processes show considerable variation. The majority of species are strictly aerobic, demanding free oxygen for their normal metabolic processes. This is secured with the intake of water with food and also by diffusion through the whole surface of the body, since structurally differentiated respiratory organs are not present. Similarly the outgo of CO_2 is apparently accomplished by the cellular membrane, probably incidentally aided to some extent by the contractile vacuolar system when it is present. The oxygen uptake and the CO_2 output varies greatly in different species and in the same species under altered internal and external conditions. Experiments indicate that the hourly rate of oxygen consumption of *Paramecium calkinsi* at 20° C. is of the order of magnitude of 28 cu.mm. per 100,000 animals.

Some typically aerobic forms are able to exist for a considerable time as facultative anaerobes and obtain energy from processes that do not require free oxygen, such as the breakdown of glycogen into lactic acid. *Paramecium* can survive for about 12 hours in the absence of free oxygen. But there are many species that are largely or entirely anaerobic, in particular various endoparasitic forms and those inhabiting mud and highly polluted sewage water. Indeed, free oxygen is lethal for certain species.

Contractile Vacuole.—One of the most interesting among the organelles of the Protozoa is the contractile vacuole that occurs in the majority of fresh-water species, but is usually absent in marine and parasitic forms other than the ciliates. The vacuole appears and disappears rhythmically from view as it gradually accumulates and then expels fluid from the cell. In most forms the vacuole occupies a definite position in the cell, but in Amoebae the general location changes as the animal flows along. Commonly there is only one vacuole, but some species possess two or several. Furthermore, the definitive vacuole, especially in the ciliates, may be the focus of a vacuolar system comprising accessory canals that radiate from the vacuole (*e.g.*, in *Paramecium*) or ramify widely through the endoplasm (*e.g.*, in *Frontonia*). In most cases the vacuole is supplied by the migration of tiny droplets of fluid and accessory vacuoles which coalesce at the contractile vacuolar locus or with some part of the canal system when such is present. Many observations indicate that at least some of the droplets of fluid originate in association with osmophilic material, probably representing the so-called Golgi apparatus.



FROM STERN, "ARCHIV F. PROTISTENKUNDE" (FISCHER)

FIG. 8.—MITOSIS (METAPHASE) DURING DIVISION OF A HELIOZOAN, ACANTHOCYSTIS ACULEATA. MAGNIFIED VERY HIGHLY

Although it is difficult to determine the nature of the delimiting surface of the vacuole, it seems clear that some types are surrounded by a structural membrane in addition to the theoretically necessary physiological membrane. Again in some cases the vacuole discharges through a definitive excretory pore, while in others the pore is temporary. The rate of vacuolar contraction varies in different species and also in the same species with changes in the osmotic pressure of the surrounding medium, temperature, and other factors, but in general the vacuolar cycle ranges in duration from a few seconds to a minute.

FROM CHEN, PROCEEDINGS NATIONAL ACADEMY SCIENCES

FIG. 9.—NUCLEUS OF A CILIATE, ZELLERIELLA INTERMEDIA, IN MITOTIC DIVISION (ANAPHASE) SHOWING TWO DAUGHTER SETS OF 24 CHROMOSOMES. MAGNIFIED ABOUT 2,000 TIMES

The first significant suggestion relative to the function of the contractile vacuolar system was made in 1776 by Lazzaro Spallanzani, who regarded it as respiratory, but it is now believed, as first emphasized by M. Hartog in 1888, to be chiefly associated with the maintenance of the proper osmotic relations between the cell and its surroundings by regulating the water content of the protoplasm. A *Paramecium* with two contractile vacuoles may eliminate its own body volume of water in less than 20 minutes. That this system also acts in an excretory capacity to eliminate CO_2 and nitrogenous wastes has not been satisfactorily determined, though undoubtedly such material must incidentally, at least, pass out in the vacuolar fluid. However, the fact that many Protozoa are without contractile vacuoles makes it clear that these organelles are not invariably necessary for such indispensable functions.

Reproduction.—Although reproduction in all animals and plants is basically dependent upon cell division, this is most evident in unicellular forms where the parent individual divides into daughter cells and so loses its individuality. The important types of cell multiplication in the Protozoa are commonly referred to as binary fission, budding and sporulation—all intrinsically asexual processes though in certain instances leading to the formation of gametes. Binary fission involves the division of the cell, both nucleus and cytoplasm, into two essentially equal daughter cells that grow into replicas of the parent. So stated the process seems simple, but obviously it involves making each

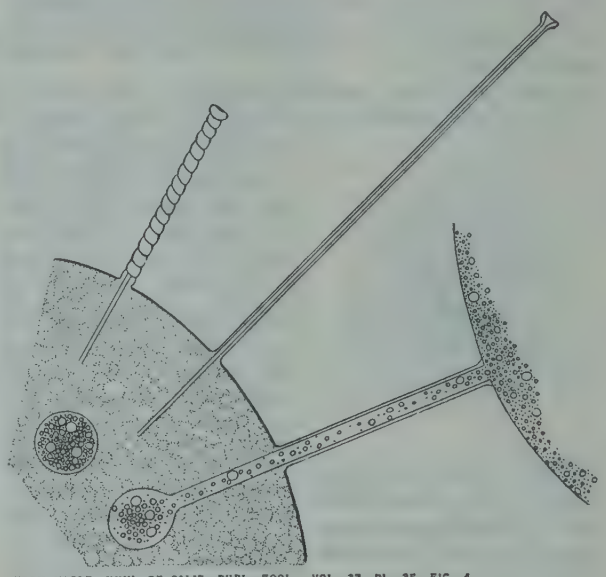
half into a whole. Dedifferentiation of various structures in the parent cell must be followed by differentiation in the daughter cells. Although some organelles are taken over intact, in general the daughter cells are essentially "new" organisms. For instance, in many of the specialized ciliates it has been possible to show that the highly modified groups of cilia, or cirri, are resorbed and new ones arise in, or migrate to, the proper relative positions on the daughter cells.

Many gradations occur between binary fission and budding, or gemmation, in which the parent cell retains its identity while producing by division one or many daughter cells. Sometimes a bud is essentially as large as the parent, so the result is nearly the same as binary fission except that parent and offspring can be distinguished; but usually the bud is much smaller, less differentiated, and gradually assumes the parent form after it has become free. This condition is well seen in the sessile Suctoria, where the buds become detached as free-swimming, ciliated embryos which finally settle down and develop tentacles and other adult characters. In some species the buds arise on the surface of the parent and in others within deeply invaginated "brood chambers" from which they escape at "birth." The former is referred to as exogenous and the latter as endogenous budding.

Multiple budding leads by various transitions to sporulation, in which the nucleus of the parent cell divides a number of times, followed by the division of the cell body into as many cells as there are nuclei, so that the parent cell becomes resolved into many progeny. Sporulation is obviously a method of very rapid multiplication and is especially characteristic of parasitic forms, such as the Sporozoa with complicated life cycles including asexual and sexual phases. Thus in many species an asexual phase, known as schizogony, is followed by the development of sex cells and zygote formation. This in turn leads to spore formation, or sporogony, and so completes the life cycle. But other variations in reproduction are legion. For instance, so-called plasmotomy sometimes occurs in multinucleate species such as some of the Opalinid ciliates; the cytoplasm divides into two parts, each retaining the nuclei that are in it at the time. A continuation of this process may produce uninucleate cells. (Fig. 4).

Colonies.—Reproduction in the vast majority of the Protozoa results in individuals that move apart and live a completely separate existence, but in certain species the cells formed by division remain associated so that colonies result. Protozoan colonies vary widely in form ranging from essentially amorphous groups of individuals, or zooids, embedded in a gelatinous substance, to those in which the zooids assume definite spatial relations with each other so as to constitute linear, platelike, spherical or arboroid colonies. All of the individuals composing a colony are, with few exceptions, structurally the same and physiologically independent, though the colony may swim by the combined action of the flagella of its component zooids (*e.g.*, *Gonium*) or contract as a whole by virtue of a common stalk (*e.g.*, certain arboroid colonies among the ciliates).

Colony formation in some of the phytoflagellates of the family Volvocidae is of special interest because there are various gradations from small groups of individuals, in structure quite similar to those of closely related noncolonial species, to complex colonies of thousands of cells. Representatives of the simpler types are the several species of *Gonium* that are square, platelike colonies of from 4 to 16 zooids, usually in a gelatinous matrix; and of *Pandorina* and *Eudorina* that consist of spherical groups of 16 or 32 zooids similarly embedded. All of the zooids have the same structure and are capable of asexual and sexual reproduction. But a differentiation of somatic and reproductive zooids appears in various species of *Pleodorina,* comprising up to 128 zooids, and *Volvox,* often consisting of many thousands of zooids connected by protoplasmic strands and forming the surface of a gelatinous sphere. So there is a demarcation of somatic and germinal regions of the colony that is prophetic of the further individualization and attendant physiological division of labour characteristic of the true multicellular organisms. In the case of *Volvox*, particularly, the fact that it is difficult to draw a hard and fast line between a colony and a metazoan individual is evident, and probably such a colony would be regarded as an individual were there not gradations between it and closely related noncolonial species. Students of phylogeny consider most acceptable the view that the Metazoa were derived from a spherical colony of flagel-



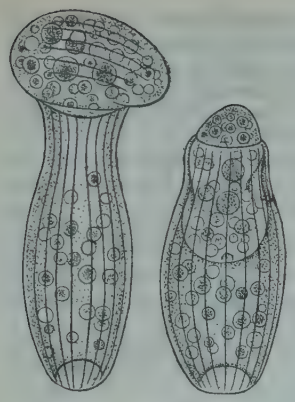
FROM NOBLE, UNIV. OF CALIF. PUBL. ZOOL., VOL. 37, PL. 35, FIG. 4

FIG. 10.—SECTION OF THE SURFACE OF A SUCTORIAN, TOKOPHRYA LEMNARUM, SHOWING TENTACLES CONTRACTED, FULLY EXTENDED AND IN THE ACT OF FEEDING. MAGNIFIED ABOUT 2,000 TIMES

lates, not greatly dissimilar to *Volvox*. This view receives support from similarities in the method of development of *Volvox* and some calcareous sponges. (Fig. 12.)

Sex.—Sexual phenomena are wide-spread in the Protozoa but evidently are not universal, as was formerly assumed, because intensive studies of many species have given no supporting evidence. Sex in the Protozoa is expressed in the same basic way as in the rest of the animal kingdom, involving intrinsically the formation of male and female sex cells, or gametes, whose nuclei unite in the zygote to form a composite nucleus, or synkaryon. In some species mature sexual individuals, which are not recognizably differentiated except by their behaviour, unite in pairs and melt together, cytoplasm with cytoplasm and nucleus with nucleus, to form a zygote. In various other species the gametes show nearly all possible gradations in differentiation, both of size and behaviour, finally resulting in minute active sperm and large passive eggs as in most Metazoa. Furthermore, in the ciliates (*e.g.*, in *Paramecium*) a unique process known as conjugation prevails, in which two similar individuals come in contact and temporarily unite about the oral region. Then in each of the conjugants two gametic nuclei of micronuclear origin are formed, one of which migrates into the other conjugant and fuses with its "stationary" nucleus to form a synkaryon. Accordingly this exchange results in mutual fertilization of the conjugating animals which thereupon separate, re-establish the typical nuclear apparatus from the synkaryon, and proceed to reproduce by binary fission. However, in some ciliates, represented by the sessile Vorticellids, mutual fertilization does not occur; the conjugants are differentiated in size and behaviour so that free-swimming microconjugants unite with and fertilize sessile macroconjugants. (Fig. 13.)

In most instances the uniting gametes are produced by distantly related cells, but sometimes the reverse is true. They may be separated merely by a cell division or two from a common parent, as in some heliozoans, *e.g.*, *Actinophrys* and *Actinosphaerium,* so that very close inbreeding, known as paedogamy, occurs; while in extreme cases the gametic nuclei arise and fuse in the



FROM WOODRUFF & SPENCER, "JOURNAL OF EXPERIMENTAL ZOOLOGY," (WISTAR INST. OF ANATOMY AND BIOLOGY)

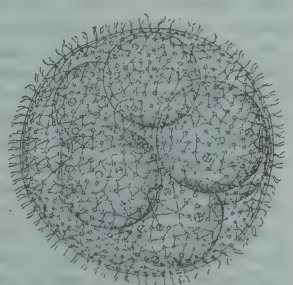
FIG. 11.—A CILIATE, SPATHIDIUM SPATHULA, CAPTURING AND SWALLOWING A COLPIDIUM. HIGHLY MAGNIFIED

same cell that produced them and so-called autogamy results. The latter takes place under certain conditions in *Paramecium* and some other ciliates, as also does endomixis in which a synkaryon is not formed although a new nuclear apparatus arises from a micronucleus. Endomixis simulates many of the nuclear phenomena of autogamy but without the attendant genetic possibilities involved in fertilization.

Furthermore, so-called mating types exist in various ciliates. Thus in *Paramecium aurelia* six such types have been described, each type conjugating with its companion mating type but not with any of the others. When many animals of two companion mating types are mixed together, usually they soon become clumped in large groups which gradually are dispersed as the conjugating pairs swim away. The types are typically established at the reorganization of the exconjugants and are recognizable solely by their mating behaviour, which obviously differentiates the members of the species into physiologically incompatible genetical varieties from the standpoint of fertilization. Variations in mating types occur in other ciliates, involving both the number of types and of companion types for each. The significance of these types in regard to sex phenomena in general is not as yet clear, some authorities interpreting them as evidence of multiple sex systems.

The nuclei throughout the trophic life of most Protozoa contain the diploid number of chromosomes characteristic of the species. Reduction to the haploid condition occurs, as typically in the Metazoa, during the formation of the gametic nuclei, and their union restores the diploid number in the zygote. However, some instances are know, especially among the phytoflagellates and sporozoans, where reduction takes place immediately after fertilization so that only the zygote is diploid. (Fig. 9.)

Genetics.—Reproduction by division unaccompanied by fertilization, *i.e.*, uniparental reproduction, results as a rule in offspring with all their characteristics the same; collectively they constitute a clone. But there are some exceptions of great interest because the clone becomes differentiated into lines of descent with divergent characters. Some of these changes are physiological, such as acclimatization to various temperatures and chemicals, whereas others are morphological, such as size and shape. Some are adaptive and some are not. In certain cases the changes directly attributable to the influence of environmental conditions are inherited for hundreds of generations after the conditions leading to their establishment no longer are present, but in most instances, perhaps all, they gradually disappear. This supports the view that such so-called enduring modifications are chiefly cytoplasmic and are not established in the basic genetic system, as also does the fact that most of them are altered or disappear after sexual reproduction. But some of the heritable variations within a clone occur without obvious environmental influence, and long-continued selective breeding may isolate and establish different strains. Presumably these are the result of mutations, but how any of the changes during asexual reproduction actually arise is not as yet clear, although the fact remains that they form divergent lines of descent, some of which may be important in the differentiation of species.



FROM DOFLEIN, "PROTOZOENKUNDE" (FISCHER), AFTER KLEIN

FIG. 12.—VOLVOX SP. WITH FIVE DAUGHTER COLONIES PRODUCED ASEXUALLY. MAGNIFIED ABOUT 150 TIMES

However, the chief immediate source of variation arises, as would be expected, from sexual reproduction. In all of the diploid species, as well as in the relatively few haploid forms, inheritance, so far as known, follows the typical Mendelian principles and their extensions, involving segregation, independent assortment, dominance, linkage, crossing-over, etc. But, of course, there are no recessives in haploid species; the offspring manifest combinations of all the characters evident in the parents.

Furthermore, recent work with pedigreed cultures of *Paramecium aurelia* reveals definite proof of the interaction of specific dominant genes and cytoplasmic factors, both of which must be present if the character involved is to be expressed in the individual, or phenotype. The cytoplasmic element cannot be perpetuated in the absence of the dominant gene in the macronucleus, and the gene cannot initiate the synthesis of the cytoplasmic element. The latter has been referred to as a "primer" of the gene. Obviously this result offers highly significant data for the interpretation of so-called cytoplasmic inheritance in general.

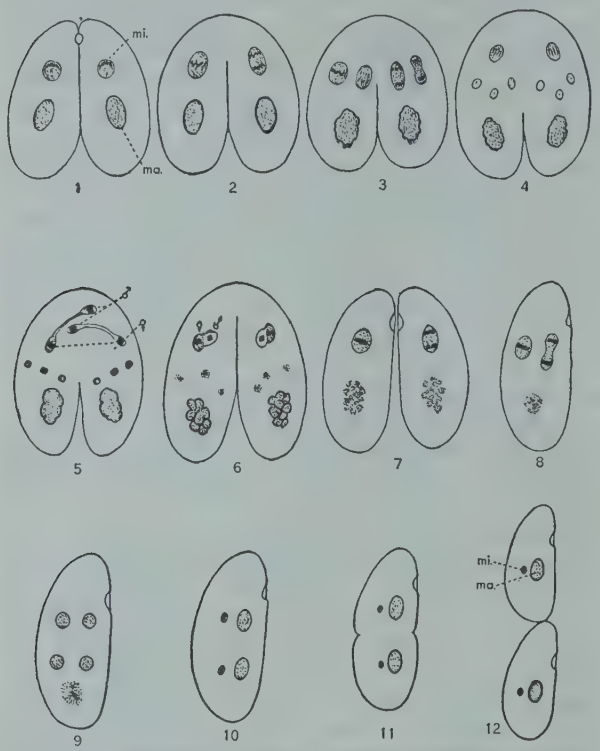
In brief, fertilization in the Protozoa, as elsewhere in animals and plants, produces hereditarily diverse strains from the two uniting gametes and thus is a source of variation that is of crucial importance in adaptation and evolution. And from the standpoint of evolution it is of great significance that the intrinsic genetic mechanism involved is the same from the Protozoa to the highest organisms, including man.

"Cycles."—In addition to its genetic results, fertilization contributes a dynamic effect that arises from the profound reorganization process involved. This aspect of fertilization has been widely studied in pedigreed races of many species of Protozoa ever since it was emphasized by the work of E. Maupas in 1888 and 1889, and elaborated by G. N. Calkins in a series of investigations begun in 1902. In general these studies on ciliates indicated that at conjugation there is initiated a cycle of reproductive activity. Thus after conjugation the rate of division rises for a considerable number of generations and then gradually wanes until death ensues unless the line is "rejuvenated" again by conjugation. This conclusion, if generally true, is of fundamental significance. But other work by various investigators has not only demonstrated that many species of Protozoa, in which fertilization normally occurs, can live under favourable environmental conditions in pedigreed cultures for many years and thousands of generations—apparently indefinitely—when fertilization is excluded, but also has revealed that there are others in which fertilization evidently does not occur at all in the life history. Therefore it is clear that basically fertilization is not a necessary phenomenon to counteract a general inherent tendency to degeneration and death in the Protozoa; and this is in agreement with the apparently limitless vegetative propagation of many plants and the greatly extended life of body cells of higher animals when cultivated *in vitro*.

Granting that fertilization in the Protozoa is not intrinsically indispensable, extensive experiments nevertheless have shown, particularly in the ciliates *Uroleptus* and *Spathidium*, that when conjugation does occur it actually produces a stimulation of the cell, especially evident in its rate of reproduction. Accordingly the dynamic aspect of conjugation may be of crucial importance—indeed have a survival value—when the organisms are exposed to unfavourable conditions. And the same result probably follows self-fertilization (autogamy), and also endomixis which involves nuclear reorganization without synkaryon formation.

Regeneration.—The power of replacing portions of the cell and specific organelles not carried over at the time of binary fission is, of course, universal in the Protozoa, but nearly equally so is the capacity to regenerate parts lost by mutilations of various kinds at other times in the life of the organism. Both processes are basically similar, involving dedifferentiation, growth, differentiation and reorganization. The animal may retain and remodel

old structures, or discard and replace them in a great variety of ways. In some instances a very small amount of cytoplasm with a nucleus suffices for a complete restoration of form. Indeed, under favourable conditions in some of the ciliates, *e.g., Spathidium,* a complete individual capable of division may regenerate from a nucleated piece comprising less than 10% of the original volume of the individual, while much less than this amount may



FROM TURNER, "FERTILIZATION IN PROTOZOA," IN CALKINS AND SUMMERS, EDS., PROTOZOA IN BIOLOGICAL RESEARCH (COLUMBIA UNIV. PRESS)

FIG. 13.—GENERAL PLAN OF CONJUGATION IN CILIATES

1, two individuals joined ventrally, micronuclei in early mitosis; 2, first meiotic (equation) division; 3, second meiotic (reduction) division, macronucleus beginning to degenerate; 4, third division of one of the nuclei in each animal to form the gametic nuclei; 5, exchange of the male (♂) gametic nuclei; 6, fusion of gametic nuclei to form synkaryon and restore diploid condition; 7, conjugants separate, first division of synkaryon; 8, second division of synkaryon; 9, four nuclei produced by the two divisions of the synkaryon, the old macronucleus disintegrates; 10, two of the four nuclei develop into new micronuclei, two into new macronuclei; 11 and 12, first fission of the exconjugant distributes one micronucleus and one macronucleus to each daughter cell, re-establishing the vegetative condition.

suffice for restoration of form without the ability to reproduce. But many other factors besides size and the presence or absence of the nucleus influence the result; among them being the part of the cell involved, the relative amount of ectoplasm and endoplasm present, the phase in the life history, etc. Although a nucleus is necessary in all cases for complete regeneration followed by normal fission, enucleated fragments may survive many hours or until destructive metabolic processes gain ascendancy. In the ciliates either a micronucleus or part of the macronucleus must remain if complete regeneration and reproduction are to occur. Amicronucleate races which are commonly found in some species possess the same power of regeneration as do typical micronucleate individuals.

Behaviour.—All Protozoa, of course, respond to many environmental factors. The reception of stimuli occurs in general over the entire surface of the cell, but sometimes special receptors are also present. Apparently pseudopodia, flagella, cilia, cirri, etc., act as tactile organs and probably as chemical receptors, but the most specialized sensory structures are photoreceptors such as the stigma, or eye spot, of many chlorophyll-bearing flagellates, represented by the various species of *Euglena* and *Volvox.* In the latter the organelle consists of a cup of pigment surrounding a photosensitive substance, and a lenslike structure near the opening of the cup. Evidence indicates that the lens brings certain light waves to a focus on the photosensitive material. More remarkable still is the eyelike apparatus of certain Dinoflagellates which is provided with a large spherical lens.

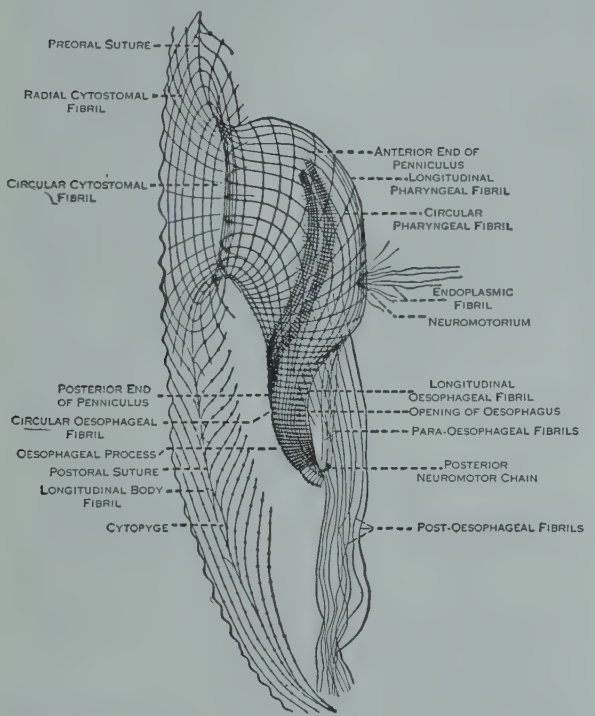
The effect of stimulation in most cases is conducted by the entire cell, but at least in certain ciliates, such as *Epidinium* (*Diplodinium*), *Euplotes* and *Paramecium,* a so-called neuromotor system of conducting fibres is found. This system is integrated with the general supporting ectoplasmic fibrillar network and specifically comprises a complex of fibres that ramify from a focus, or motorium, near the gullet and terminate at the basal bodies of the cilia or cirri. Experiments indicate that the system has a conductile function, because severance of the relationship of the fibres with the motor organs results in the loss of co-ordinated movement by the latter. (Fig. 14.)

Motor responses to particular agents are referred to as chemotaxis, thermotaxis, phototaxis, galvanotaxis, etc., in accordance with the nature of stimulus involved. Apparently in actively motile forms the reactions to stimuli are of two general but related types, one involving the trial and error method and the other directive action. In the former type of motor reaction an animal when stimulated stops and retreats, then turns at an angle to its previous course and proceeds again. And this avoiding reaction, or shock reaction, is repeated until, if possible, the animal is removed from the stimulating agent. In general, unfavourable stimuli induce responses whereas favourable ones do not, and accordingly the animals tend to collect where optimal conditions prevail; the reactions, though negative, are in the long run adaptive. In contrast to such responses, directive reactions are relatively rare and, indeed, intrinsically may involve shock reactions although the organism moves toward or away from the stimulus. They are best exhibited in the response of some chlorophyll-bearing flagellates to light, and of various species to electric currents. Changes in the intensity or direction of light rays so affect the stigma that by a series of responses the organism becomes oriented with its long axis parallel with the beam of light. If the anterior end of the cell is oriented toward the source of light, progression is in that direction. Such positive phototaxis is usual in the green flagellates, but is subject to modification by various factors, such as abrupt changes in the intensity of the light or the chemical condition of the environment; as indeed are all reactions of the Protozoa. Most Protozoa exhibit galvanotaxis by directive responses to the passage of an electric current. Amoebae extend pseudopodia toward the cathode and move in that direction. Flagellates usually proceed toward the anode and ciliates toward the cathode, largely as a result of the direct action of the current on the locomotor organs. Accordingly, when certain flagellates and ciliates are intermingled on a slide under the microscope, they can be separated by the passage of a constant current —anodically galvanotactic flagellates moving to one pole and cathodically galvanotactic ciliates to the other. Then if the current is reversed the two groups rush toward each other, pass and again assemble at opposite poles.

But the behaviour of the Protozoa is not so stereotyped as might appear from the relatively simple reactions just mentioned. In certain cases these may be integrated so that the animals exhibit potentialities beyond those of mere automata. This condition may be glimpsed if a ciliate, *Stentor roeseli,* while sessile is stimulated by a tiny stream of carmine grains. In general, when the useless carmine first reaches the peristome no reaction occurs, but as the carmine continues, the animal bends over to one side. If this behaviour does not remove the stimulus, the ciliary beat is temporarily reversed so that the carmine momentarily does not reach the oral apparatus. And, if the stimulus still continues, the organism contracts more or less violently and, finally, becomes detached and swims away. Furthermore, when a *Stentor* which has reached the contraction stage in the series of reactions is stimulated again within a few minutes, it does not run the gamut of responses but immediately contracts. Obviously a series of different physiological states has been initiated, since the animal

successively responds in a different manner to the same stimulus. Behaviour is modifiable.

Explosive Organelles.—Prominent among the various specialized organelles that contribute to the versatility of the protozoan cell are trichocysts and similar explosive structure. Trichocysts occur in many ciliates and have been most intensively studied in *Paramecium*, where they are quite evenly distributed



FROM LUND (UNIV. OF CALIF. PUBL. ZOOL., VOL. 39, P. 48, FIG. A)

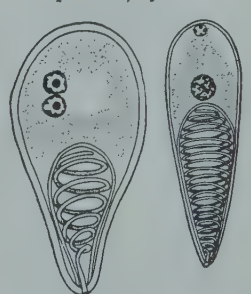
FIG. 14.—DIAGRAM OF THE NEUROMOTOR SYSTEM IN THE PERISTOMIAL REGION OF PARAMECIUM MULTIMICRONUCLEATUM. VERY HIGHLY MAGNIFIED

just beneath the surface of the cell. Each trichocyst is a minute, spindle-shaped body which, on mechanical or chemical stimulation, ejects material that instantaneously forms a relatively long filament projecting from the cell. The function of the threads has not been determined but probably is protective. Exploded trichocysts may be replaced by new ones. More complex trichocysts, called cnidotrichocysts, occur in other species, for example the ciliate *Prorodon*, where they consist of a capsule containing a coiled tube which on discharge is everted and apparently passes material to the exterior. Indeed in some species it is evident that toxic material is secreted because free-swimming prey is paralyzed upon contact with the oral region to which the trichocysts are confined. Cnidotrichocysts closely approach in structure the nematocysts of coelenterates, as is evidenced by the fact that especially complex examples found in two genera of dinoflagellates were formerly regarded as ingested nematocysts. Again, an immense group of the Sporozoa is known as the Cnidosporidia because the highly specialized spores are characterized by so-called polar capsules, each containing a spirally-wound thread that evaginates and apparently serves as an anchor when the proper position is attained in a new host. The diversity of structure and function of explosive organelles makes it obvious that they have evolved independently in different groups of Protozoa. (Fig. 15.)

Encystment.—Many species of Protozoa have the ability to seal themselves in essentially impermeable cases, or cysts, to meet various exigencies of the environment or to carry on digestion and reproduction. So-called protective cysts enable the organism to withstand desiccation, lack of food and other conditions inimical to active life and are most common in fresh-water and parasitic forms. The general procedure of encystment in free-living species, such as many ciliates, involves a complex series of events. The animal becomes quiescent while cilia, flagella, and other organelles not absolutely essential for life are resorbed, and food and inert material are ejected. Contractile vacuoles function more and more slowly and finally disappear as water is eliminated and the body becomes a relatively small sphere. While this dedifferentiation is proceeding, the cyst wall is secreted which commonly consists of an outer gelatinous layer, or ectocyst, and an inner delicate membrane, or endocyst, but there is great variation in composition and structure. The ectocyst rapidly hardens and frequently has characteristic spines, warts, etc. Within this resistant case the dormant animal, with all life processes reduced to a minimum, can survive unfavourable conditions for long periods of time. Thus cysts in samples of dry soils, tightly bottled, have yielded the ciliate *Colpoda* after 38 years, and small amoebae and flagellates after 49 years, when supplied with culture fluid; but the evidence indicates that most ciliates encysted on dry hay rarely survive more than five years. The process of excystment is broadly the reverse of encystment and is initiated by the presence of moisture or, if the cysts are already in water, by the return of favourable temperature, chemical conditions and the presence of food. The endocyst is dissolved by enzyme action induced by the animal, which thereupon ruptures the ectocyst and escapes to assume its typical form.

The world-wide distribution of many of the Protozoa is probably dependent to a large extent upon their ability to encyst, which enables them to be transported in numerous ways, such as by adhering to the feet of birds or to dry grass, and by being wafted by air currents. However, results obtained from the exposure of sterile culture media to the atmosphere indicates that only a relatively few species are usually disseminated in the air: chiefly tiny amoebae and flagellates and the ciliate *Colpoda*. And, incidentally, there is no completely satisfying evidence that the cosmopolitan *Paramecium* encysts, in spite of the prevalent notion that a culture can be established by the infusion of dry hay in sterile water.

In many parasitic forms, notably the Sporozoa, cysts are crucial in order that the parasite may weather the outside world during chance transfer to a new host. Indeed, the absence of protected stages during a parasite's life history usually indicates that it is directly transferred by an intermediate host. Many of the highly specialized protective cysts of parasites are also reproduction cysts because spore formation and other types of multiplication occur in them. Encystment in such cases does not involve a dedifferentiation of the animal but rather its specialization for the reproductive process. Furthermore, various free-living species encyst for reproduction, fertilization or simply to digest a heavy meal. In the life history of the foraminiferan *Patellina corrugata* growth cysts, fission cysts and fertilization cysts occur in sequence. Obviously, then, protozoan cysts serve such various functions, sometimes several simultaneously, that it is often impossible to distinguish sharply among the many types.



FROM CALKINS, "BIOLOGY OF THE PROTOZOA" (LEA & FEBIGER), AFTER KUDO

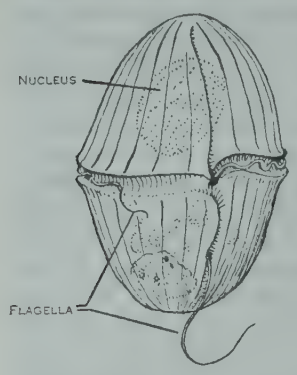
FIG. 15.—CNIDOSPORIDIAN SPORES WITH POLAR CAPSULES. VERY HIGHLY MAGNIFIED

DISTRIBUTION

Protozoa are essentially ubiquitous wherever moisture is available, but certain species are, of course, adapted to special habitats so that characteristic faunas develop. Excluding for the moment parasitic species that constitute highly specialized groups within nearly all higher animals and some plants, a few representative examples of marine and fresh-water faunas will serve as examples, but it must be borne in mind that each of these major

faunas is, in turn, formed of numerous relatively local faunal groups.

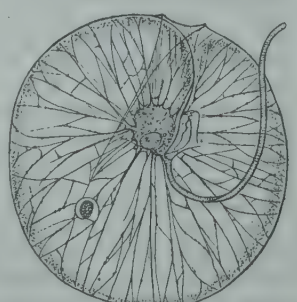
Among the flagellates the order Dinoflagellata stands pre-eminent in its contribution to the microscopic life of the sea. Typical dinoflagellates possess two flagella, usually lodged in grooves, one encircling the body and the other trailing posteriorly. Nutrition is commonly autotrophic through the presence of chromatophores, but many holozoic and parasitic species occur, and some of the zooxanthellae in the Radiolaria and Foraminifera are apparently symbiotic dinoflagellates. Although some species abound in fresh waters and are troublesome in municipal reservoirs, they are inconsequential in comparison with those constituting the marine fauna which plays an important part in the nutrition of oceanic life as a whole. This is chiefly because of photosynthetic activity that makes many species a first link in the nutritional chain and so an integral part of the so-called ocean pastures; but some species exist in such prodigious numbers that they directly constitute a significant part of the food of tiny invertebrates and so indirectly of higher animals. Vast areas of the sea may be discoloured by their presence; thus not infrequently the water appears orange like "tomato soup" from the presence of incalculable numbers of the cosmopolitan *Noctiluca miliaris*, and the same organism is responsible for much of the luminescence of marine waters. (Figs. 16, 17.)



FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)

FIG. 16.—A DINOFLAGELLATE, GYMNODINIUM SP. MAGNIFIED ABOUT 500 TIMES

The great contributions of the rhizopods to the microfauna of the sea are made by the Foraminifera and the Radiolaria. Most species of the former are bottom-dwellers that creep on the surface of the mud and ooze or attach themselves loosely to foreign material, but pelagic species are represented by enormous numbers of individuals. The shells, composed chiefly of calcium carbonate, sink to the bottom and contribute to the Globigerina ooze, so called because of the predominance of members of the Globigerinidae and closely related forms. This and similar deposits cover vast areas—perhaps one third of all the ocean floor down to approximately 5,000 yd.—and have been computed to be accumulating in certain regions at the rate of about 12 mm. in 1,000 years. At greater depths other species with arenaceous shells persist. Deposits during the geologic past are represented today by limestone, as seen in the chalk cliffs of England. Various types have rather definite geologic and geographic ranges and therefore are of significance in determining the age and characters of sediments and the general conditions under which they were laid down. Such knowledge is of great value in checking well-drillings and accordingly in locating oil-bearing strata. (Fig. 5.)



FROM PRATJE, "ARCHIV F. PROTISTENKUNDE" (FISCHER)

FIG. 17.—NOCTILUCA MILIARIS. MAGNIFIED ABOUT 50 TIMES

Although a few species of the Foraminifera inhabit fresh and brackish water, the Radiolaria are solely marine and adapted to a pelagic life. The body is typically spherical or conical and is usually supported by a silicious skeleton in a bewildering array of beautiful patterns. The distribution of the group as a whole is very extensive, both horizontally and vertically, and the skeletons accumulate in the great depths of the sea where calcareous shells of other forms become dissolved. Here in association with sponge spicules, diatom tests, and so on, they form the chief element of the Radiolarian ooze. And in the geologic past their skeletons have made large contributions to silicious rock. (Fig. 7.)

The ciliate fauna of ocean waters is by no means inconsequential, but it is not comparable in importance with those of the flagellates and rhizopods. Most typical is the wealth of marine species and individuals of the Tintinnidae, pelagic heterotrichous forms provided with vaselike protective cases consisting chiefly of a secreted organic material moulded into widely divergent but specific patterns.

As to the more varied conditions afforded by bodies of fresh water, it is impossible even to summarize the distribution of large groups of Protozoa in such broad terms. Members of the three free-living classes flourish everywhere in puddle, pond and lake, and some occur in hot springs and Arctic waters. Most of the common species abound in similar places the world over. Many species are remarkably adaptable, being equally at home in fresh or brackish water or even in the sea. Although this is true, very slight variations in conditions, particularly the type of available food and the chemical constituents of the environment, determine the presence or absence of certain species. For instance, *Paramecium* feeds chiefly on bacteria, and *Didinium* solely on *Paramecium*, so that depletion of the bacteria eventuates in the encystment of *Didinium*. This interdependence seems relatively clear-cut, but it involves various other factors not immediately apparent.

The practical impossibility of analyzing many of the elements involved in the "web of life," even in a relatively restricted environment, is well exhibited by the general development of an infusion of a few wisps of hay and water. Here the obvious components merely supply the matter and energy for the interplay of various micro-organisms present in a dormant or active state on the hay or in the water. A microscopical examination of a newly-made infusion shows very few active organisms, but if the temperature is favourable countless bacteria arise in a day or so from the relatively small number originally present. Then during the period of bacterial ascendancy another factor intrudes itself: microscopic animals, chiefly Protozoa that have been multiplying with increasing rapidity as conditions became more favourable, soon become the dominant life phase in the infusion. Usually first to appear are various species of minute flagellates, some saprozoic and others holozoic, that employ the products of organic disintegration supplied by the activity of the bacteria and the bacteria themselves. Then tiny ciliates, such as *Colpidium* and *Colpoda* appear in countless numbers and feed on the bacteria. This dominance of small ciliates is terminated after a time by the ascendancy of larger ciliates which, though feeding to some extent on the now greatly depleted bacterial population, employ chiefly the smaller Protozoa as food. And so the general nutritional cycle in the infusion continues with attendant chemical changes; saprozoic species are gradually replaced in dominance by herbivorous types, and these in turn by others that are carnivorous. But clearly this sequence of events must sooner or later terminate; extermination faces the population unless chlorophyll-bearing organisms are present to entrap and store the energy of sunlight—to form food photosynthetically. If such occurs, the hay infusion world is, indeed, a microcosm in which the various Protozoa and other organisms are reciprocally adjusted so that essentially a stable equilibrium results. (Fig. 11.)

Most free-living Protozoa find larger and relatively stable bodies of water conducive to their welfare, but specialized conditions do not always exclude them. Thus various species inhabit the fluid in the traps of carnivorous plants, such as the bladders of *Utricularia* and the pitchers of *Sarracenia*, and others flourish in the water in holes in trees. Most of these species are incidental sojourners but some apparently are especially adapted to the microclimatic factors in such unique environments. Indeed, the examination of blades of grass moist with dew usually reveals certain species making the most of a brief opportunity for activity before returning to the encysted state. And within the soil an immense fauna of Protozoa contributes to soil microbiology in association with bacteria and other fungi, algae, and various lower

animals. It appears that the majority of the Protozoa present are essentially cosmopolitan in distribution from the arctic regions to the tropics, though there are certain dominant types in nearly every soil. Most protozoan forms are found in the upper six inches of soil, but large numbers may be several feet below the surface. In general the number of species and individuals present is in direct proportion to the number of bacteria, being most numerous in rich, moist soils. Some idea of the size of the population may be gained from the fact that in one study it was estimated that at the maximum there were more than a million amoebae and flagellates per gram of soil. The view has been urged that the Protozoa may be inimical to soil fertility by destroying types of bacteria important for crop growth. This remains to be proved; but that the Protozoa form an important, active element in the soil microcosm is certainly true, even though many are in the encysted condition for considerable periods. Again here it seems clear that among the various species present some are mere casual inhabitants, while others constitute an endemic soil fauna. And in passing it should be noted that various Protozoa play a part in the so-called self-purification of streams by depleting the bacterial population, whereas others add to the contamination of municipal water supplies chiefly by liberating oily products of metabolism which impart odours to the water that may render it unpalatable. In brief, the adaptability of the Protozoa is so great that they have left hardly a niche in nature untenanted—not even in the bodies of other organisms.

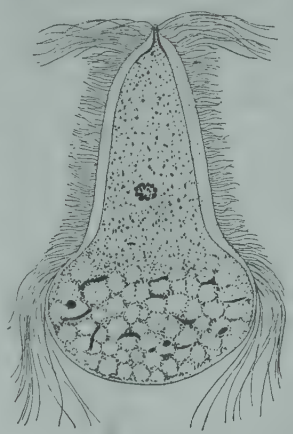
PARASITISM

The intimate association of Protozoa with other animals as commensals, symbionts, or parasites is widespread, but often it is difficult to distinguish between these types of relationship because one may grade into the other, or the same species may act in different capacities under varying conditions. Commensal associations incur no injury to either species involved, the protozoon merely gleaning food as a result of its position on the surface or in the interior of its host. Common ectocommensals among the ciliates are various vorticellids and suctorians attached to hydroids, and *Kerona* and *Trichodina* that crawl on *Hydra*. Endocommensals are more numerous, being widely distributed especially in the digestive tract of higher animals. Among them are most of the bizarre faunas of ciliates that inhabit the stomach or intestine of various herbivorous mammals, such as sheep, cattle and horses; and some of the flagellates and amoebae present in the human intestinal tract.

Symbiotic species, in which the relationship is mutually beneficial, are relatively few but include interesting examples. Thus the common *Paramecium bursaria* harbours unicellular green forms, or zoochlorellae, in its endoplasm where they multiply and, in return for a relatively safe abode and waste products of metabolism, supply the products of photosynthesis when light is available. Again an immense number of highly specialized flagellates, such as the various species of *Trichonympha* and their allies, dwell in the intestines of certain termites and wood-feeding roaches where they secrete enzymes that digest cellulose and thus make the products available to their hosts. If the flagellates are removed the insects die of starvation. And at least a few of the ciliates mentioned above that inhabit the digestive tract of cattle apparently perform a similar function, although here digestion of cellulose is dependent chiefly upon bacteria. Furthermore, in these and other cases where the protozoan fauna is enormous it may well be that it directly affords an appreciable increment to the nitrogenous food supply of the host. (Fig. 18.)

Associations in which one organism, the parasite, secures the sole advantage at the expense of the hapless host are by far the most numerous. As already mentioned, protozoan parasites have been found in nearly all higher animals that have been investigated, and they also occur in some plants. Even the Protozoa themselves are not immune. Thus a species of amoeba infests the endoplasm of certain opalinid ciliates which, in turn, live in the frog—an example of hyperparasitism.

The most intensively studied protozoan parasites are naturally those which produce serious maladies in man, in particular the malarial organisms, trypanosomes, and endamoebae. The human malarial parasites are members of a large group of the Sporozoa that are known as Haemosporidia because a part of the life history is spent in the blood of vertebrates. Very closely related to the malarial forms in man are those that parasitize birds, and their study has contributed largely to the knowledge of malaria in general. Four species of human malarial parasites had been recognized by 1945, three of them being outstanding in importance: *Plasmodium vivax,* the cause of so-called benign tertian malaria, *P. falciparum* of malignant tertian malaria, and *P. malariae* of quartan malaria. *P. ovale* also produces a benign type of tertian malaria. The life histories of all four species follow a similar general basic plan with a mosquito of the genus *Anopheles* as the invertebrate host. Asexual stages (sporozoites) inoculated by a mosquito into the human blood stream multiply in the red blood cells and probably also in the reticulo-endothelial tissues. Eventually gamete-forming stages (gametocytes) arise which demand transfer from the peripheral blood to a mosquito for further development. If this hazard is met, gametes develop and fertilization occurs in the stomach of the mosquito and then the motile zygote enters the stomach wall and forms a large oocyst within which myriads of sporozoites are formed. Rupturing of the oocyst releases the sporozoites into the body cavity from whence they reach the salivary glands of the mosquito, ready to be inoculated into man. (Fig. 4.)



FROM CALKINS, "BIOLOGY OF THE PROTOZOA" (LEA & FEBIGER), AFTER KOFOID & SWEZY

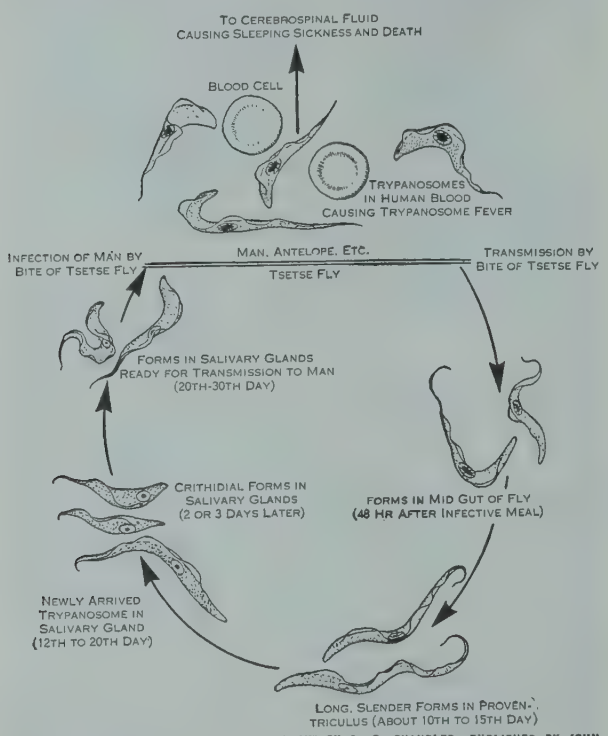
FIG. 18.—TRICHONYMPHA CAMPANULA. MAGNIFIED ABOUT 300 TIMES

The most important parasitic flagellates are members of the genus *Trypanosoma* that infest chiefly the blood stream of various vertebrates, including man, usually after a cycle of development in blood-sucking invertebrates. Trypanosomes show considerable change in form during the life history, but the typical "adult" phase found in the vertebrate circulatory system is an elongated bladelike organism, with the flagellum arising from a basal body near the posterior end of the animal and then passing forward as the edge of a delicate undulating membrane to emerge at the anterior end as a free flagellum.

The most important pathogenic forms in man are *Trypanosoma gambiensi,* the causative agent of typical African sleeping sickness, and *T. rhodesiensi,* which produces a similar but still more virulent effect. Both species are morphologically indistinguishable from each other and from *T. brucei,* which does not infect man but is the cause of "nagana" in domestic cattle of tropical Africa. All three are transmitted by tsetse flies and apparently are nonpathogenic in their natural reservoirs, certain antelopes and other wild mammals, and are essentially physiological races of one species. Another human trypanosome of high significance is *T. cruzi,* the cause of Chagas' disease, which is chiefly prevalent in Central and South America. The parasite is transmitted by triatomid bugs and multiplies in various organs of the human body. Most trypanosomes cause little disturbance in their natural hosts; for example, *T. theileri,* transmitted to cattle by tabinid flies and *T. lewisi,* to rats by fleas. The vectors of the trypanosomes of aquatic vertebrates are usually leeches, as in the case of *T. rotatorium* of the frog. (Fig. 19.)

Among the rhizopods that infest man the only true parasite is *Endamoeba histolytica,* formerly believed to be confined to tropical regions but now known to be cosmopolitan in distribution. The other five species are harmless commensals, although *E. gingivalis* of the mouth may take advantage of otherwise infected gums, and is apparently transmitted by contact because cysts are unknown. In the case of *E. histolytica,* encysted stages reach the

human intestine, usually in contaminated water or food, where excystment occurs, and the amoebae multiply in lesions they produce in the wall of the colon. In many cases no observable pathological symptoms follow while the amoebae produce a continuous supply of cysts which pass to the outer world, ready to infect another host. The evacuation by the host of more than 40,000 cysts in one day has been recorded. But sometimes this


TO CEREBROSPINAL FLUID
CAUSING SLEEPING SICKNESS AND DEATH
BLOOD CELL
TRYPANOSOMES IN HUMAN BLOOD
CAUSING TRYPANOSOME FEVER
INFECTION OF MAN BY BITE OF TSETSE FLY
MAN, ANTELOPE, ETC.
TSETSE FLY
TRANSMISSION BY BITE OF TSETSE FLY
FORMS IN SALIVARY GLANDS READY FOR TRANSMISSION TO MAN (20TH-30TH DAY)
CRITHIDIAL FORMS IN SALIVARY GLANDS (2 OR 3 DAYS LATER)
FORMS IN MID GUT OF FLY (48 HR AFTER INFECTIVE MEAL)
NEWLY ARRIVED TRYPANOSOME IN SALIVARY GLAND (12TH TO 20TH DAY)
LONG, SLENDER FORMS IN PROVENTRICULUS (ABOUT 10TH TO 15TH DAY)

ADAPTED BY PERMISSION FROM "PARASITOLOGY" BY A. C. CHANDLER, PUBLISHED BY JOHN WILEY & SONS, INC.

FIG. 19.—GENERAL SCHEME OF THE LIFE HISTORY OF TRYPANOSOMA GAMBIENSI

relatively innocuous host-parasite relationship does not prevail, either because of the particular sensitivity of the host or the special virulence of the race of amoeba involved. Then the latter become highly destructive parasites that produce serious lesions in the tissues of the colon, resulting in "amoebic dysentery." In addition the parasites pass to other organs of the body, most often forming abscesses in the liver. Incidentally, this procedure is equally unfortunate for the amoebae, since the progeny are rarely able to encyst and make a getaway to another host. (Fig. 20.)

TAXONOMY

Classification of the Protozoa offers especial difficulties, chiefly because all the variations occur within the confines of a single cell or a series of cells comprising a life cycle, whereas in other animal phyla the numerous characters of multicellular bodies combine to afford more easily discernible diagnostic features. Accordingly, taxonomic systems are to a considerable extent more tentative in the Protozoa than elsewhere in the animal kingdom. However, it is believed that the following brief classification approximates the consensus of opinion of protozoologists and will serve to give a synoptic view of the phylum. It must be emphasized, however, that the versatility of the Protozoa is so great that only the most salient characters of representative types can be cited.

PHYLUM PROTOZOA. Typically unicellular animals that stand in contrast with the rest of the animal kingdom, the multicellular animals, or Metazoa. Four classes are recognized:

Class I. MASTIGOPHORA or FLAGELLATA. The most primitive of the four great classes of Protozoa, comprising animals with one to many flagella in the principal phase of the life history. The typical form is ovate or elongate with a cortex which maintains a definite shape, but there is immense variation and some species are even temporarily amoeboid. Division is almost always longitudinal. Habitats and methods of nutrition are highly diverse; most species are free-living, but many are parasitic.

Subclass PHYTOMASTIGOPHORA. A large assemblage of the most primitive members of the class, some of which can, with reason, be classified as plants. Many species assume a so-called palmella phase in which the cells lose their flagella, round up, and secrete a gelatinous matrix in which they reproduce. Nutrition is usually autotrophic, but many species are saprozoic and some are holozoic at various phases of their life history. They are widely distributed in fresh and salt water.

Order *Chrysomonadida.* Usually small, simple forms, with one or two apical flagella, yellow or brown chromatophores, and often a red stigma. Many are remarkably protean, readily assuming amoeboid and palmella phases. In some species the palmella state is dominant. Nutrition is usually autotrophic, but may be saprozoic or holozoic. Coverings of cellulose and silica are common. So-called coccoliths, common in ocean sediments, are plates of calcium carbonate from the tests of one widely distributed family of this order. Unique silicious cysts are characteristic of the group. Representative genera are *Chromulina, Mallomonas,* and *Dinobryon,* the last usually colonial, and *Synura* and *Uroglena,* both colonial.

Order *Cryptomonadida.* Tiny flagellates with a relatively constant body form and one or two flagella, usually inserted at the anterior end of a furrow which in some species leads into a cytopharynx. Chromatophores may be yellow, brown, blue or green; but there are many colourless species that are either saprozoic or holozoic. Palmella stages occur. Some cryptomonads live as symbiotic zooxanthellae in other protozoons and in metazoons. Typical genera are *Cryptomonas* (with yellow chromatophores) and *Chilomonas* (colourless).

Order *Dinoflagellida.* A large but relatively circumscribed group; the characteristic type possesses two flagella, disposed in grooves, one of which forms a girdle while the other trails. Most species are provided with tests composed of one or numerous cellulose plates impregnated with inorganic material, but many are naked. Chromatophores are usually yellow or brown. Nutrition is autotrophic, saprozoic or holozoic. Departures from the typical body-plan are numerous, while symbiotic and parasitic species may lose all characteristic structure but form flagellated "dinospores." Representative genera are *Gymnodinium, Glenodinium, Peridinium, Ceratium* and *Blastodinium* (parasitic). The well-known *Noctiluca miliaris,* attaining about 1.5 mm. in diam., is an aberrant, floating, marine species with one small flagellum and a so-called tentacle. It was formerly assigned to a special group, the Cystoflagellata. (Figs. 16, 17.)

Order *Euglenida.* A wealth of common species, usually spindle-shaped, with one or two flagella emerging from a pit or pharynx into which a contractile vacuole discharges. A red stigma is present in the chlorophyll-bearing forms. Some species are very plastic and exhibit "euglenoid movements." Nutrition is autotrophic, saprozoic or holozoic. Encystment commonly occurs, and palmella phases are present in some species. Well-known genera include *Euglena* (green, one flagellum), *Astasia* (colourless, one flagellum), *Heteronema* and *Peranema* (colourless, two flagella). (Fig. 3.)

Order *Chloromonadida.* A largely artificial group comprising relatively rare and little-known species, usually with two flagella and small pale green chromatophores. Representative genera are *Gonyostomum* and *Vacuolaria.*

Order *Phytomonadida.* Typically small, ovate or spindle-shaped cells usually with two flagella, a red stigma and green chromatophores. Many of the phytomonads are colonial. Sexual reproduction is general with isogamous or anisogamous gametes. Common representatives of the noncolonial forms are the many species of *Chlamydomonas,* in a few of which haematochrome develops abundantly under certain conditions so that the organisms impart

a reddish tinge to melting snow, rain pools, etc. Some genera, such as *Polytoma,* comprise colourless, saprozoic forms. The family Volvocidae includes the highly interesting colonial types, represented, for example by various species of *Gonium, Pandorina, Eudorina, Pleodorina* and *Volvox.* The individual zooids are, in general, Chlamydomonas-like in form and vary in number from 4 in *Gonium* to many thousands in *Volvox.* (Fig. 12.)

FROM DOBELL, "THE AMOEBAE LIVING IN MAN" (WILLIAM WOOD & CO., 1919)

FIG. 20.—ENDAMOEBA HISTOLYTICA, SHOWING NUCLEUS AND THREE INGESTED RED BLOOD CELLS. MAGNIFIED VERY HIGHLY

Subclass Zoomastigophora. Flagellates without chlorophyll and unequivocally animal in nature, showing an immense structural range from simple to complex. Nutrition is holozoic or saprozoic. Many species are parasitic.

Order *Protomastigida.* Some of the simpler representatives, often referred to as monads, are tiny ovate forms, usually with one or two flagella, but with some amoeboid tendencies. Free, attached, and colonial species occur. Common genera include *Monas, Oicomonas* and *Anthophysa* (colonial). Members of the genus *Bodo,* with one flagellum directed anteriorly and the other trailing, are examples of somewhat more complex forms, usually possessing a cytostome, multiple basal bodies and a parabasal body near the flagellar insertion. In the genus *Cercomonas* the trailing flagellum passes along the cell surface and becomes free merely at the posterior end, whereas in *Cryptobia* (*Trypanoplasma*) it forms the edge of an undulating membrane so that these parasites superficially resemble Trypanosomes. In one group, the Choanoflagellates, the animals have a delicate cytoplasmic collar about the base of the single flagellum that aids in catching food. The remarkable similarity of these flagellates to the collar cells of sponges and the fact that a colonial representative, *Proterospongia,* forms a gelatinous mass with both collar and amoeboid zooids suggest a possible point of origin of the Porifera, or sponges.

But by far the most significant members of the Protomastigida from the standpoint of human welfare are members of the family Trypanosomidae which comprises a remarkable series of parasitic species. In general they are fusiform or bladelike cells with or without an undulating membrane connecting a part of the single flagellum with the cell surface, but all are highly polymorphic. Three genera, *Leptomonas, Phytomonas* and *Leishmania,* are very similar in the flagellate phase, with the flagellum arising from a kinetic complex at the anterior end. The leptomonads are confined to invertebrates and chiefly to insect hosts, but the phytomonads are transmitted by insects to the latex of certain plants and the leishmanias to vertebrates. In the vertebrate host leishmania loses the flagellum and rounds up as an intracellular parasite that gives rise to characteristic pathological symptoms; for example, one species produces in man the disease known as "kala azar," and another "Oriental sore." The members of the genera *Crithidia* and *Herpetomonas* are restricted to invertebrates and are similar in structure to the genera mentioned above, but with the flagellum arising further posteriorly and extending forward as the edge of a small undulating membrane. Finally, in the genus *Trypanosoma* the flagellum arises near the posterior end and proceeds forward as the edge of an extensive undulating membrane. Trypanosomes are blood-inhabiting parasites of man and other vertebrates, with an invertebrate, usually an insect or leech, as the intermediate host. The trend of evolution in the family is indicated by the progressive polymorphism exhibited by the several genera that reaches a climax in the trypanosomes whose life history recapitulates, as it were, the phases that are dominant in the other genera. (Fig. 19.)

Order *Polymastigida.* An assemblage of diverse forms usually with from three to eight flagella but sometimes with many. The majority of the species are parasites or commensals in the intestinal tract of animals. Among the simpler genera commonly represented by species in man are: *Trichomonas* with one nucleus and four anterior flagella and another flagellum which forms the edge of an undulating membrane; *Chilomastix,* with a single nucleus and four flagella, one of which undulates in a cytostomal cleft; and *Giardia,* with two nuclei and eight flagella arising from three parts of a bilaterally symmetrical body. It is not clear that any of the species are primarily pathogenic, though when present in large numbers they may aggravate abnormal conditions. The most complex polymastigotes live as commensals or symbionts in the intestine of termites and exhibit a reduplication of certain structures of the simpler species so that there may be many nuclei, each associated with several flagella, a parabasal body and other kinetic elements. Examples are *Calonympha* and *Stephanonympha.*

Order *Hypermastigida.* The acme of flagellate complexity is attained in this order, which includes a wealth of commensal and symbiotic forms chiefly in termites and cockroaches. They possess numerous flagella, either widely distributed or in tufts, and a multiplication of kinetic structures but only one nucleus. Regional differentiation of the cytoplasm is remarkable. The origin of the diversity and high specialization of the unique populations of hypermastigote and polymastigote flagellates in a restricted environment is of considerable evolutionary interest. Common examples are *Lophomonas blattarum,* found in domestic cockroaches, and various species of *Trichonympha,* present in termites and wood roaches. (Fig. 18.)

Order *Rhizomastigida.* A heterogeneous group of species that may almost equally well be included under the class Sarcodina because they are essentially amoebae with one or more permanent flagella. The best-known genus is *Mastigamoeba.*

Class Sarcodina or Rhizopoda. A huge assemblage of amoeboid animals formerly regarded as the most primitive class of the phylum. The chief general characteristic is the presence of pseudopodia for locomotion and obtaining food, though some temporarily develop flagella, and others produce flagellated gametes. Nutrition is usually holozoic.

Order *Amoebida.* The typical shell-less amoebae with pseudopodia varying from lobose to broad. Some of the simplest forms exhibit interchangeable amoeboid and flagellated phases. Among the larger fresh-water amoebae the best known is *Amoeba proteus* with lobose pseudopodia showing surface ridges, truncate bipyramidal crystals in the endoplasm, and a discoidal nucleus. Reproduction is apparently solely by binary fission. This species sometimes attains a length of more than 600 micra as it creeps along, but members of the genus *Pelomyxa* are very much larger and have many nuclei. One of the latter possibly was the amoeba observed by Rösel von Rosenhof as early as 1755 and named *Chaos chaos* by Linnaeus in 1767. In addition to the many free-living amoeba, large and small, there are numerous parasitic species, the one of outstanding importance being the widely distributed *Endamoeba histolytica,* the sole pathogenic amoeba inhabiting man. (Figs. 2, 20.)

Order *Testacea.* Amoebae with simple one-chambered tests of tectinous material in which foreign particles or secreted silicious plates are usually incorporated. The pseudopodia apparently consist solely of ectoplasm and are often threadlike. Reproduction is usually by the protrusion of a bud from the orifice of the test but, in certain cases, multiple division results in the liberation of many amoebulae that gradually assume the characters of the parent. Common representatives in fresh-water ponds and bogs are the many species of *Arcella* with yellowish, bowl-like tests, and *Difflugia* and *Euglypha* with pyriform tests. (Fig. 5.)

Order *Foraminifera.* An immense array of almost exclusively marine, shelled rhizopods of considerable importance. The shells may be tectinous, arenaceous, or silicious, but the majority are calcareous. They may consist of one or many chambers, and be imperforate or perforated by numerous tiny pores that afford, in addition to the mouth of the shell, exits for numerous fine branching and anastomosing pseudopodia. The multichambered (polythalamous) forms result from the addition to the initial chamber

of one new chamber after another and, in general, their shape and the spatial relations they assume determine the various types of shells as linear, spiral, etc. The life history typically involves an alternation of asexual and sexual generations with characteristic differences in the shells, nuclear apparatus, etc. The asexual generation produces amoeboid spores that develop into sexual individuals, while the latter give rise to amoeboid or flagellated gametes and the resulting zygotes develop into asexual individuals. Nearly 50 families had been recognized by 1945. Well-known genera include *Globigerina, Elphidium* (*Polystomella*), *Peneroplis, Patellina,* and *Camerina* (*Nummulites*), the last solely fossil. (Fig. 5.)

Order *Proteomyxa.* A relatively small heterogeneous assemblage of indefinite relationships, usually with raylike pseudopodia that frequently branch or tend to anastomose. Most species are parasites on the lower algae, such as *Spirogyra.* Representative genera include *Nuclearia, Arachnula* and *Vampyrella.*

Order *Mycetozoa.* An immense group sometimes classified among the Fungi as Myxomycetes, or "slime moulds," chiefly because, in the typical free-living species, specialized structures are developed for the production and dissemination of air-borne spores. Although this characteristic may be regarded with some assurance as an indication of convergence rather than of relationship with plants, the Mycetozoa are evidently a borderline group where formal classification is difficult or fails entirely. The most prominent phase in the life history consists of a multinucleate sheet of flowing protoplasm, the plasmodium, with great networks of anastomosing pseudopodia. Eventually spores are developed and these produce tiny amoeboid forms, each with a flagellum, that multiply and form gametes. The zygote is an amoeboid cell which increases in size by growth and union with other similar plasmodia, in some cases becoming several centimetres in diameter and containing thousands of nuclei. Nutrition is saprozoic and holozoic as the plasmodium creeps over decaying wood, leaves, etc. Common genera include *Lycogala, Physarum* and *Fuligo.* In addition to the typical Mycetozoa there are usually included in the group various forms which may be only distantly related because they exhibit wide departures in structure and life history. One of the most common is *Plasmodiophora brassicae,* an intracellular parasite which produces the disease known as clubroot in cabbages and closely related plants.

Order *Heliozoa.* A rather circumscribed group of typically spherical fresh-water forms with raylike axopodia. Protective coverings of gelatinous material, silicious spicules, etc., are often present. Most so-called sun animalcules are free-floating but some are sessile. Nutrition is holozoic. Common genera include *Actinophrys* (uninucleate) and *Actinosphaerium* (multinucleate). (Fig. 6.)

Order *Radiolaria.* An enormous assemblage of marine species adapted for pelagic life, including some of the largest Protozoa. Most are spherical and are provided with complex skeletons of remarkable and beautiful designs. The skeletons are usually silicious, but in one group they are apparently composed of strontium sulphate. The most highly characteristic feature is the definite segregation of the body into intracapsular and extracapsular regions by a perforated membrane, the central capsule. The intracapsular protoplasm is relatively homogeneous and includes from one to many nuclei, oil droplets, etc., while the extracapsular region is differentiated into several zones. The outermost consists largely of axopodia and myxopodia which have their origin within or just outside the central capsule in the surrounding "matrix" and traverse the broad "calymma": a gelatinous zone apparently secreted by the protoplasm and characterized by fluid-filled vacuoles that give the animal a frothy appearance. So-called yellow cells (zooxanthellae) are usually present in the calymma and in certain cases, at least, are modified dinoflagellates and chrysomonads living as symbionts or parasites. Reproduction by division includes the central capsule and, when possible, the skeleton. Multiple division of the nucleus and central capsule without division of the extracapsular protoplasm may give rise to temporary forms with several capsules, a condition that is permanent in some colonial species. Reproduction by tiny flagellated spores also occurs, but the formation of gametes remains to be proved. Representative genera are *Collozoum* (without a skeleton, colonial), *Thalassicolla* (without a skeleton), *Acanthometron* (with a skeleton). (Fig. 7.)

Class Sporozoa. A very large and heterogeneous assemblage of endoparasitic forms with hosts representing all animal phyla. Reproduction at some stage in the life history is by "spores," but these are not homologous throughout the class. In general, each species is limited to a specific host or to two hosts in each of which a part of the life history is spent. Transmission may be contaminative by resistant spores, or by inoculation of unprotected stages. Reproduction is usually by multiple fission (schizogony) followed by gamete formation and finally by sporulation (sporogony) to complete the life cycle. The alternation between the asexual and sexual phases is often associated with the change of hosts.

The class is sometimes divided into two subclasses, the Telosporidia and Neosporidia, with, in general, the following chief differences. In the former the production of spores terminates the life cycle, the sporozoites are vermicule in form, and the spores are without polar capsules; while in the latter, sporulation proceeds during the trophic phases of the life cycle, the sporozoites are amoeboid, and polar capsules are usually present in the spores. Though this division, suggested by Fritz Schaudinn in 1900, recognizes the natural assemblage of gregarines, coccidians and haemosporidians as Telosporidia, it fails to discriminate between the widely divergent forms included in the Neosporidia and, accordingly, it is customary to substitute for the latter group two subclasses: the Cnidosporidia with polar capsules, and the Acnidosporidia without such structures. But it is generally agreed that this is to some extent a temporary expedient awaiting further knowledge.

Subclass Telosporidia. The general characteristics are as stated above.

Order *Gregarinida.* A relatively homogeneous group of common parasites of invertebrates. For a brief period after the invasion of a host, development of the gregarine is intracellular, but most of the life history is extracellular with the parasites living in the intestine or various body cavities. Here the mature, worm-like forms (trophozoites) are either attached or move about by contortions of the body and by a characteristic gliding motion. Some gregarines are large enough to be readily visible to the naked eye. In general the body shows considerable differentiation and in some species is highly complex. In the cephaline type the body is divided into two parts (protomerite and deutomerite) by a transverse septum, and the protomerite itself may be capped by a special structure (epimerite) for attachment. The ectoplasm usually consists of several layers, including a region of myonemes which comprises both longitudinal and circular fibres, some of which may extend into the dense, granular endoplasm. Asexual reproduction by schizogony does not occur, the trophozoite proceeding directly to sexual phenomena and spore formation. The resistant spores usually pass from one host to another of the same species, but in some cases an alternate host is involved. Common examples of acephaline gregarines are the various species of *Monocystis* found in the seminal vesicles of earthworms. The more complex cephaline forms, chiefly inhabitants of the intestine of arthropods, are illustrated by members of the genus *Gregarina* that often parasitize meal beetles and cockroaches.

In addition to the eugregarines considered above, there is a small group of schizogregarines, so called because the life history includes a schizogonous cycle. The best known genera are *Ophryocystis* and *Schizocystis,* both with representative species that parasitize insects.

Order *Coccidia.* Intracellular parasites of many invertebrates and vertebrates, infesting chiefly the epithelial lining of the intestine and its derivatives, though some species invade the blood vascular system. The typical life history includes asexual multiplication by repeated schizogony followed by sexual phenomena and then sporogony involving the formation of resistant spores. Most members of the order are confined to a single host, but the

blood-dwelling haemogregarines alternate between the circulatory system and other organs of vertebrates and the intestine of invertebrates such as mites and leeches, and are without resistant spores. Representative coccidians are the various species of *Eimeria* that infest in particular mammals and birds, *Adelea ovata* living in centipedes, and *Haemogregarina stepanowi* alternating between turtles and leeches. *Isospora hominis* occurs rarely in man.

Order *Haemosporidia.* Intracellular coccidialike forms that typically undergo schizogony chiefly in the red blood cells and reticulo-endothelial tissue of vertebrates, and fertilization and sporogony in the digestive tract of blood-sucking arthropods, particularly insects. Resistant spores are not formed. The most important genus is *Plasmodium,* which comprises the malarial parasites of man carried by anopheline mosquitoes, as well as parasites of various lower vertebrates, including birds. Other representative genera are *Haemoproteus* and *Leucocytozoon,* transmitted especially to birds by biting flies. Differing somewhat from the typical haemosporidians are the piroplasms carried by ticks and often the cause of serious diseases in domestic mammals. Of especial interest is *Babesia* (*Piroplasma*) *bigemina,* the cause of Texas cattle fever. This was shown by the work of T. Smith and F. L. Kilborne in 1893, which was the first demonstration of the transmission of a protozoan parasite by an arthropod vector. Closely related to the various species of *Babesia* are members of the genus *Theileria,* such as *T. parva* that produces East Coast fever in African cattle. (Fig. 4.)

Subclass Cnidosporidia. An assemblage of species characterized by resistant spores with polar capsules. The products of the spores are amoeboid forms that start early in the life history to produce spores by internal budding. Accordingly an alternation of asexual and sexual cycles is absent, sexual phenomena occurring in the trophic stages. Species with intermediate hosts are unknown. (Fig. 15.)

Order *Myxosporidia.* Almost exclusively parasites of fishes, in which they sometimes cause severe epidemic disease. Some species develop as free forms in cavities, such as the gall and urinary bladders, while others are actual tissue parasites that produce more serious pathological effects. Common genera with many species, some infecting economically important fishes, are *Ceratomyxa, Myxidium* and *Myxobolus.*

Order *Actinomyxidia.* A small group of little-known species which inhabit the coelom and intestinal epithelium of aquatic annelids. The spores are usually triradiate and have three polar capsules. Representative genera are *Triactinomyxon* and *Hexactinomyxon.*

Order *Microsporidia.* Minute intracellular parasites that chiefly infest various tissues of arthropods and fishes. The best known species are *Nosema bombycis* of the silkworm moth and *N. apis* of bees, the former producing the pébrine disease of silkworms investigated by Louis Pasteur in 1865.

Subclass Acnidosporidia. A provisional group comprising little-known forms with simple spores lacking polar capsules.

Order *Sarcosporidia.* This order includes one important genus, *Sarcocystis,* with several species that infest the muscles of vertebrates, chiefly mammals, including mice, pigs, cattle and rarely man. The parasites form large "sarcocysts" in which crescentic spores are formed and produce a toxin that may prove fatal when injected into small mammals.

Order *Haplosporidia.* Largely an artificial assemblage of diverse forms, with affinities still to be determined, though certain species are probably closely related to the Microsporidia. They inhabit body cavities and tissues of invertebrates and lower vertebrates. Representative genera are *Haplosporidium,* present in aquatic annelids and mollusks, and *Ichthyosporidium* in fishes. A species of *Coelosporidium* occurs in cockroaches.

Class Ciliophora or Ciliata. An immense and clearly differentiated class, often called the Infusoria, characterized chiefly by the presence of cilia, and by two types of nuclei except in the subclass Protociliata. Division is typically transverse. Most species are monomorphic and are free-swimming in fresh and marine waters, though some are temporarily or permanently attached. Colony formation occurs.

Subclass Protociliata. A small subclass comprising the so-called opalinids which are endocommensals or parasites almost exclusively of frogs and toads. The body is uniformly coated with cilia but otherwise shows little similarity to other members of the class. The nuclei, from two to many in number, are not differentiated into micronuclei and macronuclei and there is no cytostome or contractile vacuole. Fertilization is by anisogamous gametes. Four genera are recognized: *Protoopalina, Zelleriella, Cepedea* and *Opalina.*

Subclass Euciliata. A very large subclass that includes all of the typical ciliates. Micronuclei and macronuclei are present and fertilization is by conjugation. Most species are free-living but some are commensals or parasites. The classification of this highly organized group of the Protozoa is based chiefly on the plan of distribution and the specialization of the cilia.

Order *Holotrichida.* The holotrichs are usually provided with unspecialized cilia, either over the entire surface or restricted to certain regions of the body. The best known genus is *Paramecium,* represented by about ten clearly-defined species, some of which are among the most widely studied animals. Among other common genera are *Chilodonella, Colpoda, Colpidium, Spathidium* and *Didinium.* Most holotrichs are free-living, but many are commensal or endoparasitic, including a unique group of astomatous species. *Ichthyopthirius multifilius* is an ectoparasite of fresh-water fishes which sometimes causes serious epidemics in aquaria. (Figs. 1, 11.)

Order *Spirotrichida.* Species with a complex adoral zone of cilia united to form membranelles, and usually an undulating membrane, in addition to other ciliation. Included are the *heterotrichous* forms with relatively short cilia over the rest of the body, represented, for example, by the various species of *Stentor, Spirostomum, Blepharisma, Bursaria* and *Balantidium;* the *oligotrichous* forms with general body ciliation reduced or wanting, as in the genera *Halteria, Tintinnidium,* and *Epidinium;* and finally the *hypotrichous* forms with markedly flattened bodies provided with cirri on the ventral surface for creeping, etc., including such common genera as *Oxytricha, Stylonychia* and *Euplotes.*

Order *Peritrichida.* Members of this order are typically bell-shaped and attached by a stalk, and accordingly are commonly called bell animalcules. Ciliation is practically restricted to the rim of the bell and peristome, and includes an adoral zone. Representatives are the many species of *Vorticella* and the closely related colonial genera *Epistylis, Zoothamnium* and *Carchesium.*

Order *Chonotrichida.* A very small group of ciliates superficially similar but clearly unrelated to the peritrichs. All live attached to aquatic arthropods. The common genus is *Spirochona.*

Subclass Suctoria. A unique but widely distributed group of fresh-water and marine species in which the cilia are confined to the young, free-swimming stages which arise as buds. The adults are typically sessile and are provided with tentacles by means of which they adhere to the prey and withdraw its contents. Many species live attached to the surface of aquatic organisms, usually as commensals but sometimes as parasites, while others are highly modified endoparasites. Some species infest *Paramecium* and other ciliates. Common genera are *Tokophrya, Acineta* and *Ephelota.* (Fig. 10.)

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(See Protophyta; Algae.)

(L. L. W.)

PROUD, JOSEPH (1745–1826), English clergyman, was born in Beaconsfield, Buckinghamshire on March 22, 1745. He served as minister of the general baptist congregation at Knipton,

Leicestershire beginning about 1772, and in 1775 accepted a similar position at Fleet, Lincolnshire, where he was ordained in 1780. In 1791 he was ordained minister in the "new church" and opened the Birmingham "temple" in the same year. He continued to preach in various churches in Manchester and London where his oratory attracted large audiences. He wrote nearly 300 hymns and published numerous books, some of which went through several editions. He died at Handsworth, near Birmingham on Aug. 3, 1826.

PROUD, ROBERT (1728–1813), U.S. educator and historian, was born near Yarm, Yorkshire on May 10, 1728. After attending a Friends' school he went to London in 1750 and continued his studies under the guidance of Dr. Fothergill. In 1759 he came to the United States and opened a boys' school in Philadelphia. In 1761 he became master of a Friends' school, a position he held until 1770, and later, from 1780 to 1790. His important work, *The History of Pennsylvania* (2 vols., 1797–98), contained much valuable material on the early history of the area. Proud died at Philadelphia on July 5, 1813.

PROUDHON, PIERRE JOSEPH (1809–1865), French socialist and political writer, was born on Jan. 15, 1809, at Besançon. He came of poor parents, and was mainly self-educated. At 19 he became a working compositor; and later, as a proofreader, he acquired a competent knowledge of theology and Hebrew, which he compared with Greek, Latin and French. On the strength of the knowledge acquired in this way he wrote an *Essai de grammaire générale*. In 1838 he obtained the *pension Suard*, a bursary of 1,500 francs a year for three years, for the encouragement of young men of promise, which was in the gift of the academy of Besançon.

In 1839 he wrote a treatise *L'Utilité de la célébration du dimanche* which contained the germs of his revolutionary ideas, and in the following year, after a short sojourn in Paris, he published *Qu'est-ce que la propriété?* His famous answer, "La propriété, c'est le vol" (property is theft), displeased the academy of Besançon, and there was some talk of withdrawing his *pension;* but he held it for the regular period. Proudhon's theory of property as the right of *aubaine* is substantially the same as the theory of capital held by Marx and most of the later socialists. Marx, however, always greatly detested Proudhon and his doctrines, and attacked him violently in his *Misère de la philosophie*. Property and capital are defined and treated by Proudhon as the power of exploiting the labour of other men, of claiming the results of labour without giving an equivalent. Proudhon's famous paradox, "La propriété, c'est le vol," is merely a trenchant expression of this general principle. As slavery is assassination inasmuch as it destroys all that is valuable and desirable in human personality, so property is theft inasmuch as it appropriates the value produced by the labour of others without rendering an equivalent. For property Proudhon would substitute individual possession, the right of occupation being equal for all men. For his third memoir on property, which took the shape of a letter to the Fourierist, Considérant, he was tried at Besançon but was acquitted. In 1846 he published his greatest work, the *Système des contradictions économiques ou philosophie de la misère*. In 1847 he settled in Paris, and in the following year gained notoriety during the revolution. He was the moving spirit of the *Représentant du peuple* and other journals of advanced views, and as member of assembly for the Seine department he proposed an impost of one-third on interest and rent, which was rejected. His attempt to found a bank which should operate by granting gratuitous credit was also a complete failure. For his violent speeches, Proudhon suffered three years of imprisonment at Paris. As Proudhon aimed at economic rather than political innovation, he accepted the second empire, and lived in comparative quiet until the publication of his work, *De la Justice dans la révolution et dans l'eglise* (1858), in which he attacked the church and other existing institutions. To escape imprisonment he fled to Brussels, returning later to France in broken health. He died at Passy on Jan. 16, 1865.

Personally Proudhon was one of the most remarkable figures of modern France. His life was marked by the severest simplicity; he was affectionate in his domestic relations, a loyal friend, and strictly upright in conduct. He opposed the prevailing French socialism; and, though an enemy of the dominant ideas and institutions, he was free from feelings of personal hate. In all that he said and did he was the son of the people, who had not been broken to the usual social and academic discipline; hence his roughness, his one-sidedness, and his exaggerations; but he is always vigorous, and often brilliant and original.

Although in his own words "the great part of his publications formed only a work of dissection and ventilation, so to speak, by means of which he slowly makes his way towards a superior conception of political and economic laws," yet the groundwork of his teaching is clear. He believed in the absolute truth of a few moral ideas, with which it was his aim to mould and suffuse political economy. Of these fundamental ideas, justice, liberty and equality were the chief. What he desiderated, for instance, in an ideal society was perfect equality of remuneration on the principle that the duration of labour is the just measure of value. He pursued this theory to its logical conclusion, but looked forward to a period in human development when the present inequality in the capacity of men would be reduced to an inappreciable minimum. From the principle of service as the equivalent of service is derived his axiom that property is the right of *aubaine, i.e.,* the right in virtue of which the sovereign, from the earliest monarchy, claimed the goods of an unnaturalized stranger who had died in his territory. Property is a right of the same nature, with a like power of appropriation in the form of rent, interest, etc. Proudhon's aim was to realize a science of society resting on principles of justice, liberty and equality thus understood; "a science absolute, rigorous, based on the nature of man and of his faculties, and on their mutual relations, a science which we have not to invent, but to discover." But he saw that such ideas could only be realized through a long process of social transformation. He attacked the schools of Saint-Simon and Fourier for thinking that society could be changed off-hand by a ready-made and complete scheme of reform.

In social change Proudhon distinguishes between the transition and the perfection of achievement. With regard to the transition he advocated the progressive abolition of the right of *aubaine,* by reducing interest, rent, etc., but he had no clear conception of the goal. The organization he desired was one on collective principles, a free association which would take account of the division of labour, and which would maintain the personality both of the man and the citizen. Connected with this was his famous paradox of *anarchy,* as the goal of the free development of society, by which he meant that through the ethical progress of men government should become unnecessary. "Government of man by man in every form," he says, "is oppression. The highest perfection of society is found in the union of order and *anarchy.*" Proudhon, indeed, was the first to use the word *anarchy,* not in its revolutionary sense, but to express the highest perfection of social organization.

A complete edition of Proudhon's works, including his posthumous writings, was published at Paris (1875). *See* also *P. J Proudhon, sa vie et sa correspondance,* by Sainte-Beuve (1875); Beauchéry, *Économie sociale de P. J. Proudhon* (Lille, 1867); Spoll, *P. J. Proudhon, étude biographique* (1867); Marchegay, *Silhouette de Proudhon* (1868); Putlitz, *P. J. Proudhon, sein Leben und seine positiven Ideen* (1881); Diehl, *P. J. Proudhon, seine Lehre und sein Leben* (Jena, 1888–89); Muelberger, *Studien über Proudhon* (Stuttgart, 1891); Desjardins, *P. J. Proudhon, sa vie, ses oeuvres et sa doctrine* (1896); Muelberger, *P. J. Proudhon* (Stuttgart, 1899).

PROUST, JOSEPH LOUIS (1754–1826), French chemist, was born on Sept. 26, 1754, at Angers, where his father was an apothecary. After beginning the study of chemistry in his father's shop he came to Paris and became apothecary in chief to the Salpetrière, also lecturing on chemistry at the *musée* of the aeronaut J. F. Pilâtre de Rozier, whom he accompanied in a balloon ascent in 1784. Next, he went to Spain, where he taught chemistry first at the artillery school of Segovia, and then at Salamanca, finally becoming in 1789 director of the royal laboratory at Madrid. In 1808 he lost both his position and his money by the fall of his patron (Charles IV), and retired first to Craon in Mayenne and then to Angers, where he died on July 5, 1826.

Proust's great contribution to chemistry was his establishment of the fundamental principle of the constant composition of many compounds. On this subject he maintained a long controversy with C. L. Berthollet, who was led by his doctrine of mass-action to deny that substances always combine in constant and definite proportions. Proust, on the other hand, maintained that compounds always contain definite quantities of their constituent elements, and that in cases where two or more elements unite to form more than one compound, the proportions in which they are present vary *per saltum*, not gradually. In 1799 he proved that copper carbonate, whether natural or artificial, always has the same composition, and later he showed that the two oxides of tin and the two sulphides of iron always contain the same relative weights of their components and that no intermediate indeterminate compounds exist. His analytical skill enabled him to demonstrate the inaccuracy of the researches by which Berthollet attempted to support the opposite view, and to show among other things that some of the compounds which Berthollet treated as oxides were in reality hydrates containing chemically combined water, and the upshot was that by 1808 he had fully vindicated his position. Proust also investigated the varieties of sugar that occur in sweet vegetable juices, distinguishing three kinds, and he showed that the sugar in grapes, of which he announced the existence to his classes at Madrid in 1799, is identical with that obtained from honey by the Russian chemist J. T. Lowitz (1757–1804).

Besides papers in scientific periodicals he published *Indagaciones sobre el estañada de cobre, la vajilla de estaño y el vidriado* (1803); *Mémoire sur le sucre de raisins* (1808); *Recueil des mémoires relatifs á la poudre à canon* (1815); and *Essai sur une des causes qui peuvent amener la formation du calcul* (1824).

PROUST, MARCEL (1871–1922), French man of letters, was born in Paris on July 10, 1871. His father was a professor of medicine, and his mother was of Jewish extraction. He was educated at the lycée Condorcet, and about 1892 he was for some time associated with Léon Blum, Louis Mirhlfeld and Tristan Bernard on the *Revue Blanche*, a periodical conducted by a select group of intellectuals, mostly Jewish. Becoming a favourite in the salons—especially those of Mme. de Caillavet and Madeleine Lemaire—he wrote a number of society love-stories (collected in 1896 under the title *Les plaisirs et les jours*) distinguished by their psychological subtlety. He also attained reputation as a clever writer of *pastiches*. He became an enthusiastic admirer of John Ruskin and translated several of his works into French, including the *Bible of Amiens*, to which he contributed a valuable preface.

In 1902 Proust's health began to fail. Thenceforward he was reluctantly obliged to lead an extremely retired and careful life, and for many years it looked as if he had altogether abandoned literature, in which his name hitherto had not been known outside a small circle of friends. He was reading and writing a great deal, however. The interminable discursiveness of Ruskin, which French readers do not suffer gladly, was to him a constant source of delight, and Saint-Simon, ever one of his favourite authors, exerted a powerful influence upon him at this time. Thus it came about that, having unlimited time at his disposal, he embarked upon a long and leisurely work, full of minute detail, in which was imprisoned, as in a net, his whole experience of life; in which the *salon* life he loved was revived in all its details and observances like the court life in Saint-Simon's memoirs; in which the people he had known provided the materials for new, fuller and richer characters (M. de Charlus, for example, is a blending of three different people of Proust's acquaintance), and in which the author sought out and lived the past over again. Hence the general title given to the 15 volumes of the series, *A la recherche du temps perdu* (1913, etc.).

This lengthy work had almost been completed when Proust published the first part, *Du côté de chez Swann*, in 1913. The freshness and minuteness of the recollections of childhood attracted some attention, but none the less Proust, who had had to publish the first part at his own expense, had difficulty in finding a publisher for the second, *L'ombre des jeunes filles en fleurs*. When it did appear its qualities were at once appreciated by Léon Daudet, whose enthusiastic articles, followed by the award of the Prix Goncourt in 1918, brought Proust's name prominently before the public, and he was read, discussed and criticised everywhere. Two more parts appeared during Proust's lifetime—*Le côté de Guermantes* and *Sodome et Gomorrhe*, both in 1921. When he died in Paris, Nov. 18, 1922, he left three parts still in manuscript—*La prisonnière*, published in 1924, *Albertine Disparue* (1926) and *Le temps retrouvé* (1926).

Proust's influence, especially since his death, has been considerable. He introduced into the novel an analytic method which has a superficial resemblance to that of Meredith, but is more properly comparable with that of Freud. That the name and notion of time should appear in the general title of his great work is not without significance. By a curious coincidence he was related by marriage to Bergson, the philosopher of "creative time," and the term "creative time" aptly describes the psychological time which Proust explores, seeks and recovers. His people are never given as "characters" in the fashion of La Bruyère or Balzac; they are always in process of development, change and continual creation.

Part of Proust's success was due to the very thing that is likely to tell against his lasting reputation, viz.: the fact that his characters, beginning with the "I" of the book, are exceptional, an erotic and mysterious group having little in common with the generality of mankind. This is true not only of *Sodome et Gomorrhe* and Proust's emphasis upon homosexuality, but also of the idle life and ultimate nothingness of the people of his world, their lack of all interests other than those of social life, and the indifference that the ordinary reader must always feel as to their fate. On the other hand, there will be a taste for Proust so long as there is a taste for psychology as an end in itself, and so long as the play of memory, the searching and brooding that pertain to the conquest of the past, afford to some men a sufficient reason for living or a romantic manner of not living. The following translations by C. K. Scott Moncrieff appeared in English: *Swann's Way* (1922); *Within a Budding Grove* (1924); *The Guermantes Way* (1925); *Cities of the Plain* (trans. of *Sodome et Gomorrhe*) (2 vols. 1927); *The Captive* (1929). (A. T.)

See Marcel Proust, an English tribute, collected by C. K. Scott Moncrieff (1923); Jacques Rivière, *Marcel Proust* (1924); L. Pierre-Quint, *Marcel Proust, sa vie, son oeuvre* (1925, Eng. trs. 1927); Benoist-Méchin, *La Musique et l'immortalité dans l'oeuvre de Marcel Proust* (1926); R. Dreyfus, *Marcel Proust à dix-sept ans* (1926), and *Souvenirs sur Marcel Proust* (1926); G. Gabory, *Essai sur Marcel Proust* (1926); *Marcel Proust*, by various writers, with bibliography (1926); P. Souday, *Marcel Proust* (1927); R. Fernandez, *Les Cahiers de Marcel Proust* (1927); and Clive Bell, *Proust* (1928). His *Lettres inédites* were published with a preface by Camille Vettard in 1926. *Chroniques*, a selection of his articles chiefly from *Le Figaro*, was edited by R. Proust (1927).

PROUSTITE, a mineral consisting of silver sulpharsenite, Ag_3AsS_3, known also as light red silver ore, and an important source of the metal. It is closely allied to the corresponding sulphantimonite, pyrargyrite, from which it was distinguished by the chemical analyses of J. L. Proust in 1804, after whom the mineral received its name. Many of the characters being so similar to those of pyrargyrite (*q.v.*) they are mentioned under that species. The colour is scarlet-vermilion and the lustre adamantine; crystals are transparent and very brilliant, but on exposure to light they soon become dull black and opaque. The streak is scarlet, the hardness 2·5, and the specific gravity 5·57. The mode of occurrence is the same as that of pyrargyrite, and the two minerals are sometimes found together. Magnificent groups of large crystals have been found at Chañarcillo in Chile; other localities which have yielded fine specimens are Freiberg and Marienberg in Saxony.

PROUT, SAMUEL (1783–1852), English water-colour painter, was born at Plymouth on Sept. 17, 1783. He spent whole summer days, in company with the ill-fated Haydon, in drawing the quiet cottages, rustic bridges and romantic water-mills of Devon. He made a journey through the Cornwall countryside for the purpose of furnishing sketches for Britton's *Beauties of Eng-*

land. After his removal in 1803 to London, which became his headquarters after 1812, a new scene of activity opened up before Prout. He now endeavoured to correct and improve his style by the study of the works of the rising school of landscape painters. To earn a living he painted marine pieces for Palser the printseller, received pupils and published many drawing books for art students. He was likewise one of the first who turned to account in his profession the newly-invented art of lithography. It was not however, until about 1818, when he visited the Continent and first saw the quaint streets and market-places of continental cities, that Prout discovered his proper sphere. All his faculties sprang into unwonted activity. His eye readily caught the picturesque features of the architecture, and his hand recorded them in drawings which were admirable in line, composition and colour. At the time of his death, on Feb. 10, 1852, there was scarcely a nook in France, Germany, Italy and the Netherlands which his quiet, benevolent, observant eye had not searched for antique gables and sculptured pieces of stone. In Venice especially there was hardly a pillar which his eye had not lovingly studied and his pencil had not dexterously copied.

See a memoir of Prout, by John Ruskin, in *Art Journal* for 1849, and the same author's *Notes on the Fine Art Society's Loan Collection of Drawings by Samuel Prout and William Hunt* (1879–80); *see* also the "Winter Number" of the *Studio* (1914–15), for reproductions of his sketches.

PROUT, WILLIAM (1785–1850), English chemist and physician, was born at Horton, Gloucestershire, on Jan. 15, 1785, and died in London on April 9, 1850. His life was spent as a practising physician in London, but he also occupied himself with chemical research. He was an active worker in physiological chemistry, and found in 1823 that the acid contents of the stomach contain hydrochloric acid which is separable by distillation. In 1815 he published anonymously in the *Annals of Philosophy* a paper in which he calculated that the atomic weights of a number of the elements are multiples of that of hydrogen; and in a second paper published in the same periodical the following year he suggested that the *πρώτη ὕλη* of the ancients is realized in hydrogen, from which the other elements are formed by some process of condensation or grouping. This view, generally known as "Prout's hypothesis," at least had the merit of stimulating inquiry, and many of the careful determinations of atomic weights undertaken since its promulgation have been provoked by the desire to test its validity. It is also particularly interesting in view of recent developments in the study of atomic structure (*see* Atom).

PROUTY, CHARLES AZRO (1853–1921), U.S. lawyer, was born in Newport, Vt. on Oct. 9, 1853. He graduated at Dartmouth college in 1875 and subsequently became principal of Newport academy. He was admitted to the bar in 1882 and practised law in Newport until 1896. In 1888 he was a member of the Vermont house of representatives and from 1888 to 1896 served as a reporter of decisions of the state supreme court. He was appointed to the U.S. Interstate Commerce commission in 1896, holding office until 1914 and serving as chairman in 1912–13. In 1914 he was made director of valuation for the commission and from 1918 to 1920 was director of public service and accounting in the U.S. Railroad administration. He died at Newport on July 8, 1921.

PROVENÇAL LANGUAGE AND LITERATURE. The term Provençal is employed in two different meanings. (1) *Lato sensu,* it embraces all idioms of Latin origin spoken in Southern France over a zone extending south of a line which starts at the mouth of the Gironde, passes through Bordeaux, Libourne, Mussidan, Péngueux, Nontron, Mouhet, Bellac, Limoges, Guéret, Chénérailles, Montluçon, Verneuil, Clermont-Ferrand, Saint-Bonnet-le-Château, Saint Sauveur-en-Rue, Gilhoc, Saint-Vallier, Romans, Die, Montmaur and finishes at Puy-Saint André. (2) *Stricto sensu,* it is applied to the idioms spoken in the Alpes-Maritimes, Basses-Alpes, Var and Bouches-du-Rhône departments. It was long customary to distinguish the dialects of Southern France by the names of the old provinces in which they occur, viz., Béarnais, Languedocien, Rouergat, etc. The classification now generally adopted is: (1) Gascon, (2) Provençal moyen and Provençal alpin (from Agen to Mentone), (3) Auvergnat and Limousin, (4) Catalan (*q.v.*).

With the 12th century arose a literary language used as a *κοινή* by the Troubadors. As some of the most celebrated of these poets, Bernard de Ventadour, Arnaud Daniel, Bertrand de Born and Jaucelm Faidit came from the Limousin, this *κοινή* was long known as *lengua lemosina;* a name, however, not to be misinterpreted. The literary language was not homogeneous, but composite.

The Troubadors conveyed this form of Provençal with them to Northern France, Italy, Spain and Portugal. When Languedoc passed to the House of France (1272) two languages, Latin almost exclusively and French to a very limited degree, were employed for administrative purposes. Minute examination of the documents contained in the archives of Southern France has recently proved that French exerted only inappreciable influence upon Provençal down to the close of mediaeval times. The Frenchification was not the outcome of a long, slow process. Indeed at the end of the Hundred Years' War, Provençal was still highly vigorous both in administrative and general use; it was then, from 1450 to 1600, very rapidly penetrated by French. First to yield was Northern Limousin; it was followed next by Périgord, Bordelais, Agenais, then Gascony, and finally by the Pyrenees which resisted until the last years of the 18th century. The initial period of this penetration may be placed about 1540 (*see* A. Brun, *Recherches historiques sur l'introduction du français dans les provinces du midi,* 1923). The various patois, continuing to be spoken by the middle class and peasantry developed freely. The new lease of life upon which the Southern idioms entered during the second half of the 19th century, must not be regarded as an unexpected accident. It had been prepared by the reawakening sense of nationality and promoted by the efforts of scholars, historians and men of letters, all of whom united in lauding the qualities of the ancient tongue and urging the Southerners to voice their native feelings and aspirations in their native "language." Among the leading representatives of the movement must be mentioned F. Mistral, not only on account of his literary masterpieces, especially his immortal *Mirèio* (1859), but also for his publication of *Lou Tresor d'ou Felibrige* (1878–86), the Provençal French dictionary which conferred *lettres de noblesse* on the new classical language of Provence, sprung from divers patois of the Bouches-du-Rhône. Provençal (including Catalan) is spoken by about 10,000,000 persons in France.

The Provençal dialects are less divergent from Latin than is the case with French. The following particulars will help to make clear what has been called "the archaic character" of Provençal and give, at the same time, a concise view of its special phonetic features.

I. Vowels

(*a*) Latin tonic free vowels: L. *amare,* Pr. *amar* (later *ama*), F. *amer* (later *aimer*). L. *pedem,* Pr. *pe,* F. *pie* (later spelt *pied*). L. *credere,* Pr. *crezer* (later *crese* in some parts), Bearnais *creder* (later *crede*); F. *croire* (later *croire*); L. *solum,* Pr. *sol,* Fr. *sueil* (later *seul*); L. *florem,* Pr. *flor,* F. *flour* (later *fleur*).

(*b*) Latin tonic free diphthong *au:* L. *aurum,* Pr. *aur,* F. *or.*

(*c*) Posttonic *a:* L. *clara,* Pr. *clara* (later *claro*), F. *clere* (later *claire*).

(*d*) Latin intertonic free *a:* L. *duramente,* Pr. *duramen,* F. *durement.*

II. Consonants

(*e*) Latin *C* and *G* before *A* were kept *C* and *G* in Provençal (except Limousin and Auvergne) and became *CH* (first pronounced TCH) and *J* (first pronounced DJ) in French (except Normanno-Picard dialect where they persisted as C and G, like Provençal): L. *caballum,* Pr. *Caval,* F. *cheval;* L. *gallina,* Pr. *Galina* (later *Galino*), F. *Geline.*

(*f*) Latin intervocalic *C:* L. *pacare,* Pr. *pagar* (later *paga*), F. *pager;* L. *securum,* Pr. *segur* (in part of Basses-Pyrénées

secur). Latin intervocalic *G:* L. *plaga*, Pr. *plaga* (later *plago*), F. *plaie;* L. *ruga*, Pr. *ruga* (later *rugo*), F. *rue*. Latin intervocalic *T:* L. *vita*, Pr. *vida* (later *vido*), F. *vie;* L. *quaternum*, Pr. *cazern*, F. *cahier*. Latin intervocalic *D:* L. *credere*, Pr. *crezer* (in part of Basses-Pyrénées *creder*), F. *croire* (later *croire*).

N.B. In some parts of Mod. Pr. there is a form *creire* which represents the state of evolution to be found in France until the 13th century. Latin intervocalic *DR, TR:* L. *quadratum*, Pr. *carat*, F. *carré*, L. *patrem*, Pr. *patre*, F. *père* (later *père*).

(*g*) In the group *S*+1 or 2 consonants, *s* has been kept in Provençal spelling and pronunciation; from French pronunciation it disappeared after the 13th century, although it was preserved in spelling until the middle of the 18th century (suppressed in the 3rd edition of the *Dictionnaire de l'Académie Française*, 1740); L. *scribere*, Pr. *escriure*, F. *escrire* (later *écrire*); L. *castellum*, Pr. *castel*, F. *chasteau* (later *château*).

(*h*) Among the final consonants let us quote *p, v, s,* Vulg. L. *capum* (cl L. *caput*), Pr. *cap* (a regression of *cat*—a form which is not attested in the documents at our disposal), F. *chief*; L. *brevem*, Pr. *brèu*, F. *bref*. Final *s* has been preserved both in spelling and pronunciation in the greatest part of Provençal; it disappeared from the pronunciation of French in the course of the 13th century. L. *causas*, Pr. *cauzas* (later *cauzos*), F. *choses*.

Among the Provençal dialects Gascon has quite peculiar features, the following three are most specially characteristic: (*a*) Change of Latin intervocalic *ll* to *r;* L. *appellare*, Gasc. *aperar* (later *apera*); (*b*) change of Latin final *ll* to *t:* L. *agenellum*, Gasc. *agnet;* (*c*) change of Latin *f* to aspirate *h:* L. *femina*, Gasc. *femna* till the end of the 13th century, then *hemna* (later *henno*).

Note that there are two other peculiar features (*d*) the pronunciation of *b* as in Spanish (*i.e.*, an intermediary sound between *b* and *v*); (*e*) the fall of Latin intervocalic *n* as in Portuguese: L. *gallina*, Gasc. *garia* (later *gario*). But (*d*) has gone beyond Gascony since the middle ages, and (*e*) is not to be found in Bordelais.

As general remarks on the morphology it may be pointed out that the declension of nouns and adjectives ceased to exist earlier than in French: the 13th century is the limit reached by the distinction between the two cases. In some parts like Béarn no trace of any declension at any time is to be found. In the conjugation we find (*a*) a past simple ending in—*ei* (like *cantei, cantest, cantet, cantem, cantetz, canteron; vendei, vendest*, etc.), most likely corresponding to L.—*ĕdi*—*ĕti*, as in *dedi steti*. (*e*) a remnant of Latin pluperfect ending in *aram* (contracted from *averam*), *iram* (contracted from *iveram*), *ederam*, e.g., *cantara* or *cantera, partira, vendera* used in the meaning of a conditional. There is a great similarity in the aspect of old and modern Provençal. The only important facts since the 15th century are (*a*) the change of final *a* into *o* (except in some parts where it has persisted as *a*, and in others where it became *e*, closer than in French).

(*i*) The great simplification of the conjugations, many verbs having passed to the—*ar* conjugation. (L. B.)

LITERATURE

Provençal literature is much more easily defined than the language in which it is expressed. Starting in the 11th and 12th centuries in several centres it thence gradually spread out, first over the greater portion, though not the whole of southern France, and then into the north of Italy and Spain. It never felt the influence of the neighbouring literatures. At the time of its highest development (12th century) the art of composing in the vulgar tongue did not exist, or was only beginning to exist, to the south of the Alps and the Pyrenees. In the north, in the country of French speech, vernacular poetry was in full bloom; but between the districts in which it had developed—Champagne, Ile de France, Picardy and Normandy—and the region in which Provençal literature had sprung up, there seems to have been an intermediate zone formed by Burgundy, Bourbonnais, Berry, Touraine and Anjou which, far on in the middle ages, appears to have remained almost barren of vernacular literature. In its rise Provençal literature stands completely by itself, and in its development it long continued to be absolutely original. It presents at several points genuine analogies with the sister-literature of northern France; but these analogies are due principally to certain primary elements common to both and only in a slight degree to mutual reaction.

It must be inquired, however, what amount of originality could belong to any, even the most original, Romanic literature in the middle ages. In all Romanic countries compositions in the vernacular began to appear while the custom of writing in Latin was still preserved by uninterrupted tradition. Even during the most barbarous periods, when intellectual life was at its lowest, it was in Latin that sermons, lives of saints more or less apocryphal, accounts of miracles designed to attract pilgrims to certain shines, monastic annals, legal documents, and contracts of all kinds were composed. When learning began to revive, as was the case in northern and central France under the influence of Charlemagne and later in the 11th century, it was Latin literature which naturally received increased attention, and the Latin language was more than ever employed in writing. Slowly and gradually the Romanic languages, especially those of France, came to occupy part of the ground formerly occupied by Latin, but even after the middle ages had passed away the parent tongue retained no small portions of its original empire. Consequently Romanic literatures in general (and this is especially true of Provençal, as it does not extend beyond the mediaeval period) afford only an incomplete representation of the intellectual development of each country. Those literatures even which are most truly national, as having been subjected to no external influence, are only to a limited extent capable of teaching us what the nation was. They were, in short, created in the interests of the illiterate part of the people, and to a considerable degree by men themselves almost devoid of literary learning. But that does not make them less interesting.

Origin.—It took poetic form; and its oldest monuments show a relative perfection and a variety from which it may be concluded that poetry had already received a considerable development. The oldest poetic text, of which the date and origin are not surely determined, is said to be a Provençal burden (Fr. *refrain*) attached to a Latin poem which has been published (*Zeitschrift fur deutsche Philologie*, 1881, p. 335) from a Vatican MS., written, it is asserted, in the 10th century. But it is useless to linger over these few words, the text of which seems corrupt, or at least has not yet been satisfactorily interpreted. The honour of being the oldest literary monument of the Provençal language must be assigned to a fragment of 257 decasyllabic verses preserved in an Orleans ms. and frequently edited and annotated since it was first printed by Raynouard in 1817 in his *Choix des poésies originales des troubadours*. The poem is consequently a didactic piece composed by a "clerk" knowing Latin. He doubtless preferred the poetic form to prose because his illiterate contemporaries were accustomed to poetry in the vulgar tongue, and because this form was better adapted to recitation; and thus his work, while a product of erudition in as far as it was an adaptation of a Latin treatise, shows that at the time when it was composed a vernacular poetry was in existence. The writing of the ms. is of the first half of the 11th century. The peculiarities of the language point to the north of the Provençal region, probably Limousin or Marche. It is the beginning of a poem in which the unknown author, taking Boethius's treatise *De consolatione philosophiae* as the groundwork of his composition, adopts and develops its ideas and gives them a Christian colouring of which there is no trace in the original. Thus from some verses in which Boethius contrasts his happy youth with his afflicted old age he draws a lengthy homily on the necessity of laying up from early years a treasure of good works. A little later, at the close of the same century, we have the poems of William IX, count of Poitiers, duke of Guienne. They consist of 11 very diverse strophic pieces, and were meant to be sung. Several are love songs; one relates a *bonne fortune* in very gross terms; and the most important of all—the only one which can

be approximately dated, being composed at the time when William was setting out for Spain to fight the Saracens (about 1119) —expresses in touching and often noble words the writer's regret for the frivolity of his past life and the apprehensions which oppressed him as he bade farewell, perhaps forever, to his country and his young son. We also know from Ordericus Vitalis that William IX had composed various poems on the incidents of his ill-fated expedition to the Holy Land in 1101. And it must further be mentioned that in one of his pieces (*Ben voil que sapchon li plusor*) he makes a very clear allusion to a kind of poetry which we know only by the specimens of later date, the *partimen,* or, as it is called in France, the *jeu parti.* William IX was born in 1071 and died in 1127. There is no doubt that the most prolific period of his literary activity was his youth. On the other hand there is no reason to believe that he created the type of poetry of which he is to us the oldest representative. It is easy to understand how his high social rank saved some of his productions from oblivion while the poems of his predecessors and contemporaries disappeared with the generations who heard and sang them. The contrast in form and subject between the Boethius poem and the stanzas of William IX is an indication that by the 11th century Provençal poetry was being rapidly developed in various directions. Whence came this poetry? How and by whose work was it formed? That it has no connection whatever with Latin poetry is generally admitted. The view which seems to meet with general acceptance, though it has not been distinctly formulated by any one, is that Romanic poetry sprang out of a popular poetry quietly holding its place from the Roman times, no specimen of which has survived—just as the Romanic languages are only continuations with local modifications of Vulgar Latin. There are both truth and error in this opinion. Romanic versification, as it appears in the Boethius poem and the verses of William IX, and a little farther north in the poem of the *Passion* and the *Life of St. Leger* (10th or 11th century), has with all its variety some general and permanent characteristics; it is rhymed, and it is composed of a definite number of syllables certain of which have the syllabic accent. This form has evident affinity with the rhythmic Latin versification, of which specimens exist from the close of the Roman empire in ecclesiastical poetry. The exact type of Romanic verse is not found in this ecclesiastical Latin poetry; the latter was not popular. However, it may be assumed that there was a popular rhythmic poetry from which Romanic verse is derived.

Again, as regards the substance, the poetic material, we find nothing in the earliest Provençal which is strictly popular. The extremely personal compositions of William IX have nothing in common with folklore. They are subjective poetry addressed to a very limited and probably rather aristocratic audience. The same may be said of the Boethius poem, though it belongs to the quite different species of edifying literature; at any rate it is not popular poetry. Vernacular compositions seem to have been at first produced for the amusement, or in the case of religious poetry, for the edification, of that part of lay society which had leisure and lands, and reckoned intellectual pastime among the good things of life. Gradually this class, intelligent, but with no Latin education, enlarged the circle of its ideas. In the 12th century, and still more in the 13th, historical works and popular treatises on contemporary science were composed for its use in the only language it understood; and vernacular literature continued gradually to develop partly on original lines and partly by borrowing from the literature of the "clerks." But in the 11th century vernacular poetry was still rather limited, and had hardly any higher object than the amusement or the edification of the upper classes. An aristocratic poetry, such as it appears in the oldest Provençal compositions, cannot be the production of shepherds and husbandmen; and there is no probability that it was invented or even very notably improved by William IX.

From what class of persons then did it proceed? Latin chroniclers of the middle ages mention as *ioculares, ioculatores,* men of a class not very highly esteemed whose profession consisted in amusing their audience either by what we still call jugglers' tricks, by exhibiting performing animals, or by recitation and song. They are called *joglars* in Provençal, *jonglers* or *jongleurs* in French; and they were the first authors of poetry in the vernacular both in the south and in the north of France. To the upper classes who welcomed them to their castles they supplied that sort of entertainment now sought at the theatre or in books of light literature. There were certain of them who, leaving buffoonery to the ruder and less intelligent members of the profession, devoted themselves to the composition of pieces intended for singing, and consequently in verse. In the north, where manners were not so refined and where the taste for warlike adventure prevailed, the jongleurs produced *chansons de geste* full of tales of battle and combat. In the courts of the southern nobles, where wealth was more abundant and a life of ease and pleasure was consequently indulged in, they produced love songs. There is probably a large amount of truth in the remark made by Dante in Ch. XXV of his *Vita nuova,* that the first to compose in the vulgar tongue did so because he wished to be understood by a lady who would have found it difficult to follow Latin verses. And in fact there are love songs among the pieces by William of Poetiers; and the same type preponderates among the compositions of the troubadours who came immediately after him. But it is worthy of note that in all this vast body of love poetry there is no epithalamium nor any address to a marriageable lady. The social conditions of the south of France in the feudal period explain in great measure the powerful development of this kind of poetry, and also its peculiar characteristics—the profound respect, the extreme deference of the poet towards the lady whom he addresses. Rich heiresses were married young, often when hardly out of their girlhood, and most frequently without their fancy being consulted. But they seem after marriage to have enjoyed great liberty. Eager for pleasure and greedy of praise, the fair ladies of the castle became the natural patronesses of the *mesnie* or household of men-at-arms and jongleurs whom their husbands maintained in their castles. Songs of love addressed to them soon became an accepted and almost conventional form of literature; and, as in social position the authors were generally far below those to whom they directed their amorous plaints, this kind of poetry was always distinguished by great reserve and an essentially respectful style. From the beginning the sentiments, real or assumed, of the poets are expressed in such a refined and guarded style that some historians, overestimating the virtue of the ladies of that time, have been misled to the belief that the love of the troubadour for the mistress of his thoughts was generally platonic and conventional.

The conditions under which Romanic poetry arose in the south of France being thus determined as accurately as the scarcity of documents allows, we now proceed to give a survey of the various forms of Provençal literature, chronological order being followed in each division. By this arrangement the wealth of each form will be better displayed; and, as it is rare for the same person to distinguish himself in more than one of them, there will be generally no occasion to introduce the same author in different sections. (*See* Edmond Faral, *Les Jongleurs en France au moyen âge,* Paris, 1910, and R. Menéndez Pidal, *Poesía juglaresca y juglares,* Madrid, 1924.)

Poetry of the Troubadours.—Centres of poetic activity are found first in Limousin and Gascony. In Limousin lived a viscount of Ventadour, Eble, who during the second part of William of Poitiers's life seems to have been brought into relation with him, and according to a contemporary historian, Geffrei, prior of Vigeois, *erat valde gratiosus in cantilenis.* We possess none of his compositions; but under his influence Bernart of Ventadour was trained to poetry. Bernart gained the love of the lady of Ventadour, and when on the discovery of their amour he had to depart elsewhere, received a gracious welcome from Eleanor of Guienne, consort (from 1152) of Henry II of England. Of Bernart's compositions we possess about 50 songs of elegant simplicity, some of which may be taken as the most perfect specimens of love poetry Provençal literature has ever produced. At the same period, or earlier, flourished Cercamon, a Gascon, who composed, says his old biographer, "pastorals" according to the ancient custom (*pastorelas a la uzansa antiga*). Among the earliest trouba-

dours is Marcabrun, a pupil of Cercamon's, from whose pen we have about 40 pieces, those which can be approximately dated ranging from 1135 to 1148 or thereabout. His songs, several of which are historical, are free from the commonplaces of their class, and contain curious strictures on the corruptions of the time.

We cannot here do more than enumerate the leading troubadours and briefly indicate in what conditions their poetry was developed and through what circumstances it fell into decay and finally disappeared: Peter of Auvergne (Peire d'Alvernha), who in certain respects must be classed with Marcabrun; Arnaut Daniel, remarkable for his complicated versification, the inventor of the *sestina*, a poetic form for which Dante and Petrarch express an admiration difficult for us to understand; Arnaut of Mareuil, who, while less famous than Arnaut Daniel, certainly surpasses him in elegant simplicity of form and delicacy of sentiment; Bertran de Born, now the most generally known of all the troubadours on account of the part he is said to have played both by his sword and his *sirventescs* in the struggle between Henry II of England and his rebel sons, though the importance of his part in the events of the time seems to have been greatly exaggerated; Peire Vidal of Toulouse, a poet of varied inspiration who grew rich with gifts bestowed on him by the greatest nobles of his time; Guiraut de Borneil, *lo maestre dels trobadors*, and at any rate master in the art of the so-called "close" style (*tobar clus*), though he has also left us some songs of charming simplicity; Gaucelm Faidit, from whom we have a touching lament (*planh*) on the death of Richard Coeur de Lion; Folquet of Marseilles, the most powerful thinker among the poets of the south, who from being a troubadour became first a monk, then an abbot, and finally bishop of Toulouse (d. 1231).

The troubadours could hardly expect to obtain a livelihood from any other quarter than the generosity of the great. It will consequently be well to mention the most important at least of those princes who are known to have been patrons and some of them practisers of the poetic art. They are arranged approximately in geographical order, and after each are inserted the names of those troubadours with whom they were connected.

France.—Eleanor of Guienne, Bernart de Ventadour (Ventadorn); Henry Curtmantle, son of Henry II of England, Bertran de Born (?); Richard Coeur de Lion, Arnaut Daniel, Piere Vidal, Folquet of Marseilles, Gaucelm Faidit; Ermengarde of Narbonne (1143–1192), Bernart de Ventadour, Peire Rogier, Peire d'Alvernha; Raimon V, count of Toulouse (1143–1194), Bernart de Ventadour, Peire Rogier, Peire Raimon, Hugh Brunet, Peire Vidal, Folquet of Marseilles, Bernart de Durfort; Raimon VI, count of Toulouse (1194–1222), Raimon de Miraval, Aimeric de Pegulhan, Aimeric de Belenoi, Ademar lo Negre; Alphonse II, count of Provence (1185–1209), Elias de Barjols; Raimon Berenger IV, count of Provence (1209–1245), Sordel; Barral, viscount of Marseilles (d. *c.* 1192), Peire Vidal, Folquet de Marseilles; William VIII, lord of Montpellier (1172–1204), Peire Raimon, Arnaut de Mareuil, Folquet de Marseilles, Guiraut de Calanson, Aimeric de Sarlat; Robert, dauphin of Auvergne (1169–1234), Peirol, Perdigon, Pierre de Maensac, Gaucelm Faidit; Guillaume du Baus, prince of Orange (1182–1218), Raimbaut de Vacqueiras, Perdigon; Savaric de Mauléon (1200–1230), Gaucelm de Puicibot, Hugh de Saint Circq; Blacatz, a Provençal noble (1200?–1236), Cadenet, Jean d'Aubusson, Sordel, Guillem Figueira; Henry I, count of Rodez (1208–1222?), Hugh de Saint Circq; perhaps Hugh IV, count of Rodez (1222?–1274) and Henry II, count of Rodez (1274–1302), Guiraut Riquier. Folquet de Lunel, Serverí de Girone, Bertran Carbonel; Nunyo Sanchez, count of Roussillon (d. 1241), Aimeric de Belenoi; Bernard IV, count of Astarac (1249–1291), Guiraut Riquier, Amanieu de Sescas.

Spain.—Alphonse II, king of Aragon (1162–1196), Peire Rogier, Peire Raimon, Peire Vidal, Cadenet, Guiraut de Cabreira, Elias de Barjols, the monk of Montaudon, Hugh Brunet; Peter II, king of Aragon (1196–1213), Raimon de Miraval, Aimeric de Pegulhan, Perdigon, Ademar lo Negre, Hugh of Saint Circq; James I, king of Aragon (1213–1276), Peire Cardinal, Bernart Sicart de Maruejols, Guiraut Riquier, At de Mons; Peter III king of Aragon (1276–1285), Paulet of Marseilles, Guiraut Riquier, Serveri de Girone; Alphonso IX, king of Leon (1138–1214), Peire Rogier, Guiraut de Borneil, Aimeric de Pegulhan, Hugh de Saint Circq; Alphonso X, king of Castile (1252–1284), Bertran de Lamanon, Bonifaci Calvo, Guiraut Riquier, Folquet de Lunel, Arnaut Plages, Bertran Carbonel.

Italy.—Boniface II, marquis of Montferrat (1192–1207), Peire Vidal, Raimbaut de Vacqueiras, Elias Cairel, Gaucelm Faidit (?); Frederick II, emperor (1215–1250), Jean d'Aubusson, Aimeric de Pegulhan, Guillem Figueira; Azzo VI, marquis of Este (1196–1212), Aimeric de Pegulhan, Rambertin de Buvalelli; Azzo VIII, marquis of Este (1215–1264), Aimeric de Pegulhan.

The first thing that strikes one in this list is that, while the troubadours find protectors in Spain and Italy, they do not seem to have been welcomed in French-speaking countries. This, however, must not be taken too absolutely. Provençal poetry was appreciated in the north of France. There is reason to believe that when Constance, daughter of one of the counts of Arles, was married in 998 to Robert, king of France, she brought along with her Provençal jongleurs. Poems by troubadours are quoted in the French romances of the beginning of the 13th century; some of them are transcribed in the old collections of French songs, and the preacher Robert de Sorbon informs us in a curious passage that one day a jongleur sang a poem by Folquet of Marseilles at the court of the king of France.

The decline and fall of troubadour poetry was mainly due to political causes. When about the beginning of the 13th century the Albigensian War had ruined a large number of the nobles and reduced to lasting poverty a part of the south of France, the profession of troubadour ceased to be lucrative. It was then that many of those poets went to spend their last days in the north of Spain and Italy, where Provençal poetry had for more than one generation been highly esteemed. Following their example, other poets who were not natives of the south of France began to compose in Provençal, and this fashion continued until, about the middle of the 13th century, they gradually abandoned the foreign tongue in northern Italy, and somewhat later in Catalonia, and took to singing the same airs in the local dialects. About the same time in the Provençal region the flame of poetry had died out save in a few places—Narbonne, Rodez, Foix and Astarac—where it kept burning feebly for a little longer. In the 14th century composition in the language of the country was still practised; but the productions of this period are mainly works for instruction and edification. As for the poetry of the troubadours, it was dead forever.

Form.—Originally the poems of the troubadours were intended to be sung. The poet usually composed the music as well as the words; and in several cases he owed his fame more to his musical than to his literary ability. Two manuscripts preserve specimens of the music of the troubadours, but, though the subject has been carefully investigated, we are not able to form a clear opinion of the originality and of the merits of these musical compositions. The following are the principal poetic forms which the troubadours employed. The oldest and most usual generic term is *vers*, by which is understood any composition intended to be sung, no matter what the subject. At the close of the 12th century it became customary to call all verse treating of love *canso*—the name *vers* being then more generally reserved for poems on other themes. The *sirventesc* differs from the *vers* and the *canso* only by its subject, being for the most part devoted to moral and political topics. The *tenson* is a debate between two interlocutors, each of whom has a stanza in turn. The *partimen* (Fr. *jeu parti*) is also a poetic debate, but it differs from the tenson in so far that the range of debate is limited. This poetic game is mentioned by William, count of Poitiers, at the end of the 11th century. The *pastoreta*, afterwards *pastorela*, is in general an account of the love adventures of a knight with a shepherdess. All these classes have one form capable of endless variations: five or more stanzas and one or two envois. The *dansa* and *balada*, intended to mark the time in dancing, are pieces with a refrain. The *alba*, which has also a refrain, is, as the name indicates, a waking or morning song

at the dawning of the day. All those classes are in stanzas. The *descort* is not thus divided, and consequently it must be set to music right through. Its name is derived from the fact that, its component parts not being equal, there is a kind of "discord" between them. It is generally reserved for themes of love. Other kinds of lyric poems, sometimes with nothing new about them except the name, were developed in the south of France; but those here mentioned are the more important.

Chansons de Geste and Historical Poems.—Northern France remains emphatically the native country of the *chanson de geste;* but, although in the south different social conditions, a more delicate taste, and a higher state of civilization prevented a similar profusion of tales of war and heroic deeds, Provençal literature has some highly important specimens of this class. The first place belongs to *Girart de Roussillon,* a poem of ten thousand lines, which relates the struggles of Charles Martel with his powerful vassal the Burgundian Gerard of Roussillon. The existing recension seems to have originated on the borders of Limousin and Poitou; but it is a recast of an older poem no longer extant, probably either of French or at least Burgundian origin. To Limousin also seems to belong the poem of *Aigar and Maurin* (end of the 12th century). Of less heroic character is the poem of *Daurel and Beton* (first half of the 13th century). Midway between legend and history may be classified the Provençal *Chanson of Antioch,* a mere fragment of which, 700 verses in extent, has been recovered in Madrid and published in *Archives de l'Orient latin,* vol. ii. This poem (*see* G. Paris, in *Romania,* xxii. 358), is one of the sources of the Spanish compilation *La gran conquista de Ultramar.* To history proper belongs the Chanson of the crusade against the Albigensians, which, in its present state, is composed of two poems one tacked to the other: the first, containing the events from the beginning of the crusade till 1213, is the work of a cleric named William of Tudela, a moderate supporter of the crusaders; the second, from 1213 to 1218, is by a vehement opponent of the enterprise. The language and style of the two parts are no less different than the opinions. Finally, about 1280, Guillaume Anelier, a native of Toulouse, composed, in the *chanson de geste* form, a poem on the war carried on in Navarre by the French in 1276 and 1277. It is an historical work of little literary merit. All these poems are in the form of *chansons de geste,* viz. in stanzas of indefinite length, with a single rhyme. *Gerard of Roussillon, Aigar and Maurin* and *Daurel and Beton* are in lines of ten, the others in lines of twelve syllables. The peculiarity of the versification in *Gerard* is that the pause in the line occurs after the sixth syllable, and not, as is usual, after the fourth.

Narrative Poems.—We possess but three Provençal romances of adventure: *Jaufré* (composed in the middle of the 13th century and dedicated to a king of Aragon, possibly James I.), *Blandin of Cornwall* and *Guillem de la Barra.* Connected with the romance of adventure is the novel (in Provençal *novas,* always in the plural), which is originally an account of an event "newly" happened. Some of those novels which have come down to us may be ranked with the most graceful works in Provençal literature; two are from the pen of the Catalan author Raimon Vidal de Besalú. One, the *Castia-gilos* (the chastisement of the jealous man), is a treatment, not easily matched for elegance, of a frequently-handled theme—the story of the husband who, in order to entrap his wife, takes the disguise of the lover whom she is expecting and receives with satisfaction blows intended, as he thinks, for him whose part he is playing; the other, *The Judgment of Love,* is the recital of a question of the law of love, departing considerably from the subjects usually treated in the novels. Mention may also be made of the novel of *The Parrot* by Arnaut de Carcassonne, in which the principal character is an eloquent parrot, who assists the amorous enterprises of his master. Novels came to be extended to the proportions of a long romance. *Flamenca,* which belongs to the novel type, has still over eight thousand lines, though the only ms. of it has lost some leaves both at the beginning and at the end. This poem, composed in all probability in 1234, is the story of a lady who by very ingenious devices, not unlike those employed in the *Miles gloriosus* of Plautus, eludes the vigilance of her jealous husband. No book in mediaeval literature betokens so much quickness of intellect or is so instructive in regard to the manners and usages of polite society in the 13th century. From the south of France the novel spread into Catalonia, where we find in the 14th century a number of novels in verse very similar to the Provençal ones, and into Italy, where in general the prose form has been adopted.

Didactic and Religious Poetry.—The more important works are: Daude de Prades (early 13th century), *Auzels cassadors,* one of the best sources for the study of falconry; a translation by Raimon d'Avignon (about A.D. 1200) of Rogier of Parme's "Surgery" (*Romania,* x. 63 and 496); the Boethius poem (unfortunately a mere fragment) already mentioned as one of the oldest documents of the language, and really a remarkable work; an early (12th century?) metrical translation of the famous *Disticha de moribus* of Dionysius Cato (*Romania,* xxv. 98 and xxix. 445). More original are some compositions of an educational character known under the name of *ensenhamenz,* and, in some respects, comparable to the English nurture-books. The most interesting are those of Garin le Brun (12th century), Arnaut de Mareuil, Arnaut Guilhem de Marsan, Amanieu de Sescas. Their general object is the education of ladies of rank. Of metrical lives of saints we possess about a dozen (see *Histoire littéraire de la France,* vol. xxxii.), among which two or three deserve a particular attention: the life of Sancta Fides (A. Thomas and E. Hoepffner's editions), written early in the 12th century; the life of St. Enimia (13th century), by Bertran of Marseilles (C. Brunel's edition) and that of St. Honorat of Lerins by Raimon Feraud (about 1300), which is distinguished by variety and elegance of versification, but it is almost entirely a translation from Latin. Lives of saints (St. Andrew, St. Thomas the Apostle, St. John the Evangelist) form a part of a poem, strictly didactic, which stands out by reason of its great extent (nearly 35,000 verses) and the somewhat original conception of its scheme—the *Breviari d'amor,* a vast encyclopaedia, on a theological basis, composed by the Minorite friar Matfre Ermengaut of Béziers ca. 1288–1300.

Drama.—The dramatic literature of southern France consists of mysteries and miracle plays seldom exceeding two or three thousand lines, which never developed into the enormous dramas of northern France, whose acting required several consecutive days. Generally those plays belong to the 15th century or to the 16th. Still, a few are more ancient and may be ascribed to the 14th century or even to the end of the 13th. The oldest appears to be the *Mystery of St. Agnes* (edited by Bartsch, 1869), written in Arles. Somewhat more recent, but not later than the beginning of the 14th century, is a Passion of Christ (not yet printed) and a mystery of the Marriage of the Virgin, which is partly adapted from a French poem of the 13th century (see *Romania* xvi. 71). A manuscript, discovered in private archives (printed by Jeanroy and Teulié, 1893), contains not less than 16 short mysteries, three founded on the Old Testament, 13 on the New. They were written in Rouergue and are partly imitated from French mysteries. At Manosque (Basses Alpes) was found a fragment of a *Ludus sancti Jacobi,* inserted in a register of notarial deeds (printed by C. Arnaud, Marseilles, 1858). The region comprised between the Rhone and the Var seems to have been particularly fond of representations of this sort, to judge by the entries in the local records (see *Romania* xxvii. 400). At the close of the 15th and the beginning of the 16th centuries many mysteries were played in that part of Dauphiné which corresponds to the present department of Hautes-Alpes. Five mysteries of this district, composed and played somewhere about 1500 (the mysteries of St. Eustace, of St. Andrew, of St. Pons, of SS. Peter and Paul and of St. Anthony of Vienne), have come down to us, and have been edited by Abbé Fazy (1883), the four others by Canon P. Guillaume (1883–1888). The influence of the contemporary French sacred drama may to some extent be traced in them.

Prose.—In the 12th century we find in Languedoc sermons, whose importance is more linguistic than literary (*Sermons du XII^e siècle en vieux provençal,* ed. by F. Armitage, Heilbronn, 1884). About the same time, in Limousin, were translated chapters xiii.–xvii. of St. John's Gospel (Bartsch, *Chrestomathie provençale*). Various translations of the New Testament and of some

parts of the Old have been done in Languedoc and Provence during the 13th and 14th centuries (*see* S. Berger, "Les Bibles provençales et vaudoises," *Romania* xviii. 353; and "Nouvelles recherches sur les Bibles provençales et catalanes," *ibid.* xix. 505). The Provençal prose rendering of some lives of saints made in the early part of the 13th century (*Revue des langues romanes,* 1890) is more interesting from a purely linguistic than from a literary point of view. To the 13th century belong certain lives of the troubadours intended to be prefixed to, and to explain their poems. Many of them were written before 1250, when the first anthologies of troubadour poetry were compiled; and some are the work of the troubadour Hugh of Saint Circq. Some were composed in the north of Italy, at a time when the troubadours found more favour east of the Alps, than in their own country. Considered as historical documents these biographies are of a very doubtful value. To the same period must be assigned *Las Razos de trobar* of the troubadour Raimon Vidal de Besalú (an elegant little treatise touching on various points of grammar and the poetic art), the *Donatz proensals* of Hugh Faidit, and the *Life of St. Douceline,* who died in 1274, near Marseilles, and founded an order of Béguines.

The leading prose-work of this period is the treatise on grammar, poetry and rhetoric known by the name of *Leys d'amors.* (*See* J. Anglade, *Las leys d'amors,* 4 vol., *Toulouse,* 1919–1920.) The *Leys d'amors* (composed in Toulouse circa 1350) was to be the starting-point and rule of the new poetry; it is the best production of this abortive renaissance. The decay of Provençal literature, caused by political circumstances, arrived too soon to allow of a full development of prose. This accounts, in some measure for the complete absence of historical compositions. The 14th and 15th centuries were in no respect a prosperous period for literature in the south of France. In the 15th century people began to write French both in verse and prose; and from that time Provençal literature became a thing of the past. From the 16th century such poetry as is written in the vernacular of southern France is generally dependent on French influence. The connection with ancient Provençal literature is entirely broken.

See Joseph Anglade, *Les Troubadours,* Paris, 1908; and *Histoire sommaire de la littérature méridionale au moyen âge.* Both volumes contain a bibliography. Documents and dissertations on various points of Provençal literature will be found in almost all the volumes of *Romania* (Paris, in progress since 1872, 8vo), and the *Revue des langues romanes* (Montpellier, in progress since 1870, 8vo). *See* also the other journals devoted to the Romanic languages, *passim.*

(X., L. B.)

MODERN PROVENÇAL LITERATURE[1]

Provençal literature never died out entirely. The Academy of Toulouse, founded in 1324, was flourishing in the 14th century, and, after many vicissitudes, is flourishing still. The poets crowned by this body between 1324 and 1498 stand in the same relation to the troubadours as the *Meistersinger* do to the *Minnesänger:* academic correctness takes the place of inspiration. The institution flourished, even to the extent of establishing branches in Catalonia and Majorca; and in 1484, when its prosperity was threatened, a semi-fabulous person, Clémence Isaure, is said to have brought about a revival by instituting fresh prizes. The town of Toulouse never ceased to supply funds of some kind. In 1513 French poems were first admitted in the competitions, and under Louis XIV. (from 1679) these were alone held eligible. This arrangement held good till 1893, when the town very properly transferred its patronage to a new *Escolo moundino,* but very soon restored its support to the older institution, on learning that Provençal poetry was again to be encouraged. In the two centuries that followed the glorious mediaeval period we have a succession of works, chiefly of a didactic and edifying character, which served to keep alive some kind of literary tradition. Religious mystery plays, which, though dull to us, probably gave keen enjoyment to the people, represent a more popular genre; the latest that have come down to us may be placed between the years 1450–1515.

[1] In accordance with general usage, we are employing the term Provençal for the whole of the south of France, save where special reservation is made.

In the 16th century there are signs of a revival and we may single out the following: the Gaston Pey de Garros who translated in 1565 the psalms into his dialect, and two years later published a volume of poems; Auger Gaillard (*c.* 1530–1595); du Bartas (in his trilingual *Salut,* 1579); Louis Bellaud de la Bellaudière (1532–1588).

Post-Renaissance.—Later on come: Claude Brueys (1570–1650), remarkable chiefly for comedies that deal largely with duped husbands (*Jardin deys musos provensalos,* not published till 1628); Gaspard Zerbin (*La Perlo deys musos et coumedies prouvensalos,* 1655). The most consistently popular form of poetry in the south of France was always the *noël.* Nicholas Saboly (1614–1675), produced the best pieces of this class. In Languedoc four poets are cited as the best of the age—Goudelin, Michel, Sage and Bonnet. This is certainly so in the case of Pierre Goudelin (Goudouli, 1579–1649), of Toulouse, the most distinguished name in south French literature between the period of the troubadours and that of Jasmin. Goudelin essayed and was successful in almost every short genre (*Lou Ramelet Moundi,* 1617, republished with additions till 1678), the piece of his which is most generally admired being the stanzas to Henri IV. Other writers worth mentioning in the 17th century are: Jean Michel, of Nîmes; Daniel Sage, of Montpellier (*Las Foulies,* 1650); the *avocat* Bonnet, author of the best among the open air plays that were annually performed at Béziers on Ascension day: a number of these (dated 1616–1657) were subsequently collected, but none can compare with the opening one, Bonnet's *Jugement de Pâris;* Nicolas Fizes, of Frontignan, whose vaudeville, the *Opéra de Frontignan* (1670), dealing with a slight love intrigue, and an idyllic poem on the fountain of Frontignan, show a real poetic gift. A number of Toulouse poets, mostly *lauréats* of the Academy, may be termed followers of Goudelin: of these François Boudet, who composed an ode, *Le Trinfe del Moundi* (1678), in honour of his native dialect deserves mention. The classical revival that may be noted about this time is also generally ascribed to Goudelin's influence. Its most distinguished representative was Jean de Valès, of Montech, who made excellent translations from Virgil and Persius, and wrote a brilliant burlesque of the former in the manner of Scarron (*Virgile deguisat,* 1648).

The best of the pastoral poets was François de Cortete (1571–1655), of Prades, whose comedies, *Ramounet* and *Miramoundo* (published, unfortunately with alterations, by his son in 1684), are written with such true feeling and in so pure a style that they can be read with real pleasure. A comedy of his dealing with Sancho Panza in the palace of the Duke has been edited. Daubasse (1664–1727), of Quercy, who belonged to the working classes, was patronized by the nobility in exchange for panegyrics. Gascony produced two typical works in the 17th century: Ader's *Gentilhomme gascoun* (1610) and G. d'Astros's *Trinfe de la lengo gascouo* (1642). Gabriel Bedout (*Parterre gascoun,* 1642) is chiefly noted for his amorous *solitari.* Louis Baron (b. 1612), celebrated with great tenderness his native village of Pouyloubrin.

In the 18th century the number of authors is much larger, but the bulk of good work produced is not equally great in proportion. The priests are mainly responsible for the literary output of Languedoc. The chief of the band is the Abbé Favre (1727–1783), the prior of Celleneuve, whose *Ou sermoun de Moussu Sistre* delivered a drunken priest against intemperance, is a masterpiece. He also wrote a successful mock-heroic poem (*Siège de Caderouss*) travesties of Homer and Virgil, a prose novel depicting the country manners of the time (*Histouèro de Jean-l'an-prés*), and two comedies, which likewise give a vivid picture of the village life he knew so well. Two genuine poets are the brothers Rigaud of Montpellier: Auguste's (1760–1835) description of a vintage is deservedly famous; and Cyrille (1750–1824) produced an equally delightful poem in the *Amours de Mounpëié.* Pierre Hellies of Toulouse (d. 1724) a poet of the people, whose vicious life finds an echo in his works, has a certain rude charm, at times distantly recalling Villon. In Provence Toussaint Gros (1698–1748), of Lyons, holds undisputed sway. His style and language are admirable, but unfortunately he wasted his gifts largely on trivial *pièces d' occasion.* Coye's (1711–1777) comedy, *ou Novy*

para, is bright and still popular, while Germain's description of a visit paid by the ancient gods to Marseilles (*Bourrido dei Dious,* 1760) has considerable humour. In Gascony the greatest poet is Cyrien Despourrins (1698–1755).

The 19th Century.—The Revolution produced a large body of literature, but nothing of lasting interest. Scholars like Raynouard (1761–1863), of Aix, occupied themselves with the brilliant literary traditions of the middle ages; newspapers sprang up (the Provençal *Boüil-Abaisso,* started by Désanat, and the bilingual *Lou Tambourin et le menestrel,* edited by Bellot, both in 1841); poets banded together and collected their pieces in volume form (thus, the nine *troubaire* who published *Lou Bouquet prouvençaou* in 1823). Much has been written about the *précurseurs de Félibrige,* and critics are sorely at variance as to the writers that most deserve this appellation. We shall not go far wrong if we include in the list Hyacinthe Morel (1756–1829), Louis Aubanel (1758–1842); Auguste Tandon, "the troubadour of Montpellier"; Fabre d'Olivet (1767–1825); Diouloufet (1771–1840); Jacques Azaïs (1778–1856); D'Astros (1780–1863), Castil-Blaze (1784–1857); the Marquis de Fare-Alais (1791–1846). While these writers were all more or less academic, and appealed to the cultured few, four poets of the people addressed a far wider public: Verdié (1779–1820), of Bordeaux, who wrote comic and satirical pieces; Jean Reboul (1796–1864), the baker of Nîmes, who never surpassed his first effort, *L'Ange et l'enfant* (1828); Victor Gelu (1806–1885), relentless and brutal, but undeniably powerful of his kind (*Fenian et Grouman; dix chansons provençales,* 1840); and, greatest of them all, the true and acknowledged forerunner of the *félibres,* Jacques Jasmin (*q.v.*).

Roumanille and Mistral.—In 1845 Joseph Roumanille (1818–1891) of Saint-Remy became usher in a small school at Avignon, which was attended by Frédéric Mistral (*q.v.*). Roumanille had composed some pieces in French; but, finding that his old mother could not understand them, he determined thenceforth to write in his native dialect only. These poems revealed a new world to young Mistral, and spurred him on to the resolve that became the one purpose of his life—*de remettre en lumière et conscience de sa gloire cette noble race qu'en plein '89 Mirabeau nomme encore la nation provençale.* There is no doubt that Mistral's is the more puissant personality, and that his finest work towers above that of his fellows; but in studying the Provençal renaissance, Roumanille's great claims should not be overlooked, and they have never been put forward with more force than by Mistral himself (in the preface of his *Isclos d'oro*). Roumanille's secular verse cannot fail to appeal to every lover of pure and sincere poetry (*Li Margaritedo,* 1836–1847; *Li Sounjarello,* 1852; *Li Flour de Sauvi,* 1850–1859, etc.), his *noëls* are second only to those of Saboly, his prose works (such as *Lou mege de Cucugnan,* 1863) sparkling with delightful humour. He it was who in 1852 collected and published *Li Prouvençalo,* an anthology in which all the names yet to become famous, and most of those famous already (such as Jasmin), are represented. In 1853 he was one of the enthusiastic circle that had gathered round J. B. Gaut at Aix, and whose literary output is contained in the *Roumavagi dei Troubaire* and in the shortlived journal *Lou gay saber* (1854). At the same time the first attempt at regulating the orthography of Provençal was made by him (in the introduction to his play, *La Part dou bon Dieu,* 1853). And in 1854 he was one of the seven poets who, on May 21, foregathered at the castle of Font-ségugne, near Avignon, and founded the *Félibrige.* (*See* Emile Ripert, *La Renaissance Provençale.*) The other six were Mistral, Aubanel, A. Mathieu (a schoolfellow of Mistral's at Avignon), E. Garcin, A. Tavan and P. Giera (owner of the castle). Of these, Théodore Aubanel (1829–1886, of Avignon, son of a printer and following the same calling) has alone proved himself worthy to rank with Mistral and Roumanille. "Zani," the girl of his youthful and passionate love, took the veil; and this event cast a shadow over his whole life, and determined the character of all his poetry (*Lou mióugrano entre-duberto,* 1860; *Li Fiho d'Avignoun,* 1883). His is, without a doubt, the deepest nature and temperament among the *félibres,* and his lyrics are the most poignant. His powerful love drama *Lou pau dou peccat* was received with enthusiasm at Montpellier in 1878, and successfully produced (some years later in Arène's version) by Antoine at his Théâtre Libre.

We need not do more than glance at the work of the fourth of the group of poets who alone, amidst the numerous writers of lyrics and other works that attain a high level of excellence, appear to us to have so far secured permanent fame by the magnitude of their achievement. Félix Gras (1844–1891) settled at Avignon in his youth. His rustic epic, *Li Carbounié* (1876) is full of elemental passion and abounds in fine descriptions of scenery, but it lacks proportion. The heroic *geste* of *Toloza* (1882), in which Simon de Montfort's invasion of the south is depicted with unbounded vigour and intensity, shows a great advance in art. *Li Roumancero provençal* (1887) is a collection of poems instinct with Provençal lore, and in *Li Papalino* (1891) we have some charming prose tales that bring to life again the Avignon of the popes. Finally, the poet gave us three tales dealing with the period of the Revolution (*Li Rouge dou miejour,* etc.).

Since the end of the 19th century the Félibrige has considerably developed: it now constitutes important groups in the different parts of Southern France from the Pyrenees to Auvergne, Velay and Dauphiné.

These groups represent the most varied opinions in politics and religion, and for the expression of their ideas they resort to the whole range of dialects and patois actually used in southern France.

The spirit of the movement is purely literary; it has never been expressed with greater terseness, force and truth than in the three verses set by Félix Gras at the head of his *Carbounié:* "I love my village more than thy village; I love my Provence more than thy province; I love France more than all."

See Emile Ripert, *Le Félibrige* (Paris, 1924); contains an excellent bibliography. (H. O.; L. B.)

PROVENCE, a province in the southeast of ancient France, bounded on the north by the Dauphiné, on the east by the Alps and Italy, on the west by the Rhône and on the south by the Mediterranean sea. About 600 B.C., according to tradition, some traders from Phocaea founded the Greek colony of Massalia (Marseilles). Other colonies in the neighbourhood, such as Antibes, Agde and Nice, originated in this settlement. During the wars which followed, the inhabitants of Massalia asked assistance from the Romans, who thus made their first entry into Gaul (125 B.C.) and conquered the territories between the Alps, the sea and the Rhône (with the province of Narbonne on the right bank of this river). These lands formed the Provincia Romana, and the name was retained by Provence. The town of Aix (Aquae Sextiae) was founded to form the capital of this conquered land. Under the empire the territory of the former Provincia was divided into the new provinces of Narbonensis II, of the Maritime Alps and of Viennensis and formed an important centre of Roman learning and civilization. Arles was made the chief town of the province, becoming after the capture of Trier by the barbarians (A.D. 418) the capital of Gaul. By the 5th century bishoprics had been founded in all the cities of Provence.

At the beginning of that century Provence was attacked by the Visigoths. In 476 Arles was captured by Euric I, and the country south of the Durance thus came definitely under Visigothic rule. The more northern cities, such as Orange, Apt and Trois-Châteaux, were joined to the kingdom of Burgundy. About 510 Visigothic Provence was ceded to Theodoric, king of the Italian Ostrogoths; and soon afterward the Ostrogoths extended their lands in the north as far as Gap and Embrun. Witigis, king of the Ostrogoths, ceded Provence to the kings of the Franks about 537, when the northern cities and those on the coast (Arles, Marseilles, Toulon, Antibes, Nice) were given back to Burgundy, while a narrow strip of territory, with Avignon, Apt, Cavaillon, Riez, etc., extending from the west to the east as far as the Alps, was added to the kingdom of Austrasia.

In the 8th century western Provence was for a time conquered by Arabs from Spain. In 739 they were expelled by Charles Martel, who brought the country definitely under Frankish rule. Under Charlemagne and Louis the Pious the history of Provence was incorporated with that of the rest of the empire and became more and more subject to the incursions of the Saracens. After

the partition of Verdun (843) it fell to the portion of the emperor Lothair. Later it went to his son, the emperor Louis II; and finally in 875 it passed to Charles the Bald, who handed it over to his brother-in-law Boso (879). The latter bore the title of king, and thus arose the kingdom of Provence (Provence, Viennois, Lyonnais and Vivarais), sometimes called Cisjuran Burgundy.

After some years of trouble the kingdom was given, in the 10th century, to Rudolph II of Burgundy, so that the kingdom of Burgundy now extended from the Aar to the Mediterranean. But under Rudolph's successors control became weaker and weaker, until Provence passed to the German kings, who then took the title of king of Arles (*see* ARLES, KINGDOM OF).

Local Countships.—At the beginning of the 10th century Provence was in a state of complete disorganization. All the real power was in the hands of local counts. It is probable that from the 9th century several of the Provençal countships were united under one count and that the count of Arles had the title of duke, or marquis, and exercised authority over the others. In the middle of the 10th century this position was held by another Boso, of unknown origin, who left it to his two sons William and Roubaud (Rotbold).

From the end of the 10th century the descendants of the two brothers, without making any partition, ruled over the different countships of Provence; only one of them, however, bore the title of marquis. The counts of Provence had, from about the middle of the 11th century, a tendency to add the name of their usual residence after their title, and thus the lordships, known later under the names of the countships of Provence, of Nice and of Venaissin grew up. At last, by the marriage of Douce, the heiress, in 1112 to Raymund-Berengar III (Ramón Berenguer), count of Barcelona, the marquisate of Provence with the overlordship of this region passed to the house of Barcelona. The definite establishment of the countships of Provence, Venaissin and Forcalquier belongs to this period.

After the death of Raymund-Berengar IV (II of Provence) in 1162, his son Alphonso II, king of Aragon, took the title of count of Provence. His succession was disputed by the count of Toulouse, Raymund V. Most of the lay and ecclesiastical lords of Provence recognized Alphonso, who in 1176 signed a treaty with his competitor, by which Raymund V sold his rights to the king of Aragon.

Alphonso was represented in Provence by his brothers Raymund-Berengar III (of Provence) and Sancho, in turn, and in 1193 by his son Alphonso, who inherited Provence but not Aragon on his father's death in 1196. This Alphonso gave Aragon and Catalonia to his brother Peter (Pedro) and kept only Provence for himself; but on the death of his father-in-law, Count William II, in 1208, whose son had been disinherited, he added to it the county of Forcalquier. It was not until after his death (1209), during the minority of his son Raymund-Berengar IV, that Provence was involved in the struggle of the count of Toulouse against Simon de Montfort, when the part played by the city of Avignon in the Albigensian movement finally led to the expedition of Louis VIII of France against the town (*see* ALBIGENSES).

Raymund-Berengar had also to fight against Raymund VII, count of Toulouse, who had received from the emperor in 1230 the countship of Forcalquier. The intervention of St. Louis, who in 1234 had married Margaret, the eldest daughter of the count of Provence (the second, Eleanor, married Henry III of England in 1236), put an end to the designs of the count of Toulouse. Raymund-Berengar died in 1245, leaving a will by which he named as his heiress his fourth daughter, Beatrice, who shortly afterward, in 1246, married the celebrated Charles of Anjou (*see* CHARLES I, king of Naples), brother of the king of France. After her death, in 1267, Charles still maintained his rights in Provence. The countship of Venaissin was left to him by his sister-in-law, Joan, countess of Toulouse, but in 1272 King Philip III took possession of it, giving it up in 1274 to Pope Gregory X, who had claimed it for the Roman Church in pursuance of the treaty of 1229 between Raymund VII of Toulouse and St. Louis.

Charles of Anjou was continually occupied with his kingdom of Naples. His government of Provence was marked by his struggles with the towns. In the first part of the 12th century the towns of Provence began to form municipal administrations and consulates, independent of the viscounts, who in theory represented the authority of the count in the towns. Marseilles, Arles, Tarascon, Avignon (whose consulate laws date from the 12th century), Brignoles and Grasse had become self-governing and elected their magistrates, sometimes negotiating with the count, as a power with a power, and concluding political or commercial treaties without consulting him. The city of Nice, which was joined to Provence in 1176, had retained its freedom. This state of affairs was in direct opposition to the arbitrary policy of Charles of Anjou. In 1251 he seized Arles and Avignon and placed them under a *viguier* (vicar) nominated by himself. In 1257 Marseilles was also subdued, and ministers nominated by the court performed their duties side by side with the municipal officials.

Annexation to France.—The successors of Charles of Anjou were chiefly interested in maintaining their rights over the kingdom of Naples. Charles II (ruled 1285–1309) lived in Provence during the latter years of his reign and tried to introduce reforms into the administration of justice and finance. Robert of Calabria (1309–43), his son, was succeeded by his granddaughter Joanna I, widow of Andrew of Hungary, who sold her rights over the city of Avignon (where the popes settled from 1309 to 1377 and subsequently during the great schism) to Clement VI in 1348 to raise money to continue the struggle against the house of Aragon in Naples. The emperor Charles IV visited Avignon and had himself crowned king of Arles in 1365. He gave up his claims to Louis I, duke of Anjou, brother of Charles V of France, but the expedition which this prince made to take possession of Provence only resulted in the seizure of Tarascon and failed before Arles (1368).

Joanna had first nominated as her heir Charles of Anjou-Gravina, duke of Durazzo, her nephew by marriage; but when he took sides against her claim to the kingdom of Naples she nominated instead Louis of Anjou as her eventual successor (1380). Louis took possession of Provence, while Charles of Durazzo made the queen prisoner at Naples and gave orders for her to be put to death (1382). Louis of Anjou also made an expedition to Naples, but did not arrive till after her death; he died in 1384. His son Louis II (ruled 1384–1417), only resident in Provence toward the end of his life, established a *parlement* in 1415. The wars carried on by his successor, Louis III (ruled 1417–34), against the kings of Aragon, his rivals at Naples, were the cause of the temporary ruin of Marseilles by the Aragonese fleet. René I (*q.v.*), duke of Anjou and Lorraine, Louis's brother and successor, after an unsuccessful attack on Naples (1460–61) retired to France, but after 1471 generally resided in Provence, where he built the castle of Tarascon and interested himself in art, literature and pastoral amusements. In 1474 he left his territories by will to his nephew Charles, count of Maine, who on his death in 1481 bequeathed Provence to Louis XI, king of France. Under Louis's successor, Charles VIII, Provence was definitely annexed to France, though even then it preserved a certain individuality. In laws relating to this country the sovereigns added to their title of king of France "and count of Provence and of Forcalquier," and Provence preserved a separate administrative organization.

Religious Troubles.—In the 16th century Protestantism made its appearance in Provence. A sentence passed in 1540 by the *parlement* of Provence against the heretics was carried out with great severity in 1545 by the president Jean de Maynier, baron d'Oppède, and the baron de la Garde. The movement drew a fair number of followers from the ranks of the lesser nobles. Charles IX's journey in Provence in 1567, followed by the establishment in the *parlement* at Aix of a court (*chambre*) in which Catholics and Protestants had an equal number of seats, led to a momentary cessation of hostilities. These were resumed between the Carcistes (Roman Catholics) and Razats (Protestants) but were again interrupted by the peace of 1576, which gave some guarantees to the Protestants, with La Seyne as a place of security, and also by the plague of 1579, which affected the whole country. The

League, on the other hand, made rapid progress in Provence, and the governor Bernard de Nogaret de La Valette and his brother Jean-Louis, duc d'Épernon (afterward governor also), vainly tried to pacify the country. La Valette and the party of the *Politiques* or Bigarrats were finally more or less reconciled to the Protestants; and, at the time of the death of Henry III, the struggle was no more than a question of local politics. In 1596 the religious wars in Provence were definitely ended by the capitulation of Marseilles.

Under Richelieu the restriction of local freedom led to a rising which Condé suppressed in 1630–31. At the time of the Fronde additional taxes were levied by the *parlement* at Aix, and a period of local unrest began which culminated in an insurrection at Marseilles in 1660 followed by the abolition of the last remaining municipal liberties of the town.

Provence was severely tried by the imperial invasions of 1706 and 1746 and the great plague of 1720.

Economic Development.—Throughout the middle ages, Provence was continually changing from the economic point of view. At the end of the ancient period and in Merovingian times it was a busy region with an important transit trade, the port of Marseilles being a commercial focus that connected Provence with the Italian ports and with the east. From the 7th century, however, trade underwent a serious crisis, caused in part by Arab expansion along the Mediterranean and by plundering of the Saracens, who blockaded the port and often attacked the coast of Provence. But as early as the 12th century trade came to life again, and the inland towns became local fairs. These fairs, however, did not enjoy so much prosperity as did those of other regions, because the important commercial roads—from Italy to Champagne and Flanders—did not cross this region. Nevertheless, Marseilles and Aigues-Mortes were ports in relation with Italy and the Latin east. At the beginning of the Angevin period (the end of the 13th century) the ports were busiest. Moreover, the towns acquired a considerable political importance and became great commercial and banking centres as well; such was the case with Avignon, where the papacy settled in the 14th century, and with Beaucaire, famous for its fairs. But later internal disturbances brought about a considerable falling off of these activities.

Administration.—Provence, with its own language and its law so closely related to Roman law, was quite separate from the other French provinces. Until 1639 it retained its provincial estates, the origin of which has been traced back to the 12th century. They met annually and included representatives of three orders: for the clergy, the archbishop of Aix, president ex officio of the estates, the other bishops of Provence and the abbots of St. Victor at Marseilles, of Montmajour and of Thoronet; for the nobility, all the men of noble birth until 1623, when this privilege was restricted to actual holders of fiefs; for the third estate, the members of the 22 chief towns of the *vigueries* (divisions corresponding to the *prévôtés* of the rest of France) and 15 other privileged places, among which were Arles and Marseilles. There were theoretically no taxes, but only supplies given freely by the estates and assessed by them. The administrative divisions of Provence were constantly changing. At the end of the *ancien régime* the government (*gouvernement*) of Provence, which corresponded to the *généralité* of Aix, was made up of eight *sénéchaussées:* those of lower Provence—Aix, Arles, Marseilles, Brignoles, Hyères, Grasse, Draguignan, Toulon; and four of upper Provence—Digne, Sisteron, Forcalquier, Castellane. For judicial purposes the *parlement* of Aix had replaced the former *conseil éminent* or *cour souveraine.* There was a *chambre des comptes* at Aix and also a *cour des aides.* A decree dated Dec. 22, 1789, divided Provence into the three departments of Bouches-du-Rhône, Basses-Alpes and Var; and in 1793 Vaucluse, the former county of Venaissin, which belonged to the pope, was added to these.

The boundaries of Var were modified in 1860 after the annexation of the county of Nice, when the department of the Alpes Maritimes was formed.

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(R. P.; M. PAC.)

PROVERBS, BOOK OF. This Old Testament book falls into nine sections. Each of these has its special stylistic and other characteristics, some of them containing evident traces of compilation from earlier collections, one (as has only lately been recognized) being almost completely paralleled in an extant Egyptian book, while individual proverbs are found to bear traces of the "international" character of their origin and are variously related to the culture of Egypt, Babylonia, Greece, etc. (*see* WISDOM LITERATURE).

Moreover, the tradition preserved in the book itself which ascribed certain parts of the book to Solomon (x. 1, xxv. 1), the "sages" (xxii. 17, xxiv. 23), Agur (xxx. 2), King Lemuel's mother (xxxi. 2) militates against the view that any one author was responsible for the composition of these various sections of the book: the ascription to Solomon in i. 1 probably referred originally to chapters i.–ix.—though this was probably the last section to be compiled.

Wellnigh the only characteristics common to all sections of the book may be summed up under three heads and these are not confined to the Book of Proverbs but are to be found in nearly all the extant gnomic literature of the Hebrews—the presuppositions that "wisdom" comes from Jehovah, that wisdom is, or should be, the guiding principle of life, and that cardinal social virtues such as industry, thrift, discretion, truthfulness, honesty, chastity, thought for others, including the lower animals, should be inculcated. Consequently in its present form the book represents the last stage in a long compilatory history and provides many useful examples of Hebrew proverbial and gnomic thought at various stages of its development. The date of each section and subsection must be alternately determined by the character of its contents, the relation in which the latter stands to the extant gnomic literature of other peoples, and the stage or stages of moral and theological development reflected in it.

Chapters i.–ix.—The first section serves as an introduction to the whole book, but in origin it is of late date and its contents suggest that, like the book as a whole, it was compiled from more than one source. At times, for instance, the motive advanced for good conduct is moral and religious (*e.g.*, ii. 5–8): at times it is frankly utilitarian (*e.g.*, vi. 1–5). Instead of a series of unrelated proverbial couplets, such as those in the following section, comparatively long discourses follow on each other. The sage addresses his remarks to young men. Though not confining his warnings to these two offenses, he warns them more especially against highway robbery and adultery—unless indeed the latter is an only too thinly veiled warning against Hellenism (*cf.* "Madam Folly" in ch. ix. 13–18) conceived of as a prostitute enticing the uninstructed ("ye simple ones") from their allegiance to their true love, the "wisdom" which comes from Jehovah, incarnate, as it were, in His religion, Judaism. Somewhat similar warnings against woman's wiles are given by Egyptian sages such as Amenophis and Ptah-hoteph, and by the Mesopotamian author of the Wisdom of Aḥikar. The section is chiefly remarkable for the developed thought contained in viii. 1–31 as to "wisdom," its relation to God, the universe and man. It is perhaps more developed than, not only Eccles. xxiv. 1–19, but also the descriptions of it in the Book of Wisdom. "Wisdom" claims to have existed prior to the universe (*cf.* "in the beginning" with the first words of Gen. i. 1 and John i. 1) as a possession of God (viii. 22 sff.), to have witnessed the creation of the universe, and even to have acted as a clerk of the works or architect in the process of the creation, unless, as the parallelism of the verse makes probable, the vocalization of the Hebrew word translated "master workman" should be altered to justify the rendering "nursling." But it is questionable whether even here the Hebrew author does more than poetically *personify the principle* of wisdom: he scarcely gives it a real *hypostasis* and does not go so far in this direction as did Philo in his description of the Logos as "a second god."

It is not, however, outside the bounds of possibility that the author of the prologue to the Fourth Gospel was considerably influenced by this description of wisdom rather than by Philo's descriptions of his Logos, even though he substituted the latter term for "wisdom." This advanced thought as to wisdom is not confined to ch. viii., but seems to be more or less presupposed throughout the section. The author's philosophy of life otherwise shows little of a pronouncedly modern character. Righteousness and wickedness are rewarded in this life (*e.g.*, ii. 21); the sacrificial worship is inculcated (ii. 9, iii. 9); the words "law" and "commandment" are used now of the Mosaic system, now of parental injunctions, now of the sage's advice. It is the language and philosophy of life characteristic of Deuteronomy which are most prominent; suffering is divine chastisement administered, however, in love (iii. 12).

Chapters x.–xxii.—The second section illustrates earlier stages in the literary productions and ideals of the exponents of wisdom. Each proverb is confined to two lines, antithetical in form if we except a few in which synonymous parallelism occurs. The utilitarianism of the compiler of this section is often overemphasized: it contains, on the contrary, sentiments which anticipate some of the highest ideals expressed in the New Testament and to which the latter owe their literary form (*e.g.*, x. 12 *cf.* 1 Cor. xiii. 7, 1 Pet. iv. 3, James v. 20; xiv. 31; xvii. 5, *cf.* Matt. xxv. 40, 45; xx. 11, *cf.* Matt. vii. 16; xx. 22, *cf.* Matt. v. 39, Rom. xii. 17, 19, etc.). It reflects, moreover at times the "prophetic" revolt against the hollowness of merely external sacrificial worship (xv. 8, xxi. 3) *cf.* the emphasis on the *national* virtue demanded by Amos (xiv. 34) and on inner purity (xx. 9) and on the omniscience of Jehovah (xv. 3, 11). Thus, in date, the section shows no trace of the developments of religious, theological and philosophical thought for which the latter post-exilic Judaism was responsible; on the other hand, along with much which might be the product of any period, it presupposes, at least in the above respects, the very latest products of pre-exilic piety.

Chapters xxii. (17) to xxiv. (22).—The third section bears the title "words of the wise." Its contents are presented to the reader in a strophic form, forming a miniature discourse, and having four lines to a strophe, as in the newly deciphered Egyptian "Teaching of Amenophis." It is the remarkable similarity of the section to this latter book which has especially concentrated attention upon it since 1924. The similarity between the two continues, with certain exceptions, throughout a considerable portion of the section and creates a problem which is scarcely solved by the theory that both reflect gnomic sayings which were common to all nations of the orient. Indeed so close is the relationship that it is possible to emend with a fair degree of certainty, on the basis of the Egyptian tradition, passages in which the Hebrew text is manifestly corrupt: thus "excellent things" (xxii. 20) without any change in the consonantal text, should be read as "thirty (sayings)," the exact number of the "chapters" into which *The Teaching of Amenophis* is divided. It would appear unlikely that the Egyptian sage borrowed from the Hebrew, and we are therefore compelled to suppose that either a copy of the Egyptian book penetrated into Palestine and its contents *gradually* became "Hebraised," its Egyptian theology *slowly* yielding to that of the Hebrews and proverbs from other sources gradually attaching themselves to it; or a Hebrew sage, visiting or living in Egypt, became acquainted with it, expurgated its Egyptian polytheism and made it acceptable to those who saw in Jehovah the only God who ruled every department of life. Either of these alternatives can best be visualised as happening in pre-exilic rather than late post-exilic days, but to dogmatise as to the exact date, whether the reign of Hezekiah, the early years of the exile or otherwise is to substitute guesswork for reason. An outstanding one among the many sayings common to the Hebrew and Egyptian gnomic writers occurs in the next section (xxiv. 23–34, an appendix to the present one) as well as already in the preceding one (xx. 22): it is the earliest extant form of "the golden rule," later extolled by Hillel and Jesus, which is thus proved to be in its origins Egyptian rather than Hebrew or Jewish.

Chapters xxv.–xxix. (27).—The fifth section, attributed traditionally to Hezekiah's scribes (xxv. 1), contains, like the second section, chiefly short independent proverbial aphorisms; but it has some of two or more verses in length, and advances from the consideration of worldly matters in chs. xxv.–xxvii. to matters of more specifically religious import in chs. xxviii., xxix., where the observance of "the law" in particular is emphasized, and prophecy is specified as a *sine qua non* of popular self-restraint (xxix. 18). In spite of the presence in this section of proverbs which occur elsewhere, it contains several of considerable interest. It reflects a somewhat hostile attitude to the monarchical form of government, but attempts to deflect criticism from the person of the king to his courtiers. Whether "the king" is a native Jewish ruler, Davidic or Maccabaean, or a Ptolemaic or Seleucid overlord, or merely figures impersonally in a set of proverbs of international vogue cannot be decided: consequently it gives no real help in fixing the date of the section. In at least two respects this collection provided the inspiration for practical and ethical advice too often supposed to have originated in Christian circles, namely xxv. 7 which evidently inspired Luke xiv. 8–11, and xxv. 21 which is quoted in Rom. xii. 20.

Chapter xxx. (1–16).—The sixth section has the cryptic and not very convincing title "The words of Agur, the son of Jakeh, of Massa (R. V. mg.)," followed by a line which has defied all efforts to translate it. This, like xxxi. 1, though a frank confession by the Jewish sages that they were prepared to welcome aphorisms of foreign origin, and having done so, openly to ascribe them to a foreign author, really throws no light upon the origins and background of the present section. It would appear to date from a period when problems of theology and philosophy were being discussed *ad nauseam* and to emanate from an author who found little comfort, but much disturbance of faith in speculations of this nature. Consequently confessing his own limitations of intellect (*v.* 2 *seq.*), he plaintively asks who in point of fact has ever penetrated into the supra-mundane sphere to return with a knowledge adequate to justify him in propounding such riddles (*v.* 4). And so he takes refuge in the revealed "word" of God and utters a warning against human endeavours to supplement it or detract from it in self-confidence or insolence. He ends by pointing out the shortcomings of his generation (*vv.* 5–14). It is the answer of a religious obscurantist rather than, as is too commonly supposed, of a pious agnostic.

Final Section.—The seventh section, chap. xxx. 15–33, consists of miscellaneous *dicta* introduced by an unintelligible line and bound together by their "numerical" form of introduction. In these few words is concentrated a wealth of insight into the normal and abnormal, the obvious and mysterious in life and nature, which, as it were in a nut-shell, illustrates the keenness and the breadth of observation to which the "wisdom" writers, the humanists of Israel, trained themselves.

The eighth section, chap. xxxi. 1–9, purports to be a further instance of foreign wisdom, again from "Massa," and indeed an illustration of a king's instruction by his mother. The vices against which he is warned include impurity, drink and maladministration of justice. These vices were prevalent in most oriental courts of the period during which the section could have been written, and do not necessarily presuppose the vices which Hellenism in particular communicated to the petty kings of oriental states into which it penetrated.

The ninth and last section, chap. xxxi. 10–31, is perhaps the masterpiece of this remarkable collection of the literary output of the humanists of Israel. Incidentally it is an "alphabetical" poem, each verse beginning with a letter of the Hebrew alphabet, and each letter appearing in its correct sequence. The lie is here given to the depressing picture, though one too often fully justified, which is mostly drawn in the Old Testament, of woman's personal and economic position among the Hebrews as the slave and chattel of her husband who was legally free to possess not one but many wives. But practice reinforced by economic necessity, probably rose in this respect above precept. At any rate, in the wealthy and prosperous household here depicted monogamy is presupposed and the poet depicts the wife as its master-mind as well as its mainstay. To what extent such a régime pressed heavily on the female slaves and other underlings we do not know since no litera-

ture emanating from them has survived.

Next to their passion for the highest morality of their day, and their unswerving loyalty to their ancestral faith, certain of the Hebrew gnomic writers whose work has survived in the Book of Proverbs will be held in honour most of all for their ability, which, as stated at the outset, is only now beginning to be realized, to master the gnomic literature of Egypt and of Mesopotamia, of Edom and of Massa, to expurgate from it what was unworthy, and to transform it into an instrument for the instruction of successive generations of the worshippers of Jehovah. Only a study of the Book of Proverbs in the light of the comparative study of gnomic literature can make the reader realize this; for instance in addition to close relationship with the Egyptian *Teaching of Amenophis,* there are more than 70 dicta in the Wisdom of Aḥikar and of these more than half find an echo in this book.

BIBLIOGRAPHY.—For the literature, which is considerable, *see* the commentaries of Toy (1898), and especially W. O. E. Oesterley, *The Book of Proverbs* (1928) in the *Westminster Commentaries,* who gives striking parallels and references to the latest literature. *See* also Cheyne, *Job and Solomon* (1887); id., in *Sem. Studies* (ed. Kohut, 1897); id., *Jew. Relig. Life* (1898); Montefiore in *Jew. Quart. Review* (1898–1890); Cohen, *Ancient Jewish Proverbs;* Elmslie, *Studies in Life from Jewish Proverbs;* Goldman, *Proverbs of the Sages* (1911). For materials for the comparative study of Hebrew proverbial literature and that of other ancient nations, *see* D. C. Simpson, *The Hebrew Book of Proverbs and The Teaching of Amenophis* in *Journal of Egyptian Archaeology* (1926); Oesterley, *The Wisdom of Egypt and the Old Testament* (1927); Langdon, *Babylonian Wisdom* (1923); Hindu: Monier-Williams, *Indian Wisdom* (1875); Arabic: Jacob, *Altarab. Parallelen z. A. T.* (1897). (D. C. S.)

PROVIDENCE, the capital and largest city of Rhode Island, U.S.A., a port of entry and the county seat of Providence county; at the head of Providence river (the north arm of Narragansett bay), 27 mi. from the Atlantic ocean, 45 mi. S.S.W. of Boston and 185 mi. E.N.E. of New York city. It is on federal highways 1, 6 and 44; and is served by the New York, New Haven and Hartford railroad and four steamship lines. There are several private airports in and near the city and state airports at Block Island, Hillsgrove, Lincoln and Westerly.

The population was 247,700 in 1950; in 1940 it was 253,504 by the federal census.

The city has a land area of 18.91 sq.mi., diversified in natural character and irregularly laid out. The Seekonk and the Providence rivers bound it on the east; the Providence and the Moshassuck divide it into east and west sides; and the Woonasquatucket divides the west side into north and south sections. The east side (the part of most historic interest) embraces hills rising to a height of 200 feet. The newer business district lies along the west bank of the Providence river, and some of the largest buildings stand on made land. Most of the factories are on the banks of the Woonasquatucket and the Moshassuck. The names of the older streets (such as Benevolent, Benefit, Hope, Friendship, Peace, Pound, Sovereign, Shilling, Dollar and Doubloon) recall the religious spirit of the early city and its commercial character. From the Union station one steps directly into the civic centre, a broad open plaza surrounded by government (Federal, city and county) and business buildings and hotels. Aloof on a hill to the west, but only half a mile distant, the most conspicuous feature of the landscape and commanding a wide view of city, bay and surrounding country, is the large State house (designed by McKim, Meade and White and completed in 1902) of Georgia marble and white granite, surmounted by a marble dome 235 ft. high. In it is a full length portrait of Washington, by Gilbert Stuart (who was born in Rhode Island), and many other interesting paintings, and here is preserved the original charter of the Colony, framed in wood from the "Gaspee." Adjacent to the civic centre on the east is the retail shopping and business district, where tall modern structures of steel and stone rise above the older buildings. An interesting building is the Arcade (1828) with six massive Ionic columns at each entrance.

The old Market house was built in 1773 and in it a local "tea-party" was held on March 1, 1775, and Rochambeau's troops were quartered later.

Behind the business area College hill rises steeply, covered with historic landmarks. On its slopes lies the campus of Brown university (*q.v.*), where Revolutionary troops were quartered in university hall. At its foot stands the First Baptist meetinghouse (built in 1775 to house the church organized by Roger Williams in 1636), which has one of the finest church spires in America, and a beautiful interior, with a crystal chandelier in use since 1792. Its bell still rings the curfew at nine o'clock. Near by is the old Colony house, where the Rhode Island Declaration of Independence was signed on May 4, 1776, two months before the event in Philadelphia. Farther up the hill are the museum and library of the Rhode Island Historical Society, the ivy-covered Athenaeum, and Pendleton house (a museum), furnished with one of the finest collections of early American furniture in existence. Among the old mansions still standing are the homes of John Brown (built in 1786), Thomas Poynton Ives (1806), Col. Joseph Nightingale (1791), Joseph Russell (1772), Peter Randell (1748), Stephen Hopkins (1742) and that of Esek Hopkins (1718–1802), commander of the American navy during the Revolution, standing in a park formed from his estate. The Providence Art club occupies the homes of Nicholas Brown (1787) and Siril Dodge (1793). Many more modest colonial houses (usually of red brick with white marble trimmings, and occasionally set in a walled garden) add to the charm of this section of the city. The Friends' meeting house was erected in 1759. The first Unitarian church (organized 1773) has a bell cast by Paul Revere and his son. The city's parks and playgrounds cover 790 ac., and there are also large reservations under the control of the State. Chief among the municipal parks is Roger Williams park (451 ac.), part of the original tract ceded to Williams by Miantonomo, in which is the cottage (1775) of Betsy Williams, a lineal descendant. The North burial ground contains the graves of many men of prominence in the early history of the State and the nation.

In addition to Brown university, Providence has within its limits the Rhode Island college of education (1854); the Rhode Island school of design, affiliated with Brown (1876); Providence college (Roman Catholic; 1919); the Rhode Island institute for the deaf (1876); and several private secondary schools of high standing. The public-school system has profited in various ways by the presence of Brown university, and has been a pioneer in such educational schemes as transition classes between kindergarten and primary grades and open-air classes for delicate children. There are two daily newspapers. The *Journal* (Independent) was established in 1829. Among the numerous charitable institutions are the Butler Hospital for the Insane, one of the oldest institutions of its kind in the country (established by a bequest of Nicholas Brown in 1841), and the Dexter Asylum for the Poor, endowed by the Dexter fund, which limits its beneficiaries to those who have a legal settlement in Providence (*i.e.,* have paid taxes for five years on $200 worth of property) and consequently is very restricted in its application. The privately supported welfare agencies and philanthropic organizations unite in a joint annual campaign for funds.

Providence river and harbour have been under improvement by the United States since 1852. The channel to the ocean is 35 ft. deep at mean low water and from 600 to 1,800 ft. wide. A state pier (built in 1913) and a municipal wharf provide modern terminal facilities for the public on equal terms, and there are 5 wharves owned by steamship lines, 10 by the railroad and 43 by other private interests. Providence is the principal port of southern New England. Its water-borne commerce averaged 4,949,060 tons annually for the years 1940–47, and in 1947 amounted to 6,436,224 tons. The great bulk of the domestic commerce consists of incoming coal, lumber, crude and fuel oil and petroleum products.

Providence is one of the leading centres of the country for the manufacture of jewellery, silverware, worsteds, textile machinery and tools.

Its aggregate factory output in 1947 was valued at $262,822,000, of which $50,806,000 represented worsteds and $39,159,000 jewellery. Among the long-established firms of national reputation are the Gorham Manufacturing company, which introduced the jewellery and silverware industry, the Brown and Sharpe

Manufacturing company and the Nicholson File company. The famous Corliss engines were first made in Providence in 1847.

The city operates under the original charter of 1832, with various amendments, providing for a mayor and council form of government.

The franchise is limited to persons who pay a tax on $134 worth of real property or $200 worth of personal property. A town meeting is still held annually for the administration of the Dexter fund.

The levy of general property taxes in 1950 was $17,399,714. Bank debits in 1949 aggregated $3,840,608,000.

Providence was founded in 1636 by Roger Williams after his banishment from the Massachusetts Bay Colony. He bought a tract of land from the Narragansett sachems Canonicus and Miantonomo, built a house opposite the confluence of the Moshassuck and the Woonasquatucket rivers (50 ft. east of North Main street), and with a few followers who had accompanied him into exile promptly set up a town government. In 1637, after the arrival of a few more settlers, a plantation covenant was adopted, embodying the novel principle of complete separation of religious and civil affairs. Providence was incorporated as a town by the colonial assembly in 1649, and was chartered as a city in 1832. The name was chosen by Roger Williams in recognition (he says) of "God's merciful providence unto me in my distress." Between 1730 and 1760 its area was reduced from 370 sq.mi. to 5.5 sq.mi. by the setting off of Scituate, Gloucester, Smithfield, Cranston, Johnston and North Providence, some of which were further subdivided subsequently; and since 1860 the 5.5 sq.mi. have been increased to over 18 by re-annexations of contiguous territory. During King Philip's War, in 1676, the town was attacked by Indians and the northern half was burned. In June 1772, a British schooner, the "Gaspee," running aground at what has since been known as Gaspee point, was captured and burned by Abraham Whipple (1733–1819) according to a plan devised by John Brown (1736–1828), one of the town's prominent merchants. During the Revolution, Providence was a centre of privateering, and in consequence of the occupation of Newport by the British took over much of the foreign commerce of that port. It remained an important port for 40 or 50 years, but after 1830 manufactures became the dominating interest. Since 1900 its water-borne commerce has again increased, more than doubling in volume in the first quarter of the century. Providence shared with Newport the honour of being the seat of the State government until 1900; since 1900 it has been the sole capital.

PROVINCE, a term applied in ancient Rome (Lat. *provincia*) to the sphere of duty assigned to one of the higher magistrates, the consuls and praetors (*qq.v.*). Only those magistrates who had military power (*imperium*) had a province. When the province of a quaestor is mentioned it refers to the province of the consul or praetor to whom the quaestor is subordinate.

When the government of conquered countries grew to be one of the most important duties of the higher magistrates, the term province, from designating the government of a conquered country as one particular duty of a Roman magistrate, came to be used generally as a designation of the country itself.

The provinces paid tribute to Rome, for it was a recognized principle that they were the estates of the Roman people and were to be managed for its benefit. The constitution of a province was drawn up by the victorious Roman general, assisted by ten commissioners appointed by the senate, and the province was governed on the lines laid down in this constitution or charter (*lex provinciae*). For administrative purposes the province was divided into districts, each with its capital, for judicial purposes into circuits (*conventus*) and in the chief town of each circuit the governor of the province held assizes.

The lands of cities captured by force of arms were turned into Roman domains, and were let out by the censors to private persons. Royal domains, such as those of Macedonia and Cyrene, were also confiscated. Communities which surrendered were usually allowed to retain their personal freedom and private property; but all the lands were subjected to a tax, consisting either of a payment in kind (*vectigal*) or of a fixed sum of money (*tributum, stipendium*). It is to this class of communities (the *civitates vectigales* or *stipendiariae*) that the majority of the provincial states belonged. In a better position were those states whose freedom was guaranteed by Rome on the ground of old alliances or special loyalty. Their freedom was recognized either by a treaty or by a decree of the Roman people or senate. As a decree of the people or senate could at any time be recalled, the position of the free states without a treaty was more precarious than that of the treaty states (*civitates foederatae*). The latter enjoyed internal freedom, retained their lands, paid no taxes, and were bound to render those services only which were expressly stipulated for in the original treaty. Amongst such treaty states were Massilia (Marseille), Athens, Rhodes and Tyre. The privileges of the free states without a treaty were somewhat similar. All political distinctions, save that between slave and freeman, disappeared when Caracalla bestowed the Roman franchise on the whole empire (A.D. 212).

Provincial Diets.—Every province had, under the empire, a provincial assembly or diet of its own (*concilium* or *commune*), and these diets are interesting as the first attempts at representative assemblies. The diet met annually, and was composed of deputies (*legati*), from the provincial districts. It arranged for the celebration of religious rites and games, especially for the worship of the emperor. The celebration was under the conduct of the high priest of the province. The diet also passed votes of thanks to the outgoing governor, or forwarded complaints against him to Rome; and it had the right of sending embassies direct to the senate or the emperor.

The Provincial Governor.—The provinces were administered by governors from Rome, who held office for a year. From the formation of the first provinces in 227 B.C. down to the time of Sulla (82 B.C.) the governors were praetors (*see* PRAETOR); from the time of Sulla to that of Augustus the praetors remained in Rome during their year of office, and at the end of it assumed the government of a province with the title of propraetor. A province which was the seat of war, or was in a disturbed state, was committed to the care either of one of the consuls for the year, or of a commander specially appointed for the purpose, with the title of proconsul. The senate determined which provinces were to be governed by consuls and which by praetors, and the consuls arranged between themselves which of the provinces each should have, and similarly with the praetors. The Sempronian law of 123 B.C. provided that the senate should nominate the two consular provinces before the election of the consuls, and that the consuls should, before their entry on office, arrange which of the two provinces each should have. The Pompeian law of 53 B.C. enacted that no one should hold the governorship of a province till at least five years after his consulship or praetorship. This law was repealed by Caesar, but was re-enacted under Augustus; it severed the connection between an urban magistracy and the governorship of a province, and turned the latter into an independent office. A provincial governorship was regularly held for one year; but it could be prolonged by a vote of the people or a decree of the senate. The necessary supplies of men and money were voted to the governor by the senate. His staff included one or more lieutenants (*legati*) and a quaestor (*q.v.*). Besides these the governor took with him young men of the upper classes to assist him in the government. These were known as the companions (*comites*) or suite of the governor. They were chosen by the governor himself, but they were maintained at the expense of the state, and under the empire, received regular pay. In addition there was a crowd of subordinates. Before setting out for his province the governor, clad in the purple military robe of his office, offered sacrifice on the Capitol; then immediately after receiving the *imperium* or military command he marched out of the city (for the *imperium* could only be exercised outside of Rome and was forfeited by staying in the city), preceded by his lictors and accompanied by his suite. His year of office began from the day he set foot in his province. In the hands of the governor all powers military and civil were united. He commanded all the troops in the province, and had power to raise levies of Roman citizens as well as of provincials, and to make

requisitions of war material. He possessed both criminal and civil jurisdiction; as criminal judge he had the power of life and death, and from his sentence none but Roman citizens could appeal; as civil judge he was guided partly by the charter of the province (*lex provinciae*), partly by the edict which it was customary for him to issue before his entrance on office (*see* PRAETOR).

Condition of the Provinces under the Republic.—The Roman people regarded the provinces as so many estates from which they were to derive revenue. Hence agriculture and commerce were encouraged, settlements were made, roads and aqueducts were constructed; in short, the Roman aimed at exploiting his empire by a system of prudent economy. But the Roman governors were apt to look on their provinces as their own peculiar prey; they had usually bought their way to office at vast expense, and they now sought in the provinces the means of reimbursing themselves for the expenditure they had incurred at Rome. Redress was to be had by a complaint to the senate; after 149 B.C. there was a court established at Rome for the trial of cases of extortion (*repetundae*) by provincial governors. But, even when the provincials had arraigned their oppressor, it was difficult to secure his condemnation at the hands of juries composed of men who had a fellow-feeling for the offender because they had themselves committed, or hoped for means of committing, similar offences. Besides the governor, two classes joined in wringing the uttermost farthing from the unhappy provincials. These were the *publicani* (*q.v.*) or farmers of the taxes, and the money-lenders (*negotiatores*). Both these classes were recruited from the *equites* (*q.v.*) and, since from 122 B.C. the juries were drawn at first exclusively and after 70 B.C. partially from that order, the provincial governor could not check their excesses without risking a condemnation at the hands of their brethren. Accordingly he generally made common cause with them.

The Provinces under the Empire.—Under the empire the provinces fared better. Romans and provincials were reduced to a common level of subjection to the emperor, who meted out equal justice. The first centuries of the Christian era were for some of the countries included in the Roman empire the happiest of their history.

Augustus, in 27 B.C., divided the provinces into imperial and senatorial. Those which required the presence of an army were placed under the direct control of the emperor; those which needed no troops were left to the senate. (1) The senatorial provinces were ruled by annual governors called proconsuls. Their powers were much the same as they had been under the republic, except that they had now no troops, or only a handful to maintain order. (2) The imperial provinces were governed by imperial lieutenants (*legati Caesaris*), who were nominated by the emperor and held office at his pleasure; all of them had the power of the sword (*ius gladii*). For the administration of the finances these lieutenants had procurators under them, while the governors of the senatorial provinces continued to have quaestors. Certain other possessions were regarded as domains of the emperor, and were managed by a procurator or praefect (*see* PRAEFECT), responsible to the emperor.

See T. Mommsen, *Roman Provinces under the Empire* (1884); T. M. Taylor, *Constitutional History of Rome* (1899); J. E. Sandys, *Companion to Latin Studies* (1921), with useful bibliography. For imperial domains, *see* H. F. Pelham, *Essays on Roman History* (1911), pp. 275–299.

PROVINCETOWN, a town of Barnstable county, Massachusetts, U.S.A., on the tip of Cape Cod; it is on federal highway 6 and is served by the New York, New Haven and Hartford railroad, and steamboats to Boston; there is an airport. Population was 3,736 in 1950; 3,668 in 1940. There are many visitors in summer, among whom are a large number of artists, attracted by the beauties of the sand dunes and the marine views. The town is almost surrounded by water, and there are three lighthouses on its coast. Its harbour (to the south) is protected on three sides by land. A magnificent beach stretches for 30 mi. along Cape Cod bay to Eastham. Provincetown is a port of entry. The principal industries still (as since its settlement) are the catching, curing, packing and selling of fish, chiefly cod and mackerel. The large whaling fleet of former days has entirely disappeared. It was in Provincetown harbour that the Pilgrims, in the cabin of the "Mayflower," drew up their memorable Compact, before proceeding to Plymouth. There John Carver was chosen as the first governor of Plymouth Colony, and this was the first landing-place (on Nov. 11 [O.S.], 1620) of the Pilgrims in the New World. There has been a settlement there since 1620. The town was set off from Truro and incorporated in 1727. Much of the territory was originally "Province land" (hence the name) and there is still a large State reservation between the village and the back ocean shore, which has been stocked with game birds and planted with beach grass and pine trees.

PROVINS, a town of northern France, capital of an arrondissement of the department of Seine-et-Marne, at the junction of the Durtain with the Voulzie (an affluent of the Seine), 59 mi. E.S.E. of Paris by rail. Pop. (1946) 8,840. Provins began to figure in history in the 9th century. Passing from the counts of Vermandois to the counts of Champagne, it quickly became prosperous. Cloth and leather were its staple manufactures, and its fairs were attended by traders from all parts of Europe, throughout which its money had currency. Plague and famine reduced the population in the 14th century and the Hundred Years' War completed its ruin. During the religious wars it sided with the Catholic party and the League, and Henry IV obtained possession of it in 1592 only after thirteen days' siege. The town has mineral waters which contain iron, lime and carbonic acid, and also a trade in roses. Provins is divided into two quarters—the *ville-haute* and the less ancient *ville-basse*—which in the 13th century were surrounded by fortifications. In the *ville-haute* stands the large tower known as the king's, Caesar's or the prisoners' tower, a very curious 12th century keep. The base is surrounded by a thick mound of masonry added by the English in the 15th century when they held the town. The tower serves as belfry to the church of St. Quiriace, which dates from the 12th century. The palace of the counts of Champagne, some fragments of which also belong to the 12th century, is occupied by the communal college. The old tithe-barn is a building of the 13th century with two fine vaulted chambers, one of which is below ground. The church of St. Ayoul dates from the 12th to the 16th centuries, the transept being oldest; it is dilapidated and the choir is used as a storehouse. St. Croix belongs partly to the 13th century. There is a subprefecture and a tribunal of commerce. There is an active trade in grain, livestock and wool, and the industries include nursery-gardening, brickmaking and the manufacture of porcelain, gas and petrol engines, agricultural implements and sugar.

PROVISION, in ecclesiastical law signifies the act by which an office or benefice is conferred by a person having competent authority for the purpose; and the word is specially used of appointments made by the pope in derogation of the rights of ecclesiastical patrons. Innocent III (1198–1216) seems to have been the first pope who directed prelates to collate his nominees to canonries and other benefices, but it was during the pontificate of Innocent IV (1243–1254) that the practice first assumed alarming proportions. The English parliament held at Carlisle in 1307 petitioned the king for a remedy against this abuse, but though he promised redress nothing was done. Meanwhile the popes had been asserting claims to appoint bishops in certain events on their own initiative, and at last Clement V (1305–1313) reserved to himself the right of appointment in all cases. After his time there is scarcely an instance of an English bishop being elected in accordance with the older procedure by the cathedral chapter. If an election were made the pope usually either overrode it by another appointment or, ignoring the election, appointed the elected clerk by a bull of provision. The Hundred Years' War caused an outburst of indignation against the use of papal provisions when non-resident French clerics were appointed to English benefices. To remedy the evil the first "Statute of Provisors" was enacted in 1351, the "Statute of Praemunire" in 1353, and a second "Statute of Provisors" in 1364. These appear to have had little effect until in 1389, a third "Statute of Provisors" was enacted which provided that the statute of 1351 should be firmly holden for ever and "put in due execution from time to time in all manner of points."

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PROVISIONAL ORDER, in Great Britain, a direction by a government department sanctioning (usually at the instance of a local authority or public undertaking) some project otherwise unattainable without private bill legislation, *e.g.*, the compulsory taking of land or the building of a tramway. Originally the order is provisional because subject to parliamentary veto. The objects depend upon the enabling statute.

The procedure generally involves: (1) preliminary local enquiry and report by a departmental inspector; (2) departmental decision as to the framing of the order; and (3) inclusion of the order (singly or grouped with others) in a provisional order confirmation bill introduced into parliament by the minister concerned. Such bills, if opposed, are referred to a select committee; they also go before examiners who see that the contents comply with standing orders. An early instance is the Inclosures Act of 1845 whereby commissioners could provisionally order the enclosure and regulation of commons. In 1853 the charity commissioners were authorized to give provisional approval to new schemes for the application and management of charities. Gradually the system was extended to the varied purposes of local government (especially the alteration of areas), public health, gas, water and electricity supply, acquisition of school and housing sites, formation of pilotage and drainage districts, facilities for harbours, docks, railways and other forms of transport, fishery regulation, validation of marriages, etc. The early enactments were later superseded and the process of devolution progressively developed. Two railway acts in 1864 initiated the provisional certificate which embodied schemes for railway construction or working agreements, and, unless the schemes were opposed, required no express parliamentary sanction. A further delegation of legislative power enabled a local authority to make orders for the acquisition of land (as under section 9 of the Local Government act, 1894). If not objected to, they had the full force of a statute; if objected to, they could be confirmed not by parliament but by the department concerned. Later a special order procedure was evolved whereby a draft of the proposed order was published and (on objection) a local enquiry was held, but a confirmatory act of parliament was not required. The National Health Insurance Act of 1928 authorized a "provisional special order." Under this variant (invented in 1912 to accelerate the action of special orders under the 1911 act) the appropriate minister, instead of waiting for criticisms of his draft orders, could bring them into force forthwith provided that he certified the expediency of such action. Some special orders, such as those which decided the application of unemployment insurance or trade boards legislation to particular trades, took effect forthwith, subject to annulment on adverse resolution by either house of parliament within a time limit; others, *e.g.*, those under the Electricity (Supply) Act of 1919 or the Gas Regulation Act of 1920, required the affirmative resolution of both houses. Special orders were often allowed to do all that a provisional order could formerly do. Scotland developed its own method under the Private Legislation (Procedure) Scotland act, 1899, operated through the Scottish Office, with special panels of commissioners for holding enquiries. Northern Ireland followed the Westminster model.

See Clifford, *Private Bill Legislation,* ii, c. 18. (C. T. C.)

PROVO, a city of Utah, U.S., on the Provo river, 3 mi. E. of Utah lake and 45 mi. S. of Salt Lake City; the county seat of Utah county. It is on federal highways 91, 89 and 50, and is served by the Denver and Rio Grande Western, the Union Pacific and the Utah (for freight only) railways. Pop. (1950) 28,937; (1940) 18,071 by the federal census. The city has an altitude of 4,549 ft., in a region of fine scenery. It is the seat of Utah State (mental) hospital and Brigham Young university (founded and endowed by President Young in 1875), with an enrolment of 6,000. Provo is a "garden city," surrounded by the richest agricultural and horticultural district of Utah, created by irrigation and industry out of the desert. It is an important industrial centre; near by is the Geneva Steel plant built during World War II at a cost of $200,000,000; there are also factories making cast-iron pipe, foundry products, steel tanks, creosoting materials, brick and tile, concrete pipe, etc. Provo was named for Etienne Provot, a French-Canadian trapper who explored the area in 1825; it was settled by the Mormons in 1849 and was chartered in 1851. It has a commission form of government.

PROVOST, a title attached to various ecclesiastical and secular offices. In ecclesiastical usage the word *praepositus* was at first applied by the church fathers to any ecclesiastical ruler or dignitary. It early, however, gained a more specific sense as applied to the official next in dignity to the abbot of a monastery, or to the superior of a single cell. In England the title provost has thus everywhere given way to that of "dean"; in Germany, on the other hand, "*Probst*" is still the style of the heads of certain chapters. The name *praepositus* was also sometimes used for the secular *advocatus* of a monastery. With the ecclesiastical use of the title is connected its English application to the heads of certain colleges; "provost" is still the style of the principals of Queen's, Oriel and Worcester colleges at Oxford, of King's college at Cambridge, of Trinity college at Dublin and of Eton college, where, however, the headmaster, though technically subordinate to the provost, is the effective head of the school.

As a secular title *praepositus* is also very old; we need only instance the *praepositus sacri cubiculi* of the late Roman empire, and the *praepositus palatii* of the Carolingian court. The important developments of the title in France are dealt with below. From France the title found its way into Scotland, where it survives in the style (provost) of the principal magistrates of the royal boroughs ("lord provost" in Edinburgh, Glasgow, Aberdeen, Perth and Dundee), and into England, where it is applied to certain officers charged with the maintenance of military discipline. A provost marshal is an officer of the army appointed when troops are on service abroad for the prompt repression of all offences. He may at any time arrest and detain for trial persons subject to military law committing offences, and may also carry into execution any punishments to be inflicted in pursuance of a court-martial (Army act, 1881, *s.* 74). A provost sergeant is an officer responsible for the maintenance of order when soldiers are in Great Britain. A provost sergeant may be either garrison or regimental, and he has under his superintendence the garrison or regimental police.

The Provost in France.—The word *prévôt* (provost) in old French law had many applications. In conformity with its etymology (*praepositus*) it could be applied to any person placed at the head of a branch of the public service, a position which, according to the old principles, habitually carried with it a right of jurisdiction. It is thus that there was at Paris the provost of Paris, who was a royal judge, and the provost of the merchants (*prévôt des marchands*), the head of the Paris municipality. There were besides—to mention only the principal provosts—the provosts of the marshals of France (*prévôts des maréchaux de France*), of whom more below; the provost of the royal palace (*prévôt de l'hôtel du roi*) or grand provost of France (*grand prévôt de France*), and the provost general (*prévôt général*) or grand provost of the mint (*grand prévôt des monnaies*). But the most important and best known provosts, who formed part of a general and comprehensive organization, were the royal provosts (*prévôts royaux*), the lower category of the royal judges. It must be borne in mind, however, that the magistrates belonging to the inferior category of royal judges (*juges subalternes*) had different designations in many parts of France. In Normandy and Burgundy they were called *châtelains,* and elsewhere—especially in the south—*viguiers.*

Some time in the 11th century the provosts replaced the viscounts wherever the viscounty had not become a fief, and it is possible that in creating them the crown was imitating the ecclesiastical organization in which the provost figured, notably in the chapters. The royal provosts had at first a double character. In the first place they fulfilled all the functions which answered locally to the royal power. They collected all the revenues of the domain and all the taxes and dues payable to the king within the

limits of their jurisdiction. Doubtless, too, they had certain military functions, being charged with the duty of calling out certain contingents for the royal service; there survived until the end of the *ancien régime* certain military provosts *prévôts d'épée* (provosts of the sword) who were replaced in the administration of justice by a lieutenant. Finally, the provosts administered justice, though certainly their competence in this matter was restricted. Their second characteristic was that their office was farmed for a time to the highest bidder. It was simply an application of the system of farming the taxes. The provost thus received the speculative right to collect the revenues of the royal domain in the district under his jurisdiction; this was his principal concern, and his judicial functions were merely accessory. By these short appointments the Crown guaranteed itself against another danger: the possible conversion by the functionary of the function into a property. Very early, however, certain provostships were bestowed *en garde; i.e.*, the provost had to account to the king for all he collected. The *prévôtés en ferme* were naturally a source of abuses and oppression, the former seeking to make the most of the concession he had bought. They disappeared in the 16th century, by which time the provosts became regular officials, their office being purchasable.

Other transformations had previously taken place. The creation of the royal *baillis* reduced the provosts to a subaltern rank. Each *bailli* had in his district a certain number of provosts, who became his inferiors in the official hierarchy. When appeals were instituted (and this was one of the earliest instances of their introduction) the provost, the sphere of whose competency was limited, was subject to an appeal to the *bailli*, though his judgment had hitherto been without appeal. Moreover, in the 14th century they had ceased to collect the revenues of the royal domain, except where the *prévôté* was *en ferme*, and royal collectors (*receveurs royaux*) had been appointed for this purpose. The summoning of the feudal contingents, the *ban* and *arrière-ban*, had passed into the hands of the *baillis*. Thus the provosts were left for their sole function as inferior judges for non-nobles. (*See* BAILIFF AND BAILIE.)

The "provosts of the marshals of France," mentioned above, were non-legal officials (*officiers de la robe courte*) forming part of the body of the *maréchaussée* which was under the *ancien régime* what the *gendarmerie* was after the Revolution. Their original function was to judge offences committed by persons following the army, but in the course of the 14th and 15th centuries they acquired the right of judging certain crimes and misdemeanours, by whomsoever committed. They became stationary, with fixed spheres of authority, and the offences falling within their competency came to be called *cas prévôtaux*. These were the worst crimes of violence, and all crimes and misdemeanours committed by old offenders (*repris de justice*), who were familiarly known as the *gibier des prévôts des maréchaux* (gaol-birds).

(J. P. E.)

PROXY (short for "procuracy"), a term denoting either (1) a person who is authorized to stand in place of another; (2) the legal instrument by which the authority is conferred. Proxies are now principally employed for certain voting purposes. A proxy may in law be either general or special. A general proxy authorizes the person to whom it is entrusted to exercise a general discretion throughout the matter in hand, while a special proxy limits the authority to some special proposal or resolution. Formerly a peer could give his vote in the British parliament by proxy, by getting another peer to vote for him in his absence, temporal peers only voting for temporal and spiritual peers for spiritual. However, on March 31, 1868, on the recommendation of a committee, a new standing order was adopted by which the practice of calling for proxies on a division was discontinued. In English and American bankruptcy proceedings creditors may vote by proxy, and every instrument of proxy, which may be either general or special, is issued either by the official receiver or trustee. Under the English Bankruptcy Act of 1914 and the American Bankruptcy Act of 1898 a creditor may still vote by proxy in the manner prescribed. A shareholder in a limited liability company may vote by proxy, and regulations to that effect prescribing the requirements are usually embodied in the articles of association. In England a proxy to vote at a meeting must bear a revenue stamp. (*See* PROCURATION.)

In the early practice of the admiralty courts a proxy was the authority by which the proctor or advocate appeared for either party to a suit. In the ecclesiastical courts a proxy is the warrant empowering a proctor to act for the party to a suit. Two proxies are usually executed, one authorizing the proctor to institute, the other to withdraw, proceedings. They are signed by the parties, attested by two witnesses, and deposited in the registry of the court (Phillimore, *Ecclesiastical Law*). In the convocations of the Church of England those who are absent are allowed to vote by proxy. (*See* also PROCURATION.) Marriage by proxy or deputy was a custom recognized either for reasons of State or ceremonial. The extension of the doctrine to ordinary marriages was recognized in a few wartime cases in the United States.

PRUDENTIUS, AURELIUS CLEMENS (348–*c.* 410), the most remarkable of the earlier Christian poets in the West, was probably born at Tarraco. The meagre autobiographical preface, which he affixed to the complete edition of his works when he was fifty-seven years old, makes it clear that he received a liberal education—being of noble family—practised as a lawyer and entered official life, and finally held some high office under Theodosius. At the age of fifty-seven he retired to a monastery, but died shortly afterwards.

Bentley calls Prudentius "the Horace and Virgil of the Christians," but his diction is stilted and his metre often faulty. The list of his works given in the preface mentions the hymns, poems against the Priscillianists and against Symmachus and *Peristephanon*. The *Diptychon* or *Dittochaeon* is not mentioned. The twelve hymns of the *Cathemerinon liber* ("Daily Round") consist of six for daily use, five for festivals, and one intended for every hour of the day. Prudentius shows Ambrose as his master here, but gives to Ambrose's mystic symbolism much clearer expression. The *Apotheosis* and *Hamartigenia* are polemic, the first against the disclaimers of the divinity of Christ, the latter against the gnostic dualism of Marcion and his followers. In them Tertullian is the source of inspiration. Of more historical interest are the two books *Contra Symmachum*, of 658 and 1,131 hexameter verses respectively, the first attacking the pagan gods, the second directed against the petition of Symmachus to the emperor for the restoration of the statue of Victory which Gratian had cast down.

The *Peristephanon* consists of fourteen hymns to martyrs. These were mostly Spanish, but some were suggested to Prudentius by sacred images in churches or by the inscriptions of Damasus. This book, with the *Cathemerinon liber* and the *Psychomachia*, was among the most widely read books of the middle ages. Its influence on the iconography of mediaeval art was great. The *Psychomachia* is aesthetically inferior, but had the greatest influence of all of Prudentius's writings. In it he depicts the struggle of Christendom with paganism under the allegory of a struggle between the Christian virtues and the pagan vices. The *Dittochaeon* is a series of quatrains, probably intended to explain forty-nine pictures of a basilica. The work is more interesting for archaeology than for literature.

Prudentius's works were published by Giselin at Antwerp in 1564, and by F. Arevalo at Rome in 1788, with complete commentary. This last is the edition reprinted in J. P. Migne's *Patrologia Latina*, vols. lix.–lx. (Paris, 1847). More recent editions are by Obbarius (Tübingen, 1845) and A. Dressel (Leipzig, 1886), while a critical edition has been undertaken by J. Bergmann.

See also J. Bergmann, *Lexicon prudentianum, fasc. i.* [a-adscendo] (Upsala, 1894); M. Schanz, *Gesch. d. röm. Lit.* (Munich, 1904); A. Ebert, *Allgem. Gesch. d. Lit. des Mittelalters*, vol. i. 2nd ed. (Leipzig, 1889); M. Manutius, *Gesch. d. christl. lat. Poesie* (Stuttgart, 1891); T. R. Glover, *Life and Letters in the Fourth Century* (Cambridge, 1901); C. Brockhaus, *Aur. Prud. Clem. in seiner Bedeutung f. d. Kirche seiner Zeit* (Leipzig, 1872); A. Pnech, *Prudence; étude sur la poésie latine chrét. au IV^e siècle* (Paris, 1888); F. St. John Thackeray, *Translations from Prudentius* (London, 1890); F. Maigret, *Le Poète chrétien Prudentius* (Paris, 1903); E. O. Winstedt, "The Double Recension in the Poems of Prudentius," *The Classical Review*, vol. xvii. (1903).

PRUD'HON, PIERRE (1758–1823), French painter, born at Cluny on April 4, 1758, was the thirteenth child of a mason.

The monks of the abbey undertook his education, and by the aid of the bishop of Mâcon he was placed with Devosge, director of the art school at Dijon. In 1778 Prud'hon went to Paris armed with a letter to Willie, the celebrated engraver, and three years later he obtained the triennial prize of the states of Burgundy, which enabled him to go to Rome, where he became intimate with Canova. He studied the work of Correggio and the affinity of his style with that of the great Italian has given him the name of "Corrège Français." He returned to Paris in 1787. The illustrations which he executed for the *Daphnis and Chloe* published by Didot brought him into notice, and his reputation was extended by the success of his decorations in the Hôtel de Landry (now Rothschild), his ceiling painting of "Truth and Wisdom" for Versailles (Louvre), and of "Diana and Jupiter" for the Gallery of Antiquities in the Louvre. In 1808 he exhibited "Crime pursued by Vengeance and Justice" (Louvre), which had been commissioned for the assize courts, and "Psyche carried off by Zephyrs." These two compositions brought Prud'hon the Legion of Honour; and in 1816 he entered the Institute. Consoled for the misery of his marriage by the devoted care of his pupil, Mlle. Mayer, Prud'hon's situation seemed enviable; but Mlle. Mayer's tragical suicide in 1821 brought ruin to his home, and Prud'hon died two years later on Feb. 16, 1823.

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PRUNE: *see* PLUM.

PRUNELLA, a term obtained from the French *Prunelle,* and applied to worsted or woollen twill fabrics of light but strong texture, produced with the three-end $\left(\frac{2}{1}\right)$ warp-face twill weave and usually woven from hank-dyed yarn of a dark purple colour both for warp and weft, or else piece-dyed in the same colour and formerly much used for clerical garments. It is now made in various grades of texture both plain and striped and used as dress material, ladies' sport skirts, and other articles of clothing both for men and women. A stronger and heavier texture of prunella cloth of a similar character to "everlasting," is also produced from a worsted warp and cotton weft and woven with the double-stitch five-end warp-face satin weave, and used for ladies' shoe-tops. The three-end warp-face twill weave is also described as the "prunella" twill, irrespective of the class of fabric to which it is applied. (H. N.)

PRURITUS (itching) is a sympton of many skin conditions, particularly dermatitis and eczema, insect bites, hives, scabies and pediculosis (lice), prickly heat and some superficial fungous infections. It may be almost entirely psychic in origin (localized neurodermatitis), and in generalized form is sometimes a symptom of internal diseases such as jaundice, diabetes and leukemia. Pruritus is probably a modified form of pain. Symptomatic treatment is unsatisfactory; relief of the underlying cause is essential. Aspirin is sometimes helpful. Excessive bathing should be avoided. The application of complex chemicals to the skin in an effort to control itching, may be productive of allergic reactions.

(D. M. P.)

PRUSSIA, a former German kingdom, became the largest and most important *Land* of the Third German Reich. It included the whole of Germany north of Saxony, Thuringia, Bavaria and Hesse, except Mecklenburg and Oldenburg, and some small enclaves, such as Brunswick. In 1938 the *Land* of Prussia comprised the provinces of East Prussia, Berlin, Brandenburg, Pomerania, Grenzmark, Silesia, province of Saxony, Schleswig-Holstein, Hanover, Westphalia, Hesse-Nassau, Rhine province and Hohenzollern. In 1945 East Prussia passed in part to the U.S.S.R. and the remainder to Poland. Poland also absorbed all Prussian territory as far as the Oder-Neisse line, expelling the German population and replacing it by Poles. The main part of the rest of Prussia was subdivided into the new *Länder* of Brandenburg and Saxony-Anhalt in eastern Germany, and Schleswig-Holstein, Lower Saxony and North Rhine-Westphalia in western Germany. Berlin was divided between the two republics. Lesser areas of Prussia were included in the *Länder* of Mecklenburg in eastern Germany, and of the Rhineland-Palatinate, Hesse and Baden-Württemberg in western Germany. Though the boundaries of the new *Länder* usually followed the former political pattern, some regard was also paid to their economic character. Prussia was formally liquidated by a law of the Allied Control council on Feb. 25, 1947.

Physical Features.—The greater part of Prussia belongs to the Great European plain, though its surface is more varied than that bare statement suggests. The plain is narrowest in the west, being only 75 mi. wide between the Weser uplands and the North sea. It includes three divisions, markedly different in character: (1) west of the lower Elbe, a region of reclaimed *Märschen* along the coast, of *Moor* or ill-drained peat bogland behind it, and of dry, sandy *Geest* lands further inland; (2) east of the Elbe, with the low Baltic heights next the coast and the belt of *Urstromtäler,* wide marshy valleys, to the south; (3) the fertile *Börde* strip along the edge of the uplands and with wide "bays" (Cologne, Münster, Leipzig and Silesia) reaching south into the mountainous country. In the southwest, most of the Rhine plateau country, the Harz and Weser uplands and part of the Triassic hill country (with the volcanic Vogelsberg and Rhön) fall within the Prussian area. The borderlands between Silesia and Czechoslovakia are also mountainous. The lowland courses of all the north German rivers are thus within the Prussian frontiers.

Prussia contains a large proportion of woodland, the most extensive forests being in East Prussia, Silesia and Brandenburg where conifers prevail. In the Rhenish and Hessian lands oaks and beeches are most prominent. The northwestern lowlands had few trees but in recent years large plantings of conifers have been made on the drier sandy lands. The heavy cutting after 1933, when importation of constructional timber was restricted, seriously depleted reserves.

Climate.—As could be expected from its position in the continent, the climate of Prussia is transitional between the rainy and changeable type of western Europe and the more stable but more extreme type of eastern Europe. Winters everywhere are usually cold enough to stop work on the land, west Prussia having one month and east Prussia three months with mean temperatures below freezing. In an average winter snow falls on 34 days in Berlin and the Rhine is ice-bound at Cologne for 21 days. Summers are generally warm (63° to 66° F. in July) and rather rainier than the winters. Rainfall decreases from west to east but temperature ranges increase, mainly because winters are colder.

Area and Population.—In 1939 Prussia had a total area of 117,883 sq.mi. and, according to the census of 1939, a population of 41,762,040. The six new *Länder,* with a total area of 55,814 sq.mi., had in 1939 a population of 28,269,000, increased to 30,766,000 by 1946. World War II and the postwar years saw considerable movements of population throughout the Prussian area. The North Rhine-Westphalian districts continued to have the densest populations (896 per sq.mi. in 1946) but the largest increases were in the eastern sections of west Germany. During the war there was a tendency to place new industrial establishments there rather than in the Rhine districts, where they were more accessible to Allied bombing. The *Auslands-deutsche* recalled between 1939 and 1944 were mainly settled in the eastern portions of Prussia. The still larger migration of about 9,000,000 people expelled from Poland and Czechoslovakia added to this westward movement. After the war the movement was continued by the refugees passing from east to west Germany. Large population increases, especially in rural districts, have been caused in this way, notably in Schleswig-Holstein and Lower Saxony.

Agriculture.—Except in Westphalia and the northern Rhinelands, and along a narrow belt from Münster to Silesia, where there was a slight predominance of industry, agriculture was everywhere the main occupation of the people of Prussia. The chief arable areas were along the Baltic coast and on the loess soils of the *Börde.* In Brandenburg and Lusatia arable land was mixed with woodland, on the geest with sandy waste. The reclaimed marshlands were either under the plow or meadow. Grasslands dominated the area from Schleswig-Holstein to the lower Rhine. Rye was the main grain crop everywhere (about 75% of the grain-growing area), especially prominent between the lower Ems and

the Weser, and in Brandenburg and Posen. Wheat and winter barley were restricted to the better soil areas of the *Börde*, the drained marsh soils of the Elbe and Vistula, and the Lower Rhine. Oats became an important crop on the northwest lowlands, especially near the sea. The potato was widely grown, with heavy production east of Berlin and the middle Elbe. On the Rhenish plateau it took the place of grain as the main food crop. In later years sugar beet had become of very great importance as a crop on the *Börde* in Hanover and Saxony, and west of Cologne. In normal years there were surpluses of rye, oats and sugar.

The production of livestock did not meet the demand before World War II, nor was there a sufficiency of dairy produce. Cattle were most numerous in Schleswig-Holstein, and pigs were raised and fattened in great numbers, particularly on the lowland between Hamburg and the Ruhr. The numbers of sheep showed a long-continued decrease. Stall feeding of cattle was general except on the North sea *Märschen* where all-year outdoor grazing of dairy cattle was possible. Forage crops were widely grown and there was considerable import of animal foodstuffs, though the spread of sugar beet, with the use of the tops and the pulp from the sugar factories, had lessened the need for this. The value of animal products far exceeded that of crops.

Most of the land east of the Elbe and in Silesia was in large holdings of more than 250 ac., that in the western lowlands and the Rhine lands in holdings of 12 to 50 ac. The farms of the *Börde* were of intermediate size. During the nazi period steps were taken to divide some of the larger holdings and to consolidate the smallest. Under Soviet direction all holdings of more than 250 ac. were to be eliminated and subdivided into farms of 20 ac. About half the farms in the eastern zone were of this size by 1952.

Before World War II western Germany imported about 40% of its food and the east German area lacked some foods (*e.g.* meat, formerly secured from Schleswig-Holstein, and supplementary grain from Silesia). The lands taken over after the war by the U.S.S.R. and Poland formerly provided nearly a quarter of Germany's agricultural production. Since the population of the German Federal and Democratic republics is roughly equivalent to the prewar population of the whole Reich the loss of these Prussian areas created a serious problem.

The principal wine-growing districts of Prussia are the Rheingau and the Rhine province. The vineyards are terraced on the stony, southward-facing slopes of the Rhine and its tributaries, especially the Saar and the Moselle. The harvest is so uncertain that the industry can be maintained only by concentration on high-grade wines.

Mining and Power Production.—Prussia was far the largest producer of minerals in the Reich. Seventy per cent of German coal (127,000,000 tons in 1938) was mined in the Ruhr and a further 13% (26,000,000 tons) in Silesia. The high-grade coking coals of the Ruhr were of special importance in the metal industries. The Silesian field came entirely into Polish hands after World War II. The utilization of the Prussian lignite (brown coal) deposits was greatly extended after 1919, the output increasing to more than 250,000,000 tons in 1943. Two-thirds of this came from Brandenburg and the area between Magdeburg and Leipzig, the one-third from the Ville field west of Cologne. Oil is found near Hanover but the output of the wells is far exceeded by the synthetic production from coal and lignite. Most of the home-produced iron ore, only a small fraction of that consumed, was mined in the Hanover area and the Siegerland. Small quantities of ores of copper and of lead and zinc are still obtained from the Harz. Before it lost the Silesian mines in 1919 Germany ranked first in Europe as a zinc producer. The Stassfurt deposits are still an important source of salt, of potash for the chemical industry and of magnesium for the making of aluminum alloys. Before World War II Germany had a larger production of electricity than any other country in Europe, nearly all from thermal stations on or near the lignite (40%) and coal (36%) fields.

Industry.—Of the 14,500,000 people employed in German industry in 1939 about 9,000,000 were in Prussian factories and workshops. The main concentrations were on the Ruhr coal field and along the Rhine front within easy reach of it, on the lignite field of the middle Elbe, and in Berlin and the North sea ports. The iron and steel industry was located on the Ruhr field because of its coke supplies. From its first development until 1919 it used principally the Lorraine ores but since that date has depended on imported (mainly Swedish) ores. Heavy engineering was closely situated around the steelworks but fabrication and light engineering were more widely dispersed; *e.g.*, shipbuilding at Bremen and Hamburg, railway material at Essen and Berlin, motor cars at Frankfurt. The largest manufacturers of electrical machinery had their works in Berlin. The heavy chemical industry, using coal, lignite and potash as basic materials, naturally developed on the Ruhr and the middle Elbe. Finer chemicals were manufactured around Frankfurt. The chief area for textiles was the Wuppertal, south of the Ruhr.

The dismantling of industrial plants and the breakup of the large cartels were prominent features of Allied policy immediately after World War II. The resulting widespread unemployment soon led to a reversal of the former and the latter was applied less drastically than was originally planned. In the German Federal Republic the production of electricity was in 1953 about double the prewar level, lignite exceeded the prewar level, and coal and textiles had reached it. Steel production was still limited to about two-thirds of the old level. In the German Democratic Republic where dismantling was carried much further and a large part of the remaining products were taken by the U.S.S.R. as reparations, output was still low though increasing as earlier restrictions were withdrawn.

Communications.—Prussia was excellently provided with internal means of communication. Its railway network included about 17,000 mi. of track. The main trunk route was from west to east, through Aachen, Cologne, Düsseldorf, Hanover, Berlin, Danzig and Königsberg. Important lines followed the Rhine in the west and radiated from Berlin to link the North sea and Baltic ports with southern Europe. In the years immediately before World War II they were supplemented by the through motor roads (*Autobahnen*). All the rivers are navigable across the plain and these were connected by an extensive canal system. The great Mittelland canal, opened in 1938, joined the Elbe with the Rhine, and the Dortmund-Ems system served the Ruhr area, while the Kiel ship canal gave a short route from Hamburg to the Baltic sea. The division of western and eastern Germany gravely disrupted the whole transport system, cutting off Hamburg from most of its hinterland and Berlin from its North sea ports.

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HISTORY

The state of Prussia, which has played so great a part in the history of Germany, came into being gradually, being formed out of wholly dissimilar components. The chief of these were the mark of Brandenburg and the state of the Teutonic Order in Prussia (*i.e.*, the country originally inhabited by Prussians, Prusi or Borussi, a Baltic people speaking a language akin to Lithuanian and Latvian). The history of each of these, up to their union, must be treated separately.

The Teutonic Order.—In 1226 the Polish duke Conrad of Mazovia invited the Teutonic knights into his territory to combat the heathen Prussians. After a difficult struggle, the order conquered the territory, exterminated most of the native population, and invited German peasants and townspeople into the country as settlers. In the 14th century the state ruled by the knights was a power in northeastern Germany. In 1308 it conquered Polish Pommerellia and for a time the Neumark also, and through its connection with the Order of the Sword, of Livonia, extended its influence as far as Estonia. A string of flourishing cities sprang up along its coast. In Marienburg, since 1309 the seat of the

grand master of the order, the splendid castle was built which to this day testifies to the past glories of the order, and formed the centre of its admirably organized administrative system. But even in the 14th century the order was beginning to decline, owing mainly to the fact that once the struggle against the heathen was ended, it lost its original spiritual character, occupied itself only with purely mundane tasks, and thus lost touch with its original purpose. The rule of the knights, who admitted none of the local nobility into their ranks, came to be felt by the inhabitants as a foreign rule. When Poland and Lithuania united into a powerful state at the end of the 14th century, and the rulers of this state began to plan the recovery of the Baltic coast, the order could not rely fully either on the nobles or on the towns in its territory. After the defeat of their army at the battle of Tannenberg (1410) the knights were forced to cede part of their territory to Poland. In a second war the Poles took Marienburg, and at the peace of Thorn (1466) forced the order to cede them West Prussia and Ermeland, with Danzig and Thorn, and to acknowledge the suzerainty of the Polish king for the rest of their territory. At the beginning of the 16th century, the Reformation began to penetrate these regions also, and the grand master of the day, Albert of Brandenburg, a grandson of the elector Albert Achilles, proceeded, with the consent of the king of Poland, to take the decisive step which was tantamount to the end of the order's rule. He went over to Protestantism, at the same time proclaiming himself hereditary duke of Prussia (1525). As his only son, Albert Frederick (1568–1618), was an imbecile, the power passed almost wholly to the estates. Albert Frederick's eldest daughter, Anna, married the elector John Sigismund, and through her Prussia passed in 1618 to the electors of Brandenburg. As Anna was also co-heiress through her mother of the great territories which had been united under the rule of the dukes of Jülich, Cleve and Berg on the lower Rhine, and as this ducal house had become extinct a few years previously (1609), the electors of Brandenburg could hope to acquire not only Prussia, but also considerable domains in west Germany. (*See* BRANDENBURG.)

Frederick William I.—Frederick William I (1713–40), the son and successor of Frederick I, has long been unjustly represented as a crude tyrant. He was a sober-minded man, without any strong intellectual interests, but a first-class organizer and imbued with a stern sense of duty, based on religious sentiment, and he devoted his whole soul to the service of the state. He resumed the work begun by his grandfather, the Great Elector, and is the true father of the Prussian administrative system and Prussian officialdom. He created a new central administrative service in the shape of the general directory, for which he drew up the instructions himself (1723). This organ acted as a general ministry, in which the agenda was distributed to the several members, partly by subject, partly on local lines, while all important measures were decided in general conference. The king reserved to himself the final decision. Each official received a commission stating his duties, emoluments and exact official regulations. All official bodies had to keep a record of, and send in a weekly report on, their activities. In most cases officials were nominated by the king at his discretion; only in the selection of the *Landräte*, who were in charge of the provincial districts (*Kreise*) the nobles still had a certain voice. Officials and magistrates were obliged to pass through a definite course of training, and could not be appointed unless they had passed the prescribed examination. The king organized a regular procedure of judicial appeal, making the *Kammergericht* in Berlin the supreme judiciary instance for the whole state. Judicial procedure was also simplified and improved in important respects. In the financial administration he introduced the strictest economy. He succeeded in increasing the revenue from the royal domains and prerogatives and from the indirect taxes to a considerable degree, and in achieving an annual surplus. This he put into a state exchequer, which contained 7,000,000 thaler at his death. He made special efforts to encourage trade and industry, following the principles of the mercantile system (*q.v.*), which at that time were everywhere accepted. As the country was thinly populated, he encouraged the immigration of efficient labour. Just as his grandfather had admitted a large number of the Huguenots expelled from France after the repeal of the Edict of Nantes by Louis XIV, so Frederick William allowed the Protestants expelled by the archbishop of Salzburg to enter his kingdom, settling most of them in East Prussia. Foremost a soldier, the king devoted particular attention to the training of the standing army, the numbers of which he raised from 40,000 to 80,000. It was still a mercenary army, recruited from volunteers at home and abroad. He took pains, however, to ensure that as high a proportion as possible should be composed of his own subjects and divided the whole Prussian territory into recruiting districts, the so-called "cantons"; each district was obliged to supply the men for one specified regiment. The recruiting was often done in a very arbitrary fashion, which gave rise to many complaints. Definite instructions were drawn up and regular inspections carried through to ensure uniformity of training; the army thus created was superior to those of most other states. It was Frederick William who first gave Prussia the characteristic stamp of a military and bureaucratic state.

For all his military inclinations, Frederick William was a peaceable man by nature, and in his foreign policy always avoided military entanglements. When he came to the throne, Prussia was embroiled in the Northern War; at the conclusion of peace he succeeded in securing Western (Hither) Pomerania up to the Peene, which had formerly been in the hands of Sweden, with the important commercial town of Stettin. He failed, however, to secure support for his claims, which were based on old succession treaties, to further portions of the Cleve-Jülich heritage and to parts of Silesia. As a loyal German, he thought it his duty to maintain as good relations as possible with the emperor; but encountered profound mistrust in Vienna, where the growing strength of the Prussian state was watched with concern, and toward the end of his life was forced into an increasingly sharp opposition to the house of Habsburg.

Frederick the Great.—Frederick William died in 1740. He was succeeded by his son, Frederick the Great (1740–86), who was at that time 28 years of age. He had had violent conflicts with his father in his younger days, as his passionate and freedom-loving nature revolted against the severe discipline which his father thought necessary. Furthermore, the younger man's inclinations led him toward the new ideas of the *Aufklärung*, while the old king was a strict Calvinist. The crown prince's attempted flight (1730) brought this conflict to a head. The king had his son imprisoned, and even had an idea of excluding him from the succession; Frederick was only able to buy a reconciliation at the price of complete submission to his father's will. He was obliged to pass through a strict training in the administrative service and the army, a training which did much to prepare him for his later career.

For Frederick's conflicts with Maria Theresa in the first half of his reign, see AUSTRIA, EMPIRE OF; AUSTRIAN SUCCESSION, WAR OF; GERMANY; SILESIA. They ended in the acquisition of Silesia, with the exception of a few small districts south of the Riesengebirge, which remained in the hands of Austria. Frederick's successful resistance in the Seven Years' War against Austria, France and Russia raised his prestige enormously. From this time onward his state was recognized as a European great power. In addition to Silesia, he had also acquired East Frisia which came to him in 1744 on the extinction of the old princely house, through a succession treaty. At the first partition of Poland (1772) he also acquired West Prussia (except Danzig and Thorn), a particularly important district because it bridged the gap between East Prussia and the Brandenburg family dominions. Frederick carried on the internal development of the Prussian state on the lines laid down by his father. He instituted a general civil code for his state in the shape of the Prussian *Landrecht*—a work not completed until after his death; accelerated judicial procedure, abolished torture, and introduced the principle that the crown should not interfere with the course of justice. In administrative matters, he sought to pay special consideration to the local peculiarities of the different provinces, and made frequent journeys of inspection to satisfy himself that his orders were being carried out. The fiscal system was further developed; but an attempt to introduce the

farming of taxes, on the French model (1766), proved unsuccessful and had to be abandoned. Under his rule the state revenue increased largely; on his death he left 55,000,000 thaler in the state exchequer. He had the low-lying country of the Oder and the Warthe drained, settled villages of colonists in the Pomeranian forests, arranged for the plantation of hops and potatoes, and founded factories. He left several detailed exposés of his administrative and political principles, notably in his political testaments of 1752 and 1767, which were designed to serve as a guide to his successor. Like his father, he considered himself the first servant of the state, and said that the prince should govern as though he had to render account to his subjects for all his measures. It did not, however, occur to him to do so. He rarely consulted with his ministers in person; he called for reports from them in writing, and dictated the answers, which he sent to them in writing. His liberal views in matters of religion led him to adopt the policy of toleration, on principle, toward the different churches: a policy which was also naturally dictated by practical considerations in a state which included a Protestant majority and a Catholic minority. His lively interest in all intellectual questions led him to take measures to improve the level of public education. In the upper schools the classics were made the principal subject of instruction. The king wished to establish compulsory primary education for all children from 5 to 13, but lack of means made it impossible to carry this out. Although Frederick was deeply influenced by the humanitarian ideas of the *Aufklärung,* and considered the furtherance of the people's welfare and of popular education to be among the monarch's essential duties, yet his guiding thought remained always to raise the forces of his comparatively small, weak state, by better organization, so as to maintain the position of power which he had won.

Collapse and Reform.—As Frederick left no issue from his marriage, contracted at his father's orders, with a princess of Brunswick, and as his younger brother, Augustus William, had predeceased him, the latter's son, Frederick William II, succeeded him on the throne (1786–97). He was indolent and dissipated, squandered the state exchequer and left the cares of government to his favourites. Under his reign no progress was made in the domestic organization of the state. In foreign affairs his participation in the war against revolutionary France brought him only losses, while the large accessions of territory that the second and third partitions of Poland (1793 and 1795) brought him were gains of but doubtful value. For the Prussian state, which after 1795 extended as far as Warsaw, thus received so large a percentage of Polish blood that had these frontiers proved permanent, its German character would have been endangered.

His son, Frederick William III (1797–1840), was a man of the best intentions, but pedantic, vacillating and narrow. The government fell more and more into the hands of the cabinet councillors who, under the system introduced by Frederick the Great, formed the sole channel of communication between the king and the ministers. But while under Frederick the councillors had been only executive organs of the king's will, under his weak successors they became the all-important personal advisers of the monarch. The Prussian state still kept the outward form given it by Frederick William I and Frederick the Great; but the living spirit was gone from it, and its swift and complete collapse after the first great military reverse (Jena, 1806), is easily comprehensible. Under the peace of Tilsit (1807) Frederick William was obliged to cede his entire territory west of the Elbe and the greater part of his acquisitions in Poland; he retained only Brandenburg, Pomerania, Prussia and Silesia. This fearful collapse, however, also released the forces of reconstruction which still lived on within the state, and during the so-called "period of reform" a complete reconstruction of the state was begun. The king himself always remained disassociated from, and at heart hostile to, these efforts, which appeared to him as a concession to Jacobinism; but as he knew no plan of his own for reconstructing the shattered state, he was forced to let the apostles of the new ideas have their way.

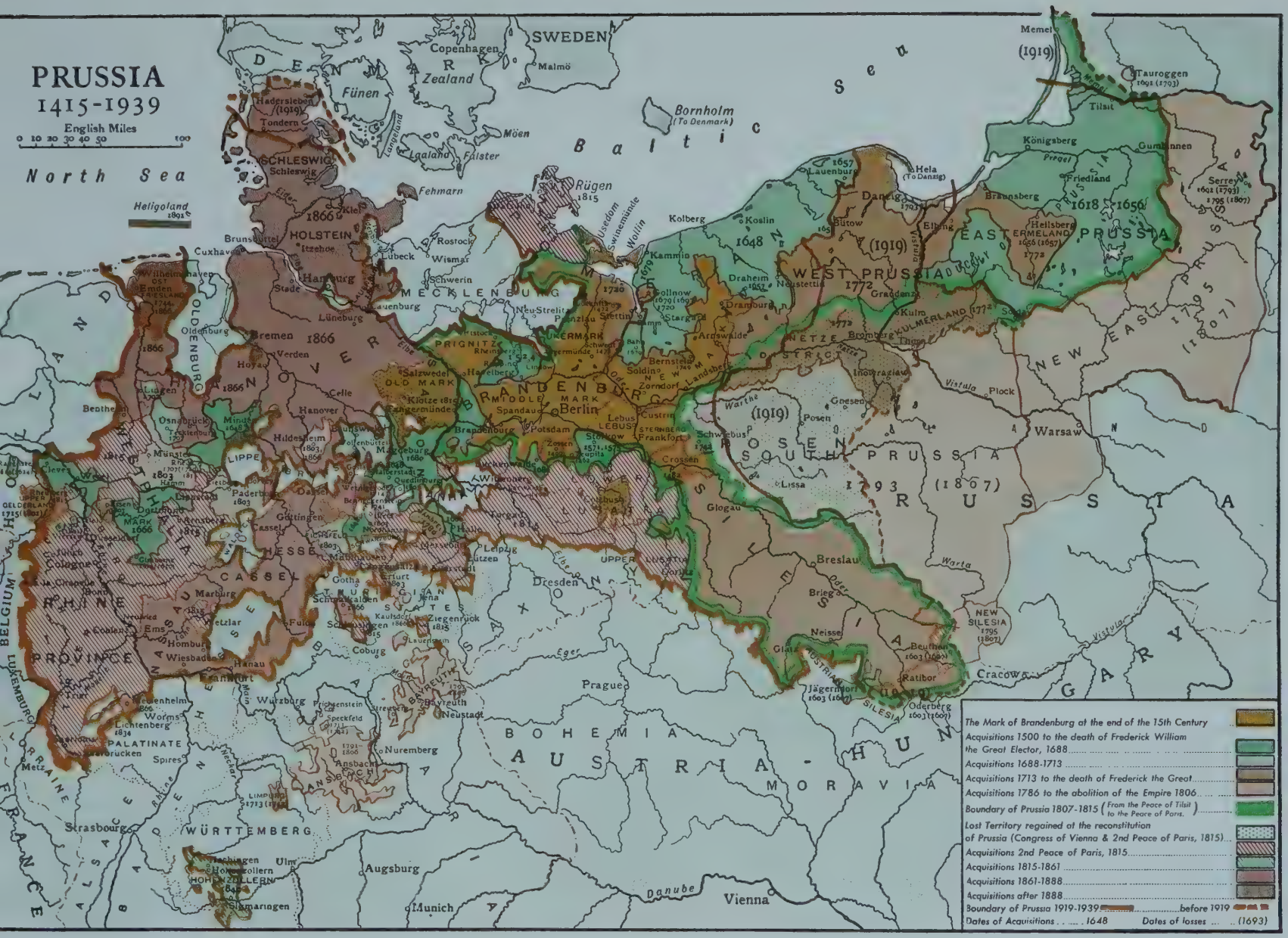
Heinrich, baron vom und zum Stein became the leading figure in the administration. He had long been urging reforms, but before 1806 without success. His fundamental idea was that in a modern state the people itself must be required to help in the conduct of public affairs because the state cannot exist unless it can count upon the willing co-operation and devotion of its citizens. The most important measures which he carried through were the liberation of the peasants from serfdom, the reintroduction of municipal self-government under the Municipal act of 1808, and the abolition of cabinet government. He also planned to introduce self-government in the rural districts and participation of representatives of the people in the provincial administration and the central government. He was unable, however, to carry these measures into practice, being dismissed in the autumn of 1808 at Napoleon's order. The reforms were taken up again by Karl, prince von Hardenberg, in 1810, on his appointment as head of the ministry, although on lines rather different from those intended by Stein. Hardenberg really inclined more to enlightened despotism than to Stein's idea of self-government. His principal achievements were the reorganization of the finance and of the administrative system, the abolition of restrictions in industrial life, and the edict of 1811 which made the peasants free proprietors of their holdings, in return for the cession of a part of them to the former landlords. The peasants were thus required to buy their ownership at the price of giving up part of their holdings. Moreover, as the smaller holdings were excluded from the measure, the landlords could now take full possession of them, and their former cultivators sank to the position of agricultural labourers without property.

These years also saw a great reorganization of the army, carried through by Generals Gerhard von Scharnhorst and Hermann von Boyen. The underlying principle was the transformation of the mercenary army into a national army. Universal service was introduced, degrading punishments abolished, admission to the corps of officers revised and the internal organization of the army rearranged in more practical form. But for these reforms in all directions, the little state would have been incapable of the great achievements which it performed during the War of Liberation.

The Congress of Vienna.—After Napoleon's defeat in Russia, the Prussian General Hans Yorck von Wartenburg took his forces over to the Russian side and Frederick William III reluctantly followed his lead. The Prussian army played a principal part in the overthrow of Napoleon and Prussia re-emerged as a great power. At the Congress of Vienna, Prussia did not recover its Polish lands lost in 1807, which now went to Russia. In compensation it received Western Pomerania, the northern half of the kingdom of Saxony, Westphalia and the Rhineland. Its population was increased from under 6,000,000 to 10,000,000. Prussia ceased to be a northeastern German state and straddled across Germany. For the first time also it counted a large number of Roman Catholics amongst its people.

In the excitement of liberation the king had promised a constitution; after 1815 the promise was ignored. All that remained of it was the assurance that the state would not raise any new loan without the consent of an elected body. Meetings of the estates were introduced for the individual provinces, but they were given only an advisory voice in local affairs. Prussia continued to be run by the old nobility and bureaucracy, who were increasingly out of touch with the liberal sentiment of the western provinces. The only striking advance in the reign of Frederick William III was the creation of the *Zollverein* (virtually complete by 1834) which brought all the German states except Austria under Prussian economic leadership.

The 1848 Revolution.—On the death of Frederick William III, his eldest son Frederick William IV (1840–61) ascended the throne. He had grown up in an age when the theories of romanticism had dominated Germany; these theories swayed him, and, like his father, he was averse at heart to the modern political demands. After long consideration, however, he determined in 1847 to convoke the members of all provincial diets to a united diet at Berlin. This body, however, immediately put forward a demand to be convoked at regular intervals, and to be recognized as a partner, with equal rights, in the legislation. The king refused to admit such claims, and the deliberations led to no practical result. Nevertheless, it was an event of no small importance


PRUSSIA
1415-1939
English Miles
0 10 30 30 40 50 100
North Sea
Heligoland 1891
Baltic Sea
SWEDEN
DENMARK
Copenhagen
Zealand
Malmö
Fünen
Bornholm (To Denmark)
Möen
Falster
Langeland
Laaland
Hadersleben (1919)
Tondern
SCHLESWIG
Schleswig
Eider
Fehmarn
Rügen 1815
Usedom
Swinemünde
Wollin
Kiel
1866
HOLSTEIN
Itzehoe
Brunsbüttel
Cuxhaven
Rostock
Lübeck
Wismar
Hamburg
Stade
Lüneburg
Schwerin
MECKLENBURG
Oldenburg
Wilhelmshaven 1937
Emden 1744 1815 1866
OLDENBURG
Bremen 1866
Verden
Hoya
Lingen
Celle
Benthe
Osnabrück
Minden 1648
Tecklenburg
Hanover
Hildesheim 1803 1866
Münster
LIPPE
Paderborn 1803
Detmold
Arnsberg
Cleves
Wesel
Lippstadt
Dortmund
Hamm
Soest
Dalsen
Göttingen
Cassel
HESSE
Marburg
Wetzlar
Ems
Hombur
Wiesbaden
Hanau
Frankfurt
Coblenz
Cologne
Aachen
Bonn
Julich
Crefeld
Düsseldorf
Elberfeld
Barmen
Solingen
Remscheid
Essen
Bochum
Dortmund
Gelsenkirchen
Recklinghausen
Duisburg
Mülheim
Oberhausen
GELDERLAND 1715 (1803)
RHINE PROVINCE
LUXEMBURG
BELGIUM
HOLLAND
Leeuwarden
Groningen
Emden
Oldenburg
Bremen
Hoya
Celle
Hanover
Hildesheim
Münster
Paderborn
Arnsberg
Dortmund
Essen
Cologne
Aachen
Bonn
Coblenz
Wetzlar
Marburg
Cassel
Göttingen
Hanau
Frankfurt
Wiesbaden
Worms
Lichtenberg
Kreuznach
Saarbrücken
Metz
Spires
PALATINATE
Strasbourg
LORRAINE
ALSACE
FRANCE
Rhine
Moselle
Saar
Nahe
Lahn
Main
Neckar
Tauber
Fulda
Eder
Weser
Aller
Leine
Ems
Elbe
Saale
Havel
Spree
Oder
Warta
Vistula
Memel (1919)
Tauroggen 1795 (1793)
Tilsit
Niemen
Königsberg
Pregel
Gumbinnen
Friedland
Serrey 1795 (1807)
Hela (To Dantzig)
1657
Lauenburg
Dantzig 1793
Bütow
Elbing
Braunsberg
1618 1650
EAST PRUSSIA
Heilsberg ERMELAND 1466 (1657) 1772
1772
WEST PRUSSIA
Graudanz
Kulmerland 1772
Thorn
Bromberg
NETZE DISTRICT
Inowrazlaw
Plock
Warsaw
NEW EAST PRUSSIA 1795 (1807)
Kolberg
Koslin
1648
Kammin
Pollnow 1679 1720
Stargard
Draheim 1657
Neustettin
Dramburg
Arnswalde
Landsberg
Bernstein
Soldin
NEW MARK
Zorndorf
Frankfort
Lebus
Custrin
Stargard
Stettin
Pyritz
Pomerania
Hinterpommern
Lauenburg
Neu Strelitz
Pasewalk
Prenzlau
Ueckermünde
Schwedt
Barnim
Lebus
Oderberg
Angermünde
Klotze
Salzwedel
OLD MARK
Gardelegen
Havelberg
Spandau
Berlin
Potsdam
Brandenburg
Zossen
Stendal
Tangermünde
Osterburg
Werben
Wittenberge
Perleberg
Ludwigslust
Schwerin
Rathenow
Ruppin
Zehdenick
Templin
Prenzlau
Angermünde
Eberswalde
Bernau
Fürstenwalde
Frankfurt
Crossen
Sternberg
Züllichau
Schwiebus
Posen
Gnesen
Lissa
Glogau
Sagan
Sprottau
Crossen
Guben
Cottbus
Luckau
Lübben
Torgau
Wittenberg
Dessau
Bernburg
Halle
Leipzig
Lützen
Merseburg
Naumburg
Weissenfels
Zeitz
Altenburg
Eisenach
Gotha
Erfurt
Weimar
Jena
Sömmerda
Arnstadt
Meiningen
Schmalkalden
Kaulsdorf
Ziegenrück
Lauenstein
Coburg
Hildburghausen
Sonneberg
Saalfeld
Rudolstadt
Greiz
Zeitz
Naumburg
Merseburg
Weissenfels
Torgau
Wittenberg
Dessau
Bernburg
Halle
Leipzig
Lützen
Dresden
Meissen
Grimma
Chemnitz
Zwickau
Plauen
Hof
Bayreuth
Baireuth
Neustadt
Culmbach
Kulmbach
Nuremberg
Ansbach
Speckfeld
Prozenstein
Würzburg
Schweinfurt
Aschaffenburg
Darmstadt
Mannheim
Heidelberg
Karlsruhe
Rastatt
Baden
Offenburg
Freiburg
Constance
Tübingen
Ulm
Augsburg
Munich
Danube
Vienna
Prague
BOHEMIA
AUSTRIA-HUNGARY
MORAVIA
Brieg
Breslau
Neisse
Glatz
Beuthen 1603 (1624)
Ratibor
Jägerndorf 1603 (1624)
Oderberg 1603 (1609)
Cracow
NEW SILESIA 1795 (1807)
AUSTRIAN SILESIA
SILESIA
Lusatia Upper
Lusatia Lower
Vistula
Warta
Oder
Elbe
Eger
Main
Danube
The Mark of Brandenburg at the end of the 15th Century
Acquisitions 1500 to the death of Frederick William the Great Elector, 1688
Acquisitions 1688-1713
Acquisitions 1713 to the death of Frederick the Great
Acquisitions 1786 to the abolition of the Empire 1806
Boundary of Prussia 1807-1815 (From the Peace of Tilsit to the Peace of Paris.)
Lost Territory regained at the reconstitution of Prussia (Congress of Vienna & 2nd Peace of Paris, 1815)
Acquisitions 2nd Peace of Paris, 1815
Acquisitions 1815-1861
Acquisitions 1861-1888
Acquisitions after 1888
Boundary of Prussia 1919-1939 before 1919
Dates of Acquisitions 1648
Dates of losses . . . . (1693)

that representatives of all parts of the Prussian state had, for the first time, met for common parliamentary debates.

Soon after this, revolution broke out all over Germany. Although the military remained the victors in the street fighting of March 18 in Berlin, the king nevertheless decided to give way and withdraw the troops from Berlin. He agreed to the convocation of a constituent national assembly, which was to meet in Berlin and collaborate with him in drawing up a constitution. But as democratic elements gained the upper hand in this assembly, the king dissolved it and enacted a constitution (Dec. 5, 1848), with the proviso that a freshly elected parliament should negotiate further on its final form. These negotiations proving very protracted, the parliament was again dissolved in the spring of 1849, and it was only when a chamber was elected on the three-class franchise that agreement was at last reached on a definitive constitution, to which the king took the oath on Feb. 4, 1850. Prussia now received a parliament, consisting of two chambers; the first chamber, called the *Herrenhaus* after 1854, was composed of representatives of the large landed proprietors and of the larger towns, and of members nominated by the king, either for life, or as hereditary members. The second chamber was elected by all taxpaying citizens, but as the electors were divided into three categories, according to taxes paid, electors with larger incomes were given much greater influence than the poorer classes. Yet, despite the limited franchise, this was a genuine constitution. The chambers had defined rights and were entitled to meet regularly. The budget was to be agreed annually between the chambers and the crown—a phrase which seemed to imply, though it did not, a large measure of parliamentary sovereignty. Inadequate as the constitution appears by democratic standards, without it there would have been later no constitutional conflict at all.

During the revolution of 1848 Frederick William IV hoped to lead the movement for unification. He said in a famous phrase: "Prussia is merged in Germany." His conservative principles soon reasserted themselves. On April 3, 1849, he refused the imperial crown, when it was offered to him by the Frankfurt national assembly; he would only accept it, he said, from the German princes. He and his friend Joseph Maria von Radowitz attempted to build a lesser German union, on conservative lines, known as the Erfurt union. In 1850 this was challenged by Austria; and as Frederick William shrank from war, Prussia was obliged to abandon its ambitions by the agreement of Olmütz or Olomouc (Nov. 2, 1850).

William I and William II.—A period of reaction followed in Prussia. Frederick William IV appointed an extremely reactionary government, which remained in power until he became insane in 1857. His brother, William, prince of Prussia, acted as regent until his death (Jan. 2, 1861) and then ascended the throne as William I. The new ruler took at first a more liberal line than his brother. In 1858 he appointed a liberal ministry under Prince Hohenzollern, and for nearly four years Prussia experienced "the new era." William and his minister of war, Albrecht, count von Roon, disagreed, however, with the chamber over the reorganization of the army. Roon wished to increase the army establishment, which had remained stationary since 1815, so that every Prussian should perform his military service. The lower chamber were ready to agree with this, but insisted in return that the period of service be reduced to two years and that the *Landwehr*, or reserve, should play a more independent part. The struggle which followed was a conflict over the character of the Prussian army, not its size. By the constitution, the taxes were imposed permanently. The chamber could not cut off supplies. It could only refuse to authorize the expenditure of money already collected. In 1861 they authorized the additional expenditure for a single year. In 1862, as their demands were still refused, they refused authorization altogether. William first thought of abdicating. At the last minute Roon persuaded him to appoint Otto von Bismarck minister president (Sept. 23, 1862).

As the lower chamber refused to accept the budget which the king and the upper chamber had put forward, Bismarck argued that there was "a hole in the constitution"; and he governed without a budget for the next few years. The liberals were helpless. It would have been unconstitutional to refuse the taxes. They could only protest and wait for Bismarck to fail in his foreign policy. Instead he succeeded, and his defeat of Austria in 1866 led many liberals over to his side. He in turn was willing to confess the illegality of his actions. He asked for and received an Act of Indemnity (Sept. 1866).

Campaigns of 1864–71 which led to union of Germany under Prussia's leadership cannot be told here. (*See* SCHLESWIG-HOLSTEIN QUESTION; GERMANY; AUSTRIA, EMPIRE OF; FRANCO-GERMAN WAR.) The acquisition of Hanover, Kurhesse, Nassau and Frankfurt-am-Main after the war of 1866, gave Prussian territory a wholly new aspect. Its eastern and western halves, which up to this date had been separated by these districts, were now linked up into a single great north German state, containing nearly two-thirds of the total population of Germany (in 1914, 40,000,000 out of a total population of 67,800,000).

With the unification of Germany in 1871 the king of Prussia became German emperor, in supreme command of all German armed forces. The Prussian army was, in fact, the main instrument by which Prussian power was extended throughout Germany. Bismarck also combined Prussia and Germany in his own person. He was both political head of the empire as *Reichskanzler* and Prussian minister president. Roon was Prussian minister president for a short period in 1872–73; but when he fell ill Bismarck resumed the office and kept it until 1890. His successor Georg Leo von Caprivi gave up the position of Prussian minister president; but this led to a conflict of policy between the two offices and ultimately to his resignation. The two posts were then reunited until the end of the empire in 1918.

The alliance concluded by Bismarck with the liberals at the time of the foundation of the empire had important effects. The Local Government act of 1872 increased the autonomy of the rural districts, thus linking up with the traditions of the age of Freiherr von Stein. The so-called *Kulturkampf*—the struggle against the Roman Catholic Church which was waged in the '70s—was also in accord with liberal ideas. It ended, however, finally, with the state restoring to the church its control over the preliminary training of the clergy, and retaining only a right of veto over appointments to ecclesiastical posts.

During the short reign of Frederick III (March–June 1888) and under William II, the situation remained in essence unchanged. The new Rural Districts act (*Landgemeindeordnung*) of 1892 carried existing institutions a step further. The fiscal reform carried through about the same time by J. von Miquel made self-assessment the basis of taxation, and provided relief for the poorer classes and heavier contributions from large incomes.

Reform of the franchise was often discussed, to give Prussia the same universal suffrage as the reich; but these proposals never came to anything, and the three-class franchise survived until the revolution of 1918.

Republic of Prussia.—The revolution ended the Prussian monarchy. It also severed the connection between the Prussian prime minister and the imperial chancellor. Prussia became a *Land* of the Weimar republic, with the same universal suffrage. Since Prussia was the most industrialized part of Germany, its parliament had always a left-wing majority. Prussia was ruled between 1918 and 1932 by the Social Democrats, sometimes alone, sometimes in coalition with the Centre. The most outstanding personality was Otto Braun, the prime minister. Since the *Land* controlled the police, the Social Democratic government of Prussia was the essential defense of German democracy.

In 1932 the coalition of Centre and Social Democrats lost their majority. Franz von Papen, then chancellor, used this excuse to overthrow Prussian democracy. He was nominated imperial commissioner for Prussia by Pres. Paul von Hindenburg and expelled the democratic government. This made easier Hitler's accession to power on Jan. 20, 1933. Soon afterward Hermann Göring took Papen's place as ruler of Prussia. The Prussian constitution was set aside by the National Socialists, its legislature was abolished but it still led a nominal existence as a component part of the reich. (*See* also BRANDENBURG; GERMANY.)

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(E. BRA.; A. J. P. T.)

PRUSSIA, in the original sense, a territory of Germany, stretching along the Baltic coast for about 220 mi. and occupying an area of 24,083 sq.mi. The eastern part of this territory formed the duchy of Prussia, conquered and colonized by the Teutonic order and acquired by the elector of Brandenburg in 1618, furnishing his successor with his regal title in 1701. The western part, severed from the eastern half and assigned to Poland in 1466, was not annexed to Prussia until the partition of Poland in 1772, while the towns of Danzig and Thorn remained Polish down to 1793. The two districts were temporarily (1824–78) united to form a single province.

PRUSSIC ACID (HCN), also known as hydrocyanic acid or hydrogen cyanide, is a highly volatile, colourless liquid of extremely poisonous character. It was discovered in 1782 by K. W. Scheele, who obtained the compound from Prussian blue. In variable but generally small proportions it is widely distributed among plants in the form of glycosides; *i.e.*, in combination with sugars. Amygdalin (*q.v.*), which is present in bitter almonds, is an example of such glycosides; it yields prussic acid upon hydrolysis.

Preparation.—A convenient method of obtaining prussic acid in the laboratory is to add a cold mixture of 100 c.c. concentrated sulphuric acid and an equal volume of water slowly to 100 g. of coarsely granular potassium cyanide in a large flask connected to two U-tubes filled with anhydrous calcium chloride. The vapours emerging from these U-tubes are condensed by passing downward through a condenser and collected. Brine cooled to −10° C. is circulated through the jacket of the condenser. A fully anhydrous product is made by adding phosphorus pentoxide to the liquid thus prepared, shaking for a short period, and distilling once more.

Prussic acid is made commercially from sodium cyanide in a continuous manner, by bringing together a 23% aqueous sodium cyanide solution and 66° Bé sulphuric acid in a lead-lined generator, and condensing and collecting the vapours evolved. The sulphuric acid is kept slightly in excess over the cyanide in the course of the reaction. The residual prussic acid in the liquid, which forms 20% of the total, is recovered by boiling the solution, the vapours being condensed after a partial enrichment in a special "cooler." Prussic acid of 97.5%–98% strength is made from the combined crude condensate by fractional distillation. Large quantities of the acid are also prepared from commercial calcium cyanide by a similar process.

Important quantities of prussic acid are made in Germany from "Schlempe," a by-product of the sugar industry resulting from the treatment of beet molasses with strontia for the purpose of recovering the sugar present in this product. Schlempe contains 4% of nitrogen in the form of betaine, $(CH_3)_3N^+-CH_2-CO_2^-$, in addition to decomposition products of vegetable proteins. It is first distilled, the tarry matter carried over by the vapours being condensed and separated; the gases escaping the condenser are next preheated by passage through a tunnel in an externally heated chamber and are then conducted through the cyanizing chamber. This chamber is filled with firebrick checkerwork and is previously heated by direct gas fire to a temperature somewhat in excess of 1,000° C. The cyanized gas contains about 7% prussic acid, 7% ammonia and 24% carbon dioxide by volume. It is freed of ammonia by scrubbing with hot, dilute sulphuric acid. The prussic acid in the emergent gases is absorbed in water; and the aqueous solution thus obtained, which contains 2%–3% prussic acid, is fractionally distilled to recover the prussic acid. The acid is condensed to liquid and further refined, or it is directly converted to sodium cyanide.

Synthetic Methods.—Several possible methods for the synthesis of prussic acid have been investigated. Two such methods developed into successful commercial processes and became employed for the preparation of the compound on a very large scale. A brief description of these processes follows.

Synthesis by Controlled Oxidation of a Hydrocarbon Ammonia Mixture.—Prussic acid is formed when a mixture of methane and ammonia, containing an insufficient amount of oxygen for complete combustion, is passed through a glowing platinum gauze. The reaction giving rise to the compound may be expressed as $2NH_3+2CH_4+3O_2 \rightarrow 2HCN+6H_2O$. Leonid Andrussow, who discovered this method, developed it into a successful technical process.

Methane and ammonia are mixed in the approximate ratio 11:10, and sufficient air is added to the mixture to give an oxygen content of about 15.5%. The mixture is passed through two or more layers of incandescent platinum iridium gauze with 3% to 5% iridium. The gauze is constructed of 0.16-mm. wire. The several layers of the gauze, resting on a special support, are held between ceramic rings inside a short tube, the whole constituting the converter. The cold gases enter the converter usually at a linear velocity of 103 cm. per second, emerging at a temperature of 1,000°–1,030° C. at a little over 500 cm. per second. The heat generated by the reaction is sufficient to maintain the gauze at the desired temperature. The gases emerging from the converter may be passed through sodium hydroxide solution, after being cooled sufficiently. The prussic acid is quantitatively absorbed, and may be recovered as sodium cyanide. Alternatively, the ammonia is removed by scrubbing with dilute acid, and the prussic acid is absorbed in cold water in special towers and recovered by distillation.

Of the total ammonia fed into the converter, approximately 63% is utilized in the formation of prussic acid, and 10% to 20% is lost by complete combustion. Platinum losses resulting from catalyst deterioration amount to about 1 g. per metric ton of hydrocyanic acid produced.

Aliphatic hydrocarbons other than methane are capable of undergoing the reaction. Methane receives preference, however, since higher hydrocarbons tend to deposit carbon and cause what is known as spotting of the catalyst. This results in loss of efficiency and a greater rate of deterioration of the gauze.

Synthesis by Dehydration of Formamide.—In this process formamide is dehydrated in the vapourized condition by passing it, in admixture with a large proportion of ammonia, over an aluminum phosphate catalyst heated to 360° C. The reaction expressing the change is $HCONH_2 \rightarrow HCN+H_2O$. The original formamide ammonia mixture contains 3%–5% of formamide. Dehydration is carried out at atmospheric pressure and proceeds very rapidly. The prussic acid formed is absorbed in sodium hydroxide solution and may be recovered as sodium cyanide.

Formamide is prepared through the reaction of anhydrous ammonia with methyl formate at 30°–60° C. under a pressure of 15 atm.: $HCOOC_2H_5+NH_3 \rightarrow HCONH_2+CH_3OH$. It is purified to analyze 99.7% by fractional distillation. Methyl formate is made by the reaction of carbon monoxide with methyl alcohol in the presence of 1% sodium as sodium methoxide: $CO+HOCH_3 \rightarrow HCOOCH_3$. The reaction is carried out at 110° C. under 100 atm., and proceeds quite readily with evolution of heat. The product is freed from the dissolved sodium methoxide by distillation, and the mixture of methyl formate and methyl alcohol thus obtained is used directly for the preparation of formamide. The methyl alcohol recovered in the distillation step contains a small amount of unreacted methyl formate and is used for the preparation of additional quantities of methyl formate. The process is, therefore, essentially a complete synthesis of prussic acid, utilizing ammonia and carbon monoxide as the starting materials.

The yield of prussic acid based on ammonia exceeds 92%; it is somewhat more than 85% when calculated on the basis of carbon monoxide used. Approximately 5.5 lb. of methyl alcohol are lost in the process for every 100 lb. of prussic acid produced. The catalyst, if it should become deactivated by a coating of carbon, is reactivated by blowing air through the heated mass. It can be used for several years before it becomes necessary to replace it.

Physical and Chemical Properties.—Prussic acid boils at 25.7° C. and freezes to a snowlike, white mass melting at −14.9° C. It is highly volatile even in the frozen condition. The dielectric constant of prussic acid is the second-highest known, indicating the strongly polar character of its molecule. In this respect, the compound bears a great resemblance to water, and like water it is a strongly ionizing solvent. The abnormally high heat of evaporation of the liquid is also ascribable to the highly polar character of the molecule. Prussic acid is miscible in all proportions with water and most organic solvents. The vapours

of prussic acid are combustible and mixtures with air containing 7%–40% prussic acid by volume are explosive. The products of combustion are carbon dioxide and nitrogen.

The elements in the molecule of prussic acid may be combined in one of two possible ways, H—C≡N or H—N=C, designated respectively as the normal (nitrile) and the iso (carbylamine) forms. The fact that both methyl cyanide, $CH_3—CN$, and methyl isocyanide, $CH_3—NC$, result from the reaction of prussic acid with diazomethane, CH_2N_2, would seem to indicate that both forms co-exist in liquid prussic acid, possibly in a state of dynamic equilibrium (*see* ISOMERISM: *Tautomerism*). Evidence indicates that the molecules of normal structure largely predominate in the liquid.

The dissociation constant of prussic acid in aqueous solution at 18° C. is 1.3×10^{-9}, or $\frac{1}{230}$ that of carbonic acid, which is itself a weak acid. The degree of acidity developed in aqueous solution is, for this reason, too small to affect the colour of most indicators (*q.v.*). The vapours of prussic acid react with remarkable rapidity, nevertheless, with solutions of alkalies, which can therefore serve effectively for the elimination of the compound from a stream of air containing prussic acid.

Polymerization of Prussic Acid.—Prussic acid in the pure form is stable and can be kept unchanged almost indefinitely in sealed glass containers. The acid gradually polymerizes in the presence of minute amounts of substances of basic character such as ammonia, sodium cyanide, etc. The polymer is a black solid of approximately the same empirical composition as prussic acid. Polymerization is accompanied with the evolution of considerable heat and is greatly accelerated as the temperature rises. For this reason, the polymerization of comparatively large quantities, which may cause a great rise in temperature with the consequent rise in pressure, may result in an explosion. The addition of small quantities of a strong acid, or of compounds giving rise to acids by gradual reaction with water, effectively stabilizes the commercial acid.

Chemical Behaviour.—Prussic acid cannot be esterified directly. Its esters, R—CN (*i.e.*, the nitriles), are usually obtained through the interaction of an alkali metal cyanide with an organic halide or sulphate. Methyl cyanide can, for example, be prepared by heating methyl iodide with an alcoholic solution of potassium cyanide, according to the equation: $KCN + ICH_3 = CH_3CN + KI$. The fact that nitriles, R—CN, may be prepared through the dehydration of the amides of the corresponding acids, $R—CONH_2$, definitely demonstrates that these compounds are normal cyanides, R—C≡N. The reaction of organic halides with silver cyanide or mercuric cyanide leads to the formation of isonitriles, R—N=C, which differ in their properties from normal nitriles.

Prussic acid combines with aldehydes and ketones in the presence of small quantities of substances of basic character, such as potassium cyanide or amines, generally at room temperature, forming cyanohydrins. Acetaldehyde cyanohydrin results, for example, from the reaction of acetaldehyde with prussic acid: $CH_3CHO + HCN = CH_3CH(OH)CN$.

Prussic acid is capable of reacting with ethylene oxide under pressure in the presence of a basic catalyst at a moderately high temperature, to form ethylene cyanohydrin: $\overline{CH_2—CH_2O}+ HCN \rightarrow HOCH_2CH_2CN$. This compound is readily dehydrated on distilling in the presence of certain catalysts to acrylonitrile, $CH_2=CHCN$. This is the basis of the technical preparation of the latter compound, which has assumed great importance. Acrylonitrile, together with butadiene, is used in the preparation of the acrylic type of synthetic rubber. In the polymeric form it is used for the manufacture of an important synthetic fibre. Another commercial synthetic fibre is made from the copolymer of acrylonitrile and vinyl chloride.

Chlorine, reacting with prussic acid in dilute aqueous solutions, gives cyanogen chloride, ClCN: $2HCN + Cl_2 = ClCN + HCl$. Bromine reacts similarly, forming cyanogen bromide.

The cyano group, C≡N, present in prussic acid, is capable of various transformations because of the reactive, or "unsaturated" character of the nitrogen-to-carbon bonds. The addition of water, or hydrolysis, can take place in steps, the formation of formamide, $HCONH_2$, being the first stage and that of ammonium formate, $HCOONH_4$, the second stage of the reaction. Hydrolysis takes place readily in the presence of concentrated hydrochloric acid, or moderately concentrated sulphuric acid. Concentrated sulphuric acid destroys the ammonium formate, the final products of the reaction being ammonium sulphate and carbon monoxide. Four atoms of hydrogen may be added to the molecule of prussic acid to obtain methylamine, $CH_3.NH_2$. Addition may be brought about by passing a mixture of prussic acid with a large excess of hydrogen over platinized asbestos heated above 150° C.

Metallic Cyanides.—The cyano group or radical behaves in many respects like an element and, combining with metals, gives the metallic cyanides which resemble the metallic halides. This resemblance is particularly marked in the case of alkali metal salts. The radical shows a marked power, on the other hand, of forming complex salts, such as potassium ferrocyanide, $K_4Fe(CN)_6$. In these compounds, usually, one metal atom forms part of the complex cyanide anion. For example, potassium ferrocyanide dissociates into the potassium cations, K^+, and ferrocyanide anions, $Fe(CN)_6\equiv$. Ferrous ions, F^{++}, and cyano ions, CN^-, are present in the solution in such minute quantities, in this instance, that ordinary analytical tests fail to reveal their presence; and the stability of the complex is such that the addition of a mineral acid yields the corresponding free ferrocyanic acid, $H_4Fe(CN)_6$. This behaviour is common to many, but not by any means all, of these complex salts. Some, like potassium zinc cyanide, $K_2Zn(CN)_4$, are easily decomposed by acids with the liberation of prussic acid.

The tendency to form complex cyanides is most marked in the metals of Group VIII, and contiguous metals (transition elements, *see* PERIODIC LAW, THE). Most complex cyanides are of the following types: $K[R(CN)_2]$, where R is Cu, Ag, Au; $K_2[R(CN)_4]$, where R is Zn, Cd, Hg, Ni, Pd, Pt; $K_4[R(CN)_6]$, where R is Cr, Mn, Fe, Co, Ru, Os, Ir; $K_3[R(CN)_6]$, where R is Cr, Mn, Fe, Co, Rh, Ir; $K_4[R(CN)_8]$, where R is Mo or W.

Sodium Cyanide is one of the two commercially most important salts of prussic acid. It is prepared in a pure form, analyzing 96%–98% NaCN, by the Castner process which utilizes the reaction of metallic sodium with ammonia and charcoal. A less pure form of the compound is made from prussic acid. In Germany a large portion of the prussic acid obtained from Schlempe is converted to sodium cyanide.

The Castner Process.—Metallic sodium is melted with charcoal in a steel vessel and dry ammonia is blown into the liquid, while the temperature is gradually raised to 600° C.; the mass is finally heated to about 850° C. in order to complete the conversion of the last remaining portion of sodium cyanamide into cyanide. The molten mass is filtered through iron turnings, after being cooled to some extent, and is cast in moulds in the form of spheroids of convenient size. The reaction proceeds in three steps: sodium amide is the first product, $Na + NH_3 = NaNH_2 + H$; the amide reacts rapidly with charcoal forming sodium cyanamide, $2NaNH_2 + C = Na_2CN_2 + 2H_2$; and this finally combines with an additional atom of carbon to form sodium cyanide, $Na_2CN_2 + C = 2NaCN$.

Preparation from Prussic Acid.—Prussic acid is absorbed in aqueous sodium hydroxide solution of such strength that a saturated solution of sodium cyanide (45% by weight) is produced. The use of an excess of prussic acid is avoided, since otherwise a dark product is obtained, because of the polymerization of the free acid. The solution is evaporated *in vacuo* to a paste, which is centrifuged to give a product containing 10% water. The remaining water is removed by drying this product on heated trays *in vacuo*. The dried powder, which analyzes 90%–92% NaCN, is compressed into rectangular cakes of convenient size.

Properties of Sodium Cyanide.—Sodium cyanide is a colourless solid crystallizing in the cubic system. It forms a dihydrate, $NaCN.2H_2O$, which crystallizes in large colourless plates decomposing above 34.7° C. Sodium cyanide is soluble in water, alcohol and anhydrous ammonia; it melts at 563.7° C.

In aqueous solution, sodium cyanide is partially hydrolysed to prussic acid and sodium hydroxide: $NaCN+H_2O=NaOH+HCN$. When aqueous solutions of sodium cyanide are heated, hydrolysis of the cyano group takes place at an appreciable rate, and ammonia and sodium formate result: $NaCN+2H_2O=HCOONa+NH_3$. This reaction also takes place at ordinary temperatures, although at an extremely slow rate.

Calcium Cyanide has acquired considerable commercial importance since its preparation from cyanamide: a mixture of 10 parts commercial calcium cyanamide, 8 parts common salt and 0.5–1 part calcium carbide is fed into an electric furnace of the arc-resistance type with conducting hearth and a single suspended graphite electrode. Alternating current passing through the charge heats this to 1,200°–1,400° C., and the fused mass overflows to a pan in which an internally water-cooled rotating drum picks up a thin layer of the melt. The cyanide is thus chilled rapidly in the form of a thin sheet which breaks into flakes as it is scraped off and collected. The product analyzes more than 45% $Ca(CN)_2$ and contains impurities derived from the coal and coke used in the manufacture of cyanamide and from the salt. Calcium cyanide is formed through the combination of calcium cyanamide with carbon. The carbon is present in the commercial product in the required amount because of its mode of formation from carbide: $CaC_2+N_2=CaCN_2+C$. Rapid cooling of the fused cyanide is essential for the prevention of reversion to cyanamide, which takes place rapidly between 400° C. and 700° C.

Calcium cyanide in the pure form is a white powder which melts at 640° C.±30° C., when heated rapidly, to a clear liquid. The melt soon becomes turbid and finally solidifies as it reverts to calcium cyanamide. An important property of calcium cyanide is its reaction with atmospheric moisture which takes place according to the equations:

$$Ca(CN)_2+H_2O\rightarrow Ca(OH)CN+HCN;$$
$$Ca(OH)CN+H_2O\rightarrow Ca(OH)_2+HCN.$$

The reaction takes place rapidly if the cyanide is finely ground and the relative humidity is in excess of 35%. It forms the basis of the use of calcium cyanide as a fumigant.

Heavy Metal Cyanides.—The simple cyanides of heavy metals are insoluble in water, with the notable exception of mercuric cyanide. Cuprous, silver and zinc cyanides have acquired some commercial importance.

Cuprous Cyanide, CuCN, the only stable cyanide of copper, is made by adding a solution of sodium cyanide to one of cuprous chloride in saturated aqueous sodium chloride. It is soluble in solutions of alkali metal cyanides. The complex salts obtained through the combination of cuprous cyanide with alkali cyanides are used in the electrodeposition of copper on iron. Cuprous cyanide is also important as a reagent for the introduction of the CN radical into aromatic compounds by reaction with aromatic diazo compounds.

Silver Cyanide, AgCN, separates as a white flocculent precipitate when hydrocyanic acid is added to an aqueous solution of a soluble silver salt. It dissolves in sodium cyanide solution, forming the complex salt $NaAg(CN)_2$, which is used in the process of electrodeposition of silver.

Zinc Cyanide, $Zn(CN)_2$, may be prepared by adding hydrocyanic acid to a solution of zinc acetate in water. It separates as white crystals which dissolve in solutions of alkali cyanides, with the formation of a complex cyanide.

Potassium Ferrocyanide, $K_4Fe(CN)_6$, together with the corresponding sodium salt, finds wide use in the preparation of Prussian blue, in the dye industry for the fixation of aniline black dyes and in the casehardening of iron by the "cementation" process. It may be prepared through the reaction of ferrous sulphate and potassium cyanide in aqueous solution. It is obtained more economically from commercial calcium cyanide. Commercial calcium cyanide is dissolved in water and treated with the calculated quantity of ferrous sulphate. To the filtered solution potassium chloride is added, thus precipitating the nearly insoluble potassium calcium ferrocyanide, $K_2CaFe(CN)_6$; this is filtered, washed and then boiled with the required quantity of aqueous potassium carbonate solution. The solution is filtered and concentrated by boiling in cast-iron vessels, and the salt is allowed to crystallize during 14 days on wires or strings suspended in the liquid. The sodium salt may be prepared similarly by the use of sodium chloride and sodium carbonate in the process in place of the potassium salts.

Potassium Ferricyanide, $K_3Fe(CN)_6$, is prepared by oxidizing potassium ferrocyanide in aqueous solution electrolytically or with chlorine. Electrolysis is carried out in diaphragm cells with nickel electrodes. Potassium ferricyanide crystallizes out from the anode liquor on cooling, and the mother liquor is replenished with fresh ferrocyanide and returned to the cell. The reaction may be represented ionically as follows: $Fe(CN)_6^{\equiv\equiv}=Fe(CN)_6^{\equiv}+-$; $H_2O+-=OH^-+\frac{1}{2}H_2$.

Oxidation with chlorine is carried out by conducting gaseous chlorine into a cold 10% solution of ferrocyanide. The reaction is represented by the equation: $2K_4Fe(CN)_6+Cl_2=2K_3Fe(CN)_6+2KCl$. The passage of chlorine is discontinued when the conversion of the ferrocyanide is just completed. The solution is evaporated to the crystallizing point, a little caustic potash is added to eliminate the small amount of Prussian green formed, which is precipitated as ferric hydroxide and removed by filtration. The ferricyanide is recovered by crystallization in an 85%–90% yield.

Iron Cyanide Blues form an important group of pigments. They may be prepared directly through the interaction of ferric salts with alkali ferrocyanides or of ferrous salts with alkali ferricyanides in neutral or acid solution. They are amorphous substances containing variable quantities of combined water. Depending upon the procedure followed in their preparation, soluble or insoluble varieties may be produced. The soluble types, which may be represented by the formula $K\,Fe[Fe(CN)_6]aq.$ and contain a maximum of four molecules of water, may be prepared by mixing cold neutral solutions of ferric chloride and potassium ferrocyanide, the latter being used in excess. Insoluble blues conform to the formula $Fe_4[Fe(CN)_6]_3aq.$ and contain a maximum of 10-11 molecules of water. They are formed when an excess of a ferric salt solution is added to a neutral or slightly acid solution of potassium ferrocyanide.

Blues prepared by the direct method lack the desirable brilliancy of colour; they are generally known as Prussian blue. Fine qualities can be prepared only by an indirect process depending upon the oxidation of potassium ferrous ferrocyanide or of mixtures of this substance with ferrous ferrocyanide:

$$6K_2Fe[Fe(CN)_6]+3H_2O+3O=$$
$$Fe[Fe(CN)_6]_3+3K_4[Fe(CN)_6]+2Fe(OH)_3;$$
$$3Fe[Fe(CN)_6]+3H_2O+3O=Fe_4[Fe(CN)_6]_3+2Fe(OH)_3.$$

Paris Blue, also called Chinese blue, is the finest of iron blues. This product is made as follows: a solution of 66 kg. ferrous sulphate (120 kg. of commercial product) in 600 l. water and one of 75 kg. potassium ferrocyanide (83 kg. of the commercial product) in 1,000 l. of water are added simultaneously to 600 l. of water with vigorous agitation. The precipitate is washed by decantation, the wet paste is brought to the boiling temperature and a solution of 44 kg. ferric chloride (80 kg. of commercial product) in 200 l. of water heated to 70° C. is added in the course of one hour to one and one-half hours. The liquid is boiled with stirring for one-half hour and diluted with boiling water to 4,000 l.; the precipitate is then washed six to eight times with hot water by decantation and finally filtered and dried first at 40°–45° C. then finally at 70° C. It is important that the ferrous sulphate solution be free of ferric sulphate; sufficient purity is assured by allowing the solution to remain in contact with iron filings for one to two days.

Five main varieties of iron blues are recognized in commerce: Prussian blue, Paris blue, bronze blue, milori blue and steel blue. In chemical composition, they are nearly identical. Milori blue is a special quality, showing a bright colour and a reddish tint. It is distinguished by exceptional softness and is largely used for printing inks.

Detection and Estimation.—The presence of prussic acid in an aqueous solution may be demonstrated by a variety of methods; one that is most commonly employed depends upon the conver-

sion of the acid into Prussian blue: one or two drops of moderately concentrated sodium hydroxide solution and of freshly made ferrous sulphate solution are added to the liquid, and the whole is boiled. The liquid is cooled and acidified, and a drop of ferric chloride solution is added; a precipitate of Prussian blue then forms if prussic acid was present in the original solution. One of the most satisfactory methods for the quantitative determination of prussic acid is titration of the acid in the form of its alkali metal salt with standard silver nitrate solution, with a few drops of 10% potassium iodide solution as an indicator. The end point is reached when a permanent opalescence is observed in the solution; at this point the reaction $2NaCN+AgNO_3=NaAg(CN)_2+NaNO_3$ is just complete. It can be seen that every formula weight (*see* MOLECULE, CHEMICAL) of silver nitrate used is equivalent to two formula weights of prussic acid.

Toxic Action.—Hydrocyanic acid is highly toxic through inhibition of cellular oxidative processes. Acute poisoning from hydrocyanic acid or its salts, the cyanides, is manifested by dizziness, nausea, staggering and loss of consciousness if the amount absorbed is sufficient. Death ensues rapidly if lethal quantities are absorbed either through ingestion of the cyanides or through the inhalation of HCN gas in sufficient amounts. However, in sublethal poisoning, recovery is usually complete within a few hours and there are no permanent aftereffects. In sublethal doses the CN radical is rapidly detoxified by the body through combination with sulphur, which forms nontoxic sulphocyanides. Man can withstand 50–60 parts of HCN per 1,000,000 parts of air for 1 hr. without serious consequences while exposure to concentrations of 200–500 parts per 1,000,000 parts of air for 30 min. is usually fatal.

First-Aid Treatment for Cyanide Poisoning.—Carry patient to fresh air and have him lie down and keep warm. Call a physician. If the patient is breathing, break an amyl nitrite pearl in a cloth and hold lightly over the nose for not more than 15 sec. to 20 sec. or have him inhale aromatic spirits of ammonia. Repeat every 5 min. for 25 min. if recovery is not forthcoming. This poison is rapid in action and few patients survive.

If the patient has stopped breathing, give artificial respiration until breathing starts; then administer amyl nitrite as above.

If cyanides have been swallowed and the patient is conscious, give one pint of 1% sodium thiosulphate solution (or soapy water or mustard water) by mouth every 15 min. until vomiting occurs. Never give anything by mouth to an unconscious person. During World War II, *p*-aminopropiophenone, administered orally, was found by the medical division of the chemical warfare service, U.S. army, to have value in the prophylaxis of cyanide poisoning.

Pest Control.—The use of prussic acid for the control of insect and other pests has become quite general since D. W. Coquillet first employed the compound in 1886 for the control of scale insects of citrus trees in California. Prussic acid is extensively used as a fumigant for the control of insects in stored goods, of household pests and of insect and rodent pests occurring in ships and railways cars, and for a variety of other purposes, as well as for the control of scale insects of citrus trees and certain other agricultural pests. The liquid is available in stout steel cylinders for shipment over long distances. A product consisting of prussic acid absorbed in wood pulp disks or in granular diatomaceous earth in sealed tins is also available.

Periodic general fumigation of flour mills has become common practice in the United States. Liquid in cylinders is used for this purpose. It is sprayed at each floor from special spray nozzles attached to a permanent piping system, or to rubber hose reaching all parts of the floor. The liquid is ejected with compressed air. This method of application is also utilized in the fumigation of other large buildings and ships. The most effective and economical method of flour-mill fumigation consists in injecting the liquid into the various machines, thus producing the highest concentration of the fumigant at the sources of infestation. An elaborate permanent machinery piping system forms an essential part of this method.

The pressure of demand for effective measures directed at the prevention of insect damage to stored goods led to the development of vacuum fumigation technique. Specially constructed large cylindrical or rectangular air-tight chambers are used for this purpose. The commodities to be fumigated are introduced into the chamber on special trucks, the chambers are sealed tight and evacuated, and the prussic acid is then injected in the form of vapours. The doses required may vary, according to the commodities fumigated and the magnitude of the load, between one and one-half and three pounds or more per 1,000 cu.ft. of space.

A convenient method of fumigation of dwelling houses and commercial establishments of moderate size utilizes disks of wood pulp impregnated with liquid prussic acid. The disks are contained in sealed metal cans which are opened just before use by means of a special cutter. The disks are evenly scattered throughout the various floors of the building on heavy paper placed on the floor.

The introduction of calcium cyanide made possible the satisfactory solution of a number of difficult pest control problems. It has already been pointed out that the mode of action of this product depends upon its reaction with the moisture contained in the atmosphere, generating vapours of prussic acid. Calcium cyanide in the finely ground form is the most effective agent known for the destruction of burrowing animals such as rats, rabbits, ground hogs, etc. It is also one of the best fumigants for the control of ants and termites in their nests. In areas where liquid hydrocyanic acid is not locally available, calcium cyanide is used successfully for the control of the scale insects of citrus trees. Calcium cyanide is used as a fumigant for the destruction of aphids and other sucking insects in greenhouses. A granular form is best suited for this purpose; it is applied on the walks in a thin layer in quantities corresponding to one-eighth ounce to one-fourth ounce per 1,000 cu.ft. of space. Application is begun an hour after sunset and the house is allowed to remain closed overnight. The temperature within the house should be rising and preferably between 60° F. and 70° F., and the air should be calm. Several applications at weekly intervals are recommended.

An important use of calcium cyanide is the fumigation of grain in storage, for which a granular form of the product is used. It is applied to the grain at a controlled rate by a special device at the time the grain is run into the bin. A dosage of 10 lb. to 20 lb. per 1,000 bu. of wheat gives satisfactory control of insects without damage to the grain.

Casehardening.—Casehardening of iron or steel articles by immersion in a fused cyanide bath came into general use, especially in the United States and Canada, after its introduction in 1910. The bath material usually consists of 60% sodium cyanide mixed with other salts such as sodium carbonate or sodium chloride. It is fused in mild steel or chromium-steel pots and the temperature is raised to a point above 760° C. The cyanide gradually decomposes and the resulting carbon combines with, and penetrates into, the metal.

The rate of penetration of carbon into mild steel is about 0.01 in. per hour and about 50% greater when nickel steel is used. Casehardening usually implies a case depth of 0.015 in.–0.060 in.; cases of smaller depth, in some instances only 0.005 in. thick, are produced for surface hardening.

Sodium cyanide is added to heat-treating baths to prevent decarburation of the treated pieces. A concentration of 10% is usually regarded sufficient for this purpose, but lower or higher concentrations may be used in connection with low and high carbon steels.

Electroplating.—A solution containing the double cyanide of sodium and silver, $NaAg(CN)_2$, or the corresponding potassium salt, and a molecular excess of the alkali cyanide serves for electroplating metal articles with silver. The article to be plated, its surface thoroughly cleaned, and a sheet of silver are suspended in the solution a few inches apart; and a direct current is passed through at a rate of three amperes per square foot of surface. The article to be plated is made the cathode, the silver the anode. As electrolysis proceeds, the silver anode gradually dissolves, and an equal quantity of the metal is deposited out of the solution upon the surface of the article. The concentrations of the double salt commonly used correspond to two ounces to four ounces silver per imperial gallon. The solution improves with use. Plating with gold, gold-silver or gold-copper alloys is done in a similar way.

Cyanide solutions are also used in deposition of copper, zinc, brass and cadmium, more especially on iron.

Flotation.—In the flotation process of ore concentration, separation of metal sulphides is effected by a rising current of air bubbles through the vigorously agitated water suspension of the ore containing a little oil or other flotation agents. The metal sulphides rise with the froth and are obtained in a concentrated form by collecting the froth. G. E. Sheridan and G. G. Griswold discovered in 1922 that the addition of a small amount of sodium cyanide to the suspension of ore previously made faintly alkaline with soda ash prevents the flotation of zinc and iron sulphides without affecting that of lead and copper sulphides. By making use of this effect the sulphides of zinc and iron may be separated from those of lead and copper. The iron and zinc sulphides may be separated by a second treatment in more strongly alkaline solution, the zinc alone floating.

Sodium and calcium cyanides are used extensively in the process of gold and silver extraction. (*See* CYANIDE PROCESS.)

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PRUTZ, HANS (1843–1929), German historian, son of Robert Eduard Prutz (1816–1872), the essayist and historian, was born at Jena on May 20, 1843, and studied at Jena and Berlin. His *Preussische Geschichte* (4 vols., Stuttgart, 1899–1902) is an attempt to apply scientific rather than patriotic canons to a subject which has been mainly in the hands of historians with a Prussian bias. In 1902 Prutz resigned the chair of history in the university of Königsberg, which he had held since 1877.

His other works include: *Aus Phönicien,* a collection of historical and geographical sketches (1876); *Quellen-beiträge zur Geschichte der Kreuzzüge* (1876); *Kulturgeschichte der Kreuzzüge* (1883); *Staatengeschichte des Abendlandes im Mittelalter* (1885–87); *Geheimlehre und Geheimstatuten des Tempelherrenordens* (Danzig, 1879); *Entwickelung und Untergang des Tempelherrenordens* (1888); *D. geistl. Orden,* (1907).

PRYNNE, WILLIAM (1600–1669), English parliamentarian, son of Thomas Prynne, born at Swainswick near Bath, was educated at Bath Grammar School and at Oriel College, Oxford. He was called to the bar at Lincoln's Inn in 1628. He was Puritan. In 1629 Prynne came forward as the assailant of Arminianism in doctrine and of ceremonialism in practice, and thus drew down upon himself the anger of Laud. *Histrio-mastix,* published in 1633, was a violent attack upon stage plays in general, in which the author pointed out that kings and emperors who had favoured the drama had been carried off by violent deaths, and applied a disgraceful epithet to actresses, which, as Henrietta Maria was taking part in the rehearsal of a ballet, was supposed to apply to the queen. After a year's imprisonment in the Tower Prynne was sentenced by the star chamber on Feb. 17, 1634 to be imprisoned for life, and also to be fined £5,000, expelled from Lincoln's Inn, rendered incapable of returning to his profession, degraded from his degree in the university of Oxford, and set in the pillory, where he was to lose both his ears. The latter portion of the sentence was carried out on May 7, and the rest of his punishment inflicted except the fine and part of the imprisonment. There is no reason to suppose that his punishment was unpopular.

In 1637 he was once more in the star chamber, together with Bastwick and Burton. In *A Divine Tragedy lately acted* he had attacked the Declaration of Sports, and in *News from Ipswich* he had assailed Wren and the bishops generally. On June 30 a fresh sentence, delivered on the 14th, was executed. The stumps of Prynne's ears were shorn off in the pillory, and he was branded on the cheeks with the letters S.L., meaning "seditious libeller," which Prynne, however, interpreted as "*stigmata laudis.*" He was removed to Carnarvon Castle, and thence to Mont Orgueil Castle in Jersey, where he occupied himself in writing against popery.

Immediately upon the meeting of the Long Parliament in 1640 Prynne was liberated. On Nov. 28 he entered London in triumph, and on March 2, 1641, reparation was voted by the Commons, at the expense of his persecutors. Prynne now attacked the bishops and the Roman Catholics and defended the taking up of arms by the parliament. He showed a vindictive energy in the prosecution of Archbishop Laud. He manipulated the evidence against him, and having been entrusted with the search of Laud's papers, he published a garbled edition of the archbishop's private "Diary," entitled *A Breviate of the Life of Archbishop Laud.* He also published *Hidden Works of Darkness brought to Light* in order to prejudice the archbishop's case, and after his execution, *Canterbury's Doom . . .* an unfinished account of the trial commissioned by the House of Commons. Prynne supported a national church controlled by the state, and issued a series of tracts against independency. He denounced Milton's *Divorce at Pleasure,* was answered in the *Colasterion,* and contemptuously referred to in the sonnet "On the Forcers of Conscience." He also opposed violently the Presbyterian system, and denied the right of any Church to excommunicate except by leave of the state (e.g., *Four Short Questions* [1645]; *A Vindication of Four Serious Questions* [1645]). He was throughout an enemy of individual freedom in religion.

Prynne took the side of the parliament against the army in 1647, supported the cause of the eleven impeached members, and visited the university of Oxford as one of the parliamentary commissioners. In 1648 Prynne was returned as member for Newport in Cornwall. He at once took part against those who called for the execution of Charles; the result was his inclusion in "Pride's Purge" on Dec. 6, when, having resisted military violence, he was imprisoned. After recovering his liberty Prynne retired to Swainswick. On June 7, 1649, he was assessed to the monthly contribution laid on the country by parliament. He not only refused to pay, but published *A Legal Vindication of the Liberties of England,* arguing that no tax could be raised without the consent of the two houses. He was imprisoned in various places from 1650 to 1653, and on his release renewed his pamphleteering activities.

On the restoration of the Rump Parliament by the army of the 7th of May 1659 fourteen of the secluded members, with Prynne among them, claimed admittance. He was prevented from taking his seat, and a second attempt in December also failed. He was returned for Bath to the Convention parliament and to the parliament of 1661. During 1663 he served constantly on committees, and was chairman of the committee of supply in July, and again in April 1664. The last time he addressed the House appears to have been in Nov. 1667.

Prynne died unmarried, in his lodgings at Lincoln's Inn, on Oct. 24, 1669, and was buried in the walk under the chapel there.

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PRYOR, ROGER ATKINSON (1828–1919), U.S. soldier and jurist, was born near Petersburg, Va., on July 19, 1828. He graduated at the law school of the University of Virginia in 1848, and in 1849 was admitted to the bar. He served as a Democrat in the National House of Representatives, 1859–61, and was re-elected for the succeeding term, but owing to the secession of Virginia did not take his seat. He served in the provisional Confederate congress (1861) and also in the first regular congress (1862) of the Confederate constitution. He entered the Confederate army as a colonel, became a brigadier-general (April 16, 1862), and took part in the battles of Williamsburg, Seven Pines, second Bull Run and Antietam. Owing to a disagreement with President Davis he resigned his commission in 1863, and entered Gen. Fitzhugh Lee's cavalry as a private. He was taken prisoner Nov. 1864, but was released on parole by order of the president. In 1865 he removed to New York city, where he practised law. He was judge of the New York court of common pleas, 1890–94, and of the New York supreme court, 1894–99, when he retired from the bench. He died in New

York city on March 14, 1919.

PRYTANEUM AND PRYTANIS. 1. In ancient Greece, each State, city or village possessed its own central hearth and sacred fire; the fire (*cf.* at Rome the fire in the temple of Vesta) was kept alight continuously, tended by the king or members of his family. The building in which this fire was kept was the Prytaneum (Πρυτανεῖον), and the chieftain (the king or prytanis) probably made it his residence. The word prytanis is applied to those who, after the abolition of monarchy, held the chief office in the State. Rulers of this name are found at Rhodes as late as the 1st century B.C. The Prytaneum was regarded as the religious and political centre of the community. When colonists went out they took with them a brand from the Prytaneum altar to kindle the new fire in the colony; the fatherless daughters of Aristeides, regarded as children of the State at Athens, were married from the Prytaneum as from their home; foreign ambassadors and citizens who had deserved especially well of the State were entertained in the Prytaneum as public guests. In Achaea, this central hall was called the *Leïton* (town-hall), and a similar building is known to have existed at Elis. The site of the Prytaneum at Athens cannot be definitely fixed. The Prytaneum mentioned by Pausanias, probably the original centre of the ancient city, was situated somewhere east of the northern cliff of the Acropolis. Curtius places the original Prytaneum south of the Acropolis in the old Agora, and regards that of Pausanias as a building of Roman times (*Stadtgeschichte,* p. 302). Many authorities hold that the original Prytaneum of the Cecropian city must have been on the Acropolis. From Aristotle's *Constitution of Athens* (ch. 3) we know that the Prytaneum was the official residence of the archons, but, when the new Agora was constructed they took their meals in the *Thesmotheteion* for the sake of convenience. There was also a court of justice called the court of the Prytaneum; it tried murderers who could not be found, and inanimate objects which had been the means of causing death.

2. For the PRYTANEIS of the Boulē *see* BOULE.

PRZEMYSL, a town of Poland, in the province of Lemberg (Lwow), 60 mi. W. of Lwow by railway. Pop. (1931), 51,379, mostly Polish. It is situated on the river San, and is the seat of a Roman Catholic and a Greek Catholic bishop, the cathedral dating from the 15th century. The industries comprise the manufacture of machinery, the refining of naphtha, corn-milling and the sawing of timber. On the hill above the town are the ruins of an old castle, said to have been founded by Casimir the Great.

Przemysl was founded at an early date on the borderland between Poland and Russia. Russian princes founded a state there in the 11th century, which became absorbed in the principality of Galich or Halicz and was annexed by Casimir the Great after 1340. It was occupied by Austria from 1773 to 1915. Polish after 1918, it was occupied by the U.S.S.R. in 1939 and Germany in 1941.

PRZEMYSL, SIEGES OF. In 1914 Przemysl was protected by a ring of forts 36 m. in circumference. Some of the forts were of recent construction, but the fortress as a whole was not strictly up-to-date. To clear the foreground in front of the fortified line no fewer than 18 villages and some five miles of forest were levelled to the ground on mobilization. The armament of the fortress included four large modern howitzers of about 12in. calibre and some 9in. and 6in. howitzers of older pattern. There were in all about 1,000 guns in the fortress, but more than half of these were old, short-range weapons of little value except for close defence. There were 114 machine-guns, of which two-thirds were mobile.

The eventual garrison left in the fortress when the Austrian armies retreated from the San on Sept. 18, 1914, consisted of: 61½ battalions (of which 40½ were Landsturm), seven squadrons, four field batteries, 43 fortress artillery companies, 48 Landsturm artillery brigades, eight sapper companies, and various technical and administrative units. The total strength was approximately 130,000 men and 21,000 horses. Provisions were available for three months.

The First Siege.—The Austrian armies withdrew from the San on Sept. 18; by Sept. 24 the investment of the fortress was complete. On the south-west front the garrison held a line a mile or two in advance of the ring of forts; elsewhere the line of the forts was held. The siege of the fortress was undertaken by Radko-Dimitriev's III. Army. While the arrival of the siege artillery material was still delayed by the state of the communications, the Austrians renewed the offensive in the early days of Oct. (*see* VISTULA-SAN, BATTLES OF THE). In the hope of capturing Przemysl by a *coup de main* before the progress of the enemy offensive compelled the raising of the siege, Radko-Dimitriev carried out several violent assaults between Oct. 5–8 against the Siedliska group of works to the south-east of the town. These assaults broke down with heavy loss, and the approach of the Austrian III. Army necessitated the withdrawal of the investing forces. The fortress was entered by Austrian infantry of the field armies on Oct. 11, on which date Radko-Dimitriev's III. Army retreated to the east bank of the San.

Period Between the First and Second Sieges.—During the Austrian attempts to force the San line, which lasted throughout October, the fortress lay in the centre of the battle line and its garrison took an active part in the operations. Its reserves of supplies and material were also largely drawn on by the field armies to make good the deficiencies caused by the poor working of the lines of communication. During their retreat the Russians had systematically destroyed the railways and bridges, and the continued wet weather had rendered the roads almost impassable. Thus it was natural that the reserves of Przemysl should be used for the benefit of the field armies, from whose operations great results were expected at the time. But when the offensive proved fruitless and Russian pressure necessitated a retirement which would leave the fortress again isolated, special efforts were made hastily to reprovision it. They were so far successful that the fortress was enabled to hold out for 4½ months in the second siege.

Second Siege, Nov. 6, 1914–March 22, 1915.—The strength of the garrison was approximately the same as in the first siege, but a detachment of aeroplanes had been added. Kusmanek had now laid out new entrenched positions from one to two miles in advance of the line of forts, to give more depth to the defence and to keep the Russian siege artillery at a greater distance. On Nov. 9 the investment of the fortress for the second time was complete. The siege was now undertaken by a specially formed XI. Army under General Selivanov, consisting of four divisions of second-line troops. It had been decided to reduce the fortress by blockade rather than by assault. During November and December such fighting as occurred was initiated rather by the sorties of the garrison than by the attacks of the besiegers.

During February and the first half of March the Austrian field armies made repeated efforts to advance to the relief of the fortress, but unsuccessfully (*see* CARPATHIANS, BATTLES OF THE). Meanwhile the Russians had gradually closed in and had commenced a systematic bombardment of the fortress. On March 13 they carried the advanced positions on its north front. Kusmanek's situation was now desperate; his supplies and munitions were almost exhausted, and the final effort of the field armies to come to his rescue had definitely been abandoned. He determined on an attempt to save a portion of the garrison by a break-through to the east. The effort was made on the morning of the 19th, but was soon brought to a stand. The fate of the fortress was now sealed. On the morning of March 22 Kusmanek surrendered, after destroying the works and military stores as far as possible. The numbers of the garrison then amounted to about 110,000.

Recapture of the Fortress.—The Russians did not hold the fortress for long. At the beginning of May Mackensen's offensive on the Dunajec broke through the Russian line and drove their armies back to the San (*see* DUNAJEC-SAN). On May 30 the

Austrians attacked on the south-west and the Germans on the north of the fortress. The former made little progress, but the German heavy artillery, which included 42 cm. howitzers, made short work of the northern group of forts. On the night of June 2 the Russians abandoned the fortress.

Conclusions.—Przemysl was the only land fortress of World War I which stood a prolonged siege after complete investment, but the length of its resistance was seemingly due to the Russians' lack of efficient siege artillery, as is confirmed by the speed with which Mackensen's heavy guns reduced the forts at the time of its recapture. Nor can it be admitted that the fortress served any strategical aim commensurate with the efforts expended on its defense and attempted relief. It is true that its resistance during the first siege was of value to the Austrians when their armies again advanced to the San, in assuring to them a bridgehead over the river. But during the second seige Przemysl was an embarrassment rather than a source of strength and led to several ill-considered efforts at relief which cost the Austrian field armies dearly. The fortress did not control any line of supply vital to the Russian armies operating west of it toward Cracow, since there was a railway available through Jarostow. The Russians could therefore afford in the second siege to resort to a simple blockade by second-line troops, so that the fortress did not even weaken their field armies to any appreciable extent.

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PRZHEVALSK: *see* KARAKOL.

PSALMANAZAR, GEORGE (*c.* 1679–1763), French adventurer. After various escapades, including a pilgrimage to Rome in the guise of a Japanese convert, he came to London, where he imposed on many people, notably on the bishop of London, who employed him to translate the Catechism into what was supposed to be Japanese. In 1704 and 1707 he published fictitious works on Formosa. Eventually he confessed to his imposture. He died in London on May 3, 1763. His memoirs, *Memoirs of . . . commonly known by the name of George Psalmanazar* (1764) do not disclose his real name or the place of his birth. His fictitious publications include: *Historical and Geographical Description of Formosa* (1704); *Dialogue between a Japanese and a Formosan* (1707); *An Enquiry into the Objections . . . with George Psalmanazar's Answer* (undated).

See P. W. Sergeant, *Liars and Fakers* (London, 1926).

PSALMS, the first in order and importance (*cf.* Luke xxiv. 44) of the third division of the Hebrew Old Testament, known as the "Writings." The Hebrew name of the Psalms is *tehillim,* or "praise-songs," which expresses a predominant, though by no means the entire, character of the collection. This anthology of Hebrew poetry also includes petitions (iv.), laments (xliv.), imprecations (lviii.), meditations (cxix.), historical reviews (cvi.), and even a marriage ode (xlv.). But there can be no doubt that the purpose of the collection was to gather the sacred poetry of Israel for use in the *post-exilic* worship of the temple. This is shown by the technical and professional titles of the psalms, as well as by their general character and their occasional references (note the definite allusions to the destruction of Jerusalem, the exile or the dispersion in li. 18, lxxxix. 38, 44, cvi. 47, cxxvi. 1, cxxxvii. 1, cxlvii. 2).

As the book lies before us, it is a collection of collections, being divided into five books, which themselves contain certain smaller distinguishable groups of psalms. The first four books are each closed by a doxology, at least as old as the Septuagint version (second half of 2nd century B.C.). In Bk. I. (i.–xli.) practically all the psalms are ascribed to David (the exceptions can be explained). In Bk. II. (xlii.–lxxii.) there is more variety, xlii.–xlix. being ascribed to "the sons of Korah," l. to Asaph, li.–lxv. to David, lxvi., lxvii. simply to "the chief musician" or choir-conductor, lxviii.–lxx. to David, lxxii. to Solomon (lxxi. is anonymous). The editorial note at the end of this book, "Finished are the prayers of David the son of Jesse," shows there was once a collection of "Davidic" psalms, and that there has been a rearrangement of material bringing psalms of other groups above the rubric. In Bk. III. (lxxiii.–lxxxix.) there is an "Asaph" group (lxxiii.–lxxxiii.) followed by a miscellaneous appendix (Korah, David, Ethan). We have clear evidence of other editorial work in the overwhelming predominance of the name "Elohim" for God in Psalm xlii.–lxxxiii. as compared with the personal name, "Yahweh" (the occurrences are 200:43; in Psalms, i.–xli. 15:272); this is confirmed by the fact that Ps. xiv. of the first Book reappears as Ps. liii., with its fourfold "Yahweh" changed into "Elohim" (so also in Pss. xl. 13–17 and lxx.). In Bks. II. and III. alone do we get psalms ascribed to guilds of temple-singers. Bks. IV. and V. are divided by the doxology of cvi. 48 (*cf.* 1 Chron. xvi. 35, 36, where a liturgical formula has been transformed into a historical statement). But the division seems artificial (perhaps made to get five books of psalms corresponding with the five books of the law), since Psalms cv.–cvii. are closely related in subject-matter. If, therefore, we take Bks. IV. and V. together, we find in them a distinct group of "Pilgrim" psalms (cxx.–cxxxiv.), and a scattered one of "Hallelujah" psalms (civ.–cvi., cxi.–cxiii., cxv.–cxvii., cxxxv., cxlvi.–cl.) largely liturgical. Ps. cviii. seems to have been made by combining lvii. 7–11 and lx. 5–12, which again proves the existence of separate collections, since the same material would not originally appear twice in the same collection.

The Hebrew psalms are in rhythmical, but unrhymed verse, the most frequent type being that of the three-beat line. The other characteristic of Hebrew poetry is its parallelism ("synonymous," li. 2; "antithetic," i. 6; "synthetic," cxxi. 4). The musical accompaniment was melodic unison, not the harmonies of modern music, so that its chief use, beyond support to the singers, was to synchronize the beats, as by cymbals (1 Chron. xv. 19, xvi. 5). Six distinct instruments are named in Ps. cl. (*see* Wellhausen, *Psalms,* Appendix, "Music of the Ancient Hebrews"). The singing was by professional choirs with a response ("Amen," "Hallelujah") from the worshippers (1 Chron. xvi. 36, 2 Chron. xxix. 27, 28). For a glowing description of the ritual *see* Ecclus. l. 11–21.

At first sight, the contents of the Psalter may seem to occasion relatively little difficulty to the exegete, as compared with the prophecies. The psalms are for the most part simple and often conventional in language, and without those references to obscure historical events which make the writings of the prophets so difficult. But the apparent gain is really a great loss to historical exegesis. Whilst the absence of reference to contemporary events makes the psalms much more capable of use then than now in worship and devotion—it was in some measure due, we may suppose, to elimination and adaptation—yet it also makes the investigation of the original meaning more difficult. Thus it is usually impossible to give a precise historical background to a particular psalm. The titles professing to do this, and to ascribe authorship, are of little use for critical purposes, and represent a late and usually worthless conjecture. Scholars have now generally abandoned the earlier attempts to ascribe particular psalms to precise events from the Davidic down to the Maccabean age; there is considerable variety of opinion as to the nature, date, authorship and origin of the psalms considered individually.

Four main questions arise: (1) to what extent are the psalms primarily and originally "cultic," more or less officially composed for use in public worship, and to what extent are they private religious lyrics, gathered from many sources, and subsequently adapted to use in the temple-services? (2) In close relation with this question comes another as to the significance of the speaker in many of the psalms; does the "I" mean the whole community, or is it an individual person who is speaking? (3) To what period of the religious history of Israel do the psalms chiefly belong, and to what extent are they pre-exilic in origin, though admittedly post-exilic in present adaptation and arrangement? (4) Are they a native product or are they dependent on Babylonian or Egyptian models, as the creation stories of Genesis are dependent on Babylonian mythology? It will be seen that these are not merely academic questions, for each of them may affect the exegesis of

a particular psalm. A quarter of a century ago, the answers to these four questions generally given by critical scholarship were as follows: (1) the psalms are chiefly poems of the individual, though some were intended from the outset for use in the temple; (2) the "I" of the psalms usually represents the community; (3) the psalms are almost wholly post-exilic in origin; (4) they are native products. All these answers are now being met with vigorous criticism. At the present moment the protagonists in this criticism are the German scholar, Gunkel, and the Norwegian scholar, Mowinckel. Some account of their views must be given, as they cannot be neglected by the modern student of the psalms.

Gunkel's leading principle is that the psalms should be studied in their "classes" (*Gattungen*) or types, of which he finds four of chief importance, viz., "hymns" (*e.g.*, cxlv., cxlvii., cxlviii., cl.), "national laments" (*e.g.*, xliv., lxxix., lxxx., lxxxiii.), "individual laments" (iii., xiii., liv., lxxxviii.) and "individual thanksgivings" (xxx., lxvi., 13 *seq.*). These classes are differentiated by the use of regular formulae, such as "Deliver us, Yahweh," or "I will thank Yahweh," and by more or less regular forms of composition, so that we are not left to subjective impressions only when deciding as to what class a particular psalm belongs. On the basis of this differentiation Gunkel constructs a general history of the "classes," partly from internal evidence, such as the greater length, individualization, or composite character of the later representatives of the class, and partly from the parallels with psalm-like compositions found elsewhere in the Old Testament, which it is possible to date with confidence, such as the Song of Miriam (Exod. xv. 21), the song of the seraphim heard by Isaiah in the temple (vi. 3), the lyrics of Jeremiah and the "Psalms of Solomon" (1st century B.C.). Gunkel's general conclusion is that hymns of praise and national laments were found at an early date, whilst individual laments arose later, but *prior* to Jeremiah. He admits that prophecy influenced the language, eschatological outlook and spirituality of the Psalms, but claims that this influence was exerted before as well as after the exile. He argues that the existence of similar compositions in Babylonia and Egypt at a much earlier date confirms the intrinsic evidence that "Psalm-composition belongs to the earliest periods of Israel's history."

Mowinckel, whilst recognizing and using the classification of psalms by their type, throws his emphasis on their cultic character, and indeed barely admits the existence of any psalms not cultic in origin (his exceptions are i., cxii., cxxvii.). The psalms were composed by the temple-singers, whom he regards as existing from the early days of the temple. The class of psalms to which he gives primary attention is that containing references to the enthronement of Yahweh as king (xlvii., xciii., xcv.–c., with which many others are to be linked). These he connects with an alleged festival of the New Year (originally beginning in the autumn), a festival after the analogy of that celebrated at Babylon in honour of Marduk. The cultic acts of this festival (*e.g.*, the procession bringing the ark into the temple) were realistically conceived, *i.e.*, they were supposed to help in bringing about that which they "dramatized." Thus they anticipated the future (eschatology) while recalling the past (mythology). There is a similar "realism" in Mowinckel's interpretation of the numerous petitionary psalms, which are held to attribute misfortune and sickness to magicians and sorcerers, who are the original "workers of iniquity" so frequently mentioned. Such psalms were employed, with suitable accompanying rites, as part of the temple-cult; they counteracted adverse magic by exorcisms and imprecations of these "enemies." There were prophets as well as priests, or priest-prophets, attached to the temple, who gave oracles; thus the petition of Ps. lxxxv. 1–7 is answered by the oracle of vv. 8–13. It should be said that a "cultic" interpretation of the psalms as a whole has been independently urged by other scholars, *e.g.*, by J. P. Peters, who further conjectures that the "Elohistic" psalms belonged to northern temples (*cf.* the northern "Elohistic" saga-writers), the Korahite to Dan, the Asaphite to Bethel, and were afterwards incorporated in the liturgy of Jerusalem.

It will be seen, therefore, that there is considerable division of opinion at the present time in regard to our first question, the cultic element in the Psalter, Mowinckel regarding practically the whole Psalter as cultic in origin, whilst Gunkel regards the majority of the psalms as of private and occasional origin, though subsequently introduced into the cult. On this point Gunkel's view seems more convincing, from the intrinsic evidence and from the general probabilities. Like a modern hymn-book, the Psalter seems to contain many poems not originally intended for use in worship, but subsequently adapted to it—indeed, the religious wealth of the Psalter seems largely due to this variety of origin. On the other hand, Mowinckel does make a strong case for the special interpretation of the psalms of the enthronement of Yahweh, even though he brings far too many under this head. His explanation of the "eschatological" features is also attractive; less so seems his too sweeping connection of sickness and misfortune with magic, though there is probably an element of real truth in his contentions (the tendency of those who discover some neglected truth is to generalize to excess on the basis of it). In a collection so extensive and varied as the Psalter we need not regard any one explanation or theory as necessarily applicable to more than a part of the material. Variety of origin almost follows from variety of date, and their issue is most naturally variety of meaning, even where the same conventional phrases may be used.

In regard to the closely linked question as to the collective or individual interpretation of the speaker in the psalms, Gunkel follows Balla in reaction from the view that was general a quarter of a century ago (*e.g.*, Smend, Cheyne), *i.e.*, that the "I" of the Psalms is collective, personifying the nation. Mowinckel agrees with Gunkel so far as the "individual laments" are concerned, but recognizes a primitive "corporate personality" finding utterance through the leader or king as its representative. We may ask whether this principle does not admit of a wider application than even Mowinckel allows. It seems to go a long way towards explaining the puzzling combination of "collective" and "individual" elements in such a psalm as the xxii., and the rapid transitions so often found (*cf.* xliv. 5–7 and 14, 15). The same phenomena occur in relation to the Servant of Yahweh in Deutero-Isaiah, and admit of the same explanation—that the primitive mind draws no such hard and fast limits between the individual and the community as we do (see *The Cross of the Servant*, by H. Wheeler Robinson, pp. 32–36; *The Psalmists*, ed. D. C. Simpson, pp. 82 *seq.*). We may often find it impossible to decide whether a psalm is collective or individual—because the ancient category was neither one nor the other, but a third category including both.

In regard to dating the composition of individual psalms, there seems to be some danger of a similar excessive reaction from the view associated with the name of Wellhausen, open as that is to criticism. The arguments of Gunkel and Mowinckel, amongst others, do show in their different ways that psalms were composed in the pre-exilic period, a fact which has been too grudgingly admitted. The intrinsic evidence of some of the psalms, such as the reference to a human king, or the processional features of the second part of xxiv. ("Lift up your heads, O ye gates"), or the primitive cosmology of the first part of xix., confirms the probability that some of these pre-exilic productions would survive in a post-exilic Psalter. So long as we are thinking of the origin and original meaning of a particular psalm, we must always be prepared to admit that it may go back to a relatively early date, however much modified in its present adaptation to the needs of the second temple. On the other hand, we use any psalm in its present form as an early document only at considerable risk; we may conjecture, but we cannot prove. The main reasons for regarding the contents of the Psalter as largely post-exilic remain unaffected by recent criticism, *i.e.*, those that spring from the general relation of the religion of the psalms to the prophetic religion. If with Gunkel we regard the majority of the psalms as the expression of individual piety, we have to ask whether such wide-spread piety is conceivable before the work of the great prophets. The psalms represent a partial fulfilment of the prophecy of the New Covenant made by Jeremiah; is it likely that they preceded it? We cannot reasonably doubt

that the prophets of the 8th and 7th centuries were pioneers, and that they taught truths that were new to their contemporaries, even though they may have used forms of expression and even of thought which were more or less conventional. Nor can there be any doubt that the religion of the Psalter as a whole is closely related to the prophetic teaching. We seem to have parallel phenomena in the formulation of Israel's laws (Deuteronomy, the Law of Holiness, the Priestly Code) and in the Wisdom Literature; in all three cases ancient elements are given a new setting, but the new setting gives them a new meaning. Laws, proverbs and psalms are alike reinterpreted and restated in the light of the prophetic teaching, which had certainly taken time to permeate the nation's religion. Nothing has come to us through the editorial sieve that could not be given a plausibly orthodox meaning according to post-exilic standards. Thus the psalms as a whole must still be treated as a post-exilic book. This might be confirmed by the subtler test of psychological usage, hardly to be simulated; the word "spirit," for example, is used of man in the psalms with psychical predicates in a way not found elsewhere in the pre-exilic literature of the Old Testament.

As for the relation of the psalms to the similar compositions of Babylonia, we find many interesting and instructive parallels of form, language and thought, but not less striking differences which must not be ignored, due to the far higher religious standpoint of Israel, and the suppression of magic in the interests of religion (though some of the older forms and expressions doubtless continued to be used). The resemblances may be partly explained by the independent development of closely related peoples (G. R. Driver, in *The Psalmists*, pp. 109 *seq.*), and partly by the entrance of the Hebrews into a land dominated by Mesopotamian influence (as the Tell el-Amarna tablets prove); but it is quite possible that there was some direct influence also, even prior to the exile. This possibility also applies, but in a much smaller degree, to the influence of Egypt; there is the well-known parallelism of the "Hymn to the Sun" of Ikhnaton with Ps. civ., which matches the close relation of the "Teaching of Amenophis" to our canonical Book of Proverbs. But whatever contributions came directly or indirectly from without, there is good ground for holding that in all that really matters the Psalter is a native product, and that to Israel still belongs the undiminished glory of carrying the religious lyric to its highest point of development.

Any attempt to characterize the teaching of this anthology must be made with the full consciousness of its variety of authorship, purpose and date. It is the most varied of the books of the Old Testament, and offers many unreconciled antitheses. Devotion to the sacrificial system and ritual of the temple is found side by side with prophetic protests against the popular reliance on them. Faith in the exact retributive justice of God within the limits of earthly life does not exclude the perplexities of those who could not be blind to the sufferings of the innocent and the prosperity of the wicked. The nationalistic demand for supremacy over, and even for vengeance on, enemies is neighbour to the universalistic sense of Israel's missionary stewardship for all the world. The recoil from the shadow of death, which leaves no light of Yahweh's presence beyond the grave, does not wholly prevent the conviction of a fellowship with God that virtually conquers death. But certain comprehensive truths may be usefully remembered in the study of the Psalms.

The central religious principle is, of course, the idea of God. The monotheism is sometimes implicit rather than explicit, for there are a number of references to other "gods" (lxxxvi. 8, lxxxix. 6, xcv. 3, etc.); yet these are perhaps no more than the survival of ancient phraseology. The general standpoint of the psalms is that of an exalted and imageless monotheism (cxv.), unlimited in power, universal in range. The most prominent attributes of Yahweh are "lovingkindness" (*chesedh*) and "righteousness" (*ṣedheḳ, ṣedhaḳah*), combined in cxlv. 17, expanded in xxxvi. 6–11; they are complementary, not antithetical. To these must be added the mystery and majesty of God—the quality which we have come to call "the numinous," best expressed in Ps. xc.; the wrath of God cannot be measured by human norms of right and wrong. This great God is omnipresent (cxxxix. 7–12), and eternal (xc. 1, 2; cii. 26–28). Around this great and exalted personal centre in heaven, but on the lower level of earth, we may trace a series of concentric circles in nature, history, human society, the temple, narrowing at last to the personal religion in which man can look right up to God. Nature is directly controlled in all its detail by God, and no "laws of nature" come between Him and His creation. The cosmology of the "nature" psalms (viii., xix. 1–6, xxix., lxv., civ., cxlviii.) is crude; man walks on a flat earth, with the "shades" of Sheol beneath his feet, and Yahweh with His angels above his head, on the solid firmament; round about the earth is the primaeval ocean and its monsters, overcome long since by Yahweh's creative power. The great facts which emerge from this primitive setting of man's life are the dignity and glory of his high place (viii.) amid the glories of Yahweh's creation (xix. 1–6) and His universal providence (civ.). The power of the enthroned Yahweh is manifest in the majesty of the thunderstorm which sweeps the earth, whilst in the heavenly palace His angels glorify Him (xxix.).

The peculiar providence of God is, however, best seen in the redemptive history of Israel (lxxxi. 10). At great crises, Yahweh has intervened to save His chosen people (cxiv.). The God of the past (cv., cvi.) will be the God of the future, when His rule shall be proved supreme over all (xlvii., and the other "enthronement" psalms). A prince of the house of David shall be his vicegerent (lxxxix. 35 *seq.*; *cf.* ii., lxxii.) and the final judgment of men shall vindicate His righteousness (i. 5). This is the essential faith of the righteous, the company of those who fear Yahweh and are remembered by Him (*cf.* Mal. iii. 16), the group to whom we seem to owe the most "spiritual" of the psalms. They live in a society of mingled elements, and have many enemies, without and within, for there are imprecations against unworthy Israelites (lxix., cix.) as well as against the ungodly heathen (cxxxvii., lxxxiii., lix., lviii.), and they may be under unjust rulers (lii.). Their great problem is that which troubled the best minds and hearts of Israel, and found no solution within the Old Testament, *i.e.*, the strange and perplexing prosperity of the wicked and the adversity of the righteous in a world governed by an omnipotent and righteous God (xlix., xxxix., xxxvii., lxxiii.).

The sacramental centre of this faith is the Temple in Jerusalem, to which the exile turns with passionate longing (xlii., xliii.—originally a single psalm). (The devotion to the "Law" came later, except for i., xix. 7–14, cxix.) To the temple come the pilgrims from afar (cxx.–cxxxiv.), full of pride in the holy city (xlviii.), the spiritual home of many proselytes as well as of Jewish exiles (lxxxvii.). The temple is Yahweh's earthly dwelling-place (cxxxii. 13, 14) to which His "guests" may come (xv., xxiv.); its sacrifices (lxvi. 13–15, cxvi. 13) and processions (lxviii. 24–27, cxviii., xxvi. 6) mark supreme moments of religious experience. This is the normal attitude of the Psalmists towards the temple; but the emphasis of the Book is prophetic rather than priestly, and this finds utterance sometimes in the contrast of "spiritual" religion with external rites (xl., l., li., except for the added verses, li. 18, 19). The personal religion of the psalmists is marked by trust in Yahweh based on history and experience (xvi., xxiii., xci., ciii.), by the consciousness of "righteousness" (xviii. 20–24), not divorced from fundamental ethical qualities (xv., xxiv., ci., l.), by the awakening to a sense of sin and of the need of forgiveness, usually, it would seem, through misfortune, sickness, the fear of death (xxxii., li., cxxx.), and in the highest examples, by a victorious conviction of fellowship with God (lxxiii. 23–26) which even death will not be able to break. This last is the more noteworthy, because there does not seem to be either here or elsewhere in the psalms any explicit teaching of immortality or resurrection (some have found the hope in xvi., xvii., xlix.).

Such is the relatively simple faith of the most influential book of the Old Testament, which has claimed so supreme a place in the public worship and private devotion of Jew and Christian. Its magical secret lies in its simple and concrete expression of universal religious experience. Its value is altogether independent of our enquiries into its sources; indeed, it has won its place by its lowly submissiveness to reinterpretation in order to meet the ever-changing needs of the unchanging human heart.

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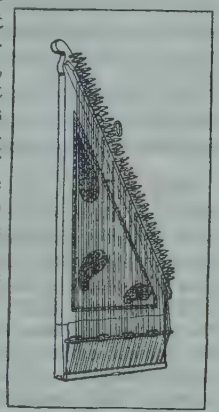
(H. W. R.; X.)

PSALTERY, PSALTERION or SAWTRIE, an ancient stringed instrument twanged by fingers or plectrum, and mentioned many times in the English Bible, though precisely what form of instrument is implied by these various references is doubtful. In its mediaeval form it consisted of a shallow box sound chest over which strings varying in number were stretched, being fastened at one side to pegs and at the other to wrest pins. In the early rectangular form the strings, numbering 10 to 12, were of uniform length, the pitch being varied by their thickness and tension. When the triangular form succeeded the rectangular, the stringing was that of the harp, pitch being dependent on the length. The psaltery was held in an upright position against the chest of the performer, until, owing to the increasing number of strings, it grew too cumbersome, when it was placed flat on a table or on the knee. From the psaltery descended the spinet and the harpsichord.



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THE PSALTERY, A MEDIAEVAL INSTRUMENT PLAYED BY FINGERS OR PLECTRUM

PSAMMETICHUS (Egypt. PSAMMETK), the name of three kings of the Saite, 26th dynasty, called by Herodotus respectively Psammetichus, Psammis and Psammenitus. The first of these is generally considered to be the founder of the dynasty; Manetho, however, carries it back through three or four predecessors who ruled at Sais as petty kings under the 25th, Ethiopian, dynasty. It is known from cuneiform texts that 20 local princelings were appointed by Esar Haddon and confirmed by Assur-bani-pal to govern Egypt. Niku (Necho), father of Psammetichus, was the chief of these kinglets, but they seem to have been quite unable to hold the Egyptians to the hated Assyrians against the more sympathetic Ethiopians. The labyrinth built by a king of the 12th dynasty is ascribed by Herodotus to the Dodecarchy, or rule of 12, which must represent this combination of rulers. If the dynasties were numbered thus before Manetho, the numeral may be the cause of Herodotus' confusion.

After his father's death Psammetichus I (664–610 B.C.) was able to defy the Assyrians and the Ethiopians, and during a long reign marked by intimate relations with the Greeks restored the prosperity of Egypt. The short reign of the second Psammetichus (594–588 B.C.) is noteworthy for the graffiti of his Greek, Phoenician and Carian mercenaries at Abu Simbel (*q.v.*). The third of the name was the unfortunate prince whose reign terminated after six months in the Persian conquest of Egypt (525 B.C.). It has been conjectured that the family of the Psammetichi was of Libyan origin; on the other hand, some would recognize Negro features in a portrait of Psammetichus I, which might connect him with the Ethiopian rulers.

See EGYPT: *History;* F. L. Griffith, *Catalogue of the Rylands Demotic Papyri;* the portrait H. Schäfer in *Zeitschrift für aegyptische Sprache*, xxxiii, 116. (F. Ll. G.)

PSELLUS, MICHAEL CONSTANTINE, THE YOUNGER, (1018–*c.* 1079), Byzantine writer, was born at Nicomedia, or Constantinople, of a consular and patrician family. Under Constantine Monomachus (1042–54) he became one of the most influential men in the empire. As professor of philosophy at Constantinople he revived the cult of Plato at a time when Aristotle held the field. At the height of his success as a teacher he was recalled to court, where he became state secretary and vestarch, with the honorary title of "Υπατος τῶν Φιλοσόφων (prince of philosophers). Presently he entered the monastery of Olympus (near Prusa in Bithynia), where he assumed the name of Michael. But, finding the life little to his taste, he resumed his public career. Under Isaac I (Comnenus) and Constantine X (Ducas) he exercised great influence, and was prime minister during the regency of Eudocia and the reign of his pupil Michael Parapinaces (1071–78). It is probable that he died soon after the fall of Parapinaces.

In character Psellus was servile, unscrupulous and weak. But as a literary man, he will be remembered as the forerunner of the great Renaissance Platonists. His works embraced politics, astronomy, medicine, music, theology, jurisprudence, physics, grammar and history.

Of his works, which are very numerous, many have not yet been printed. We may mention: *Chronographia* (from 976–1077); three Epitaphioi or funeral orations over the patriarchs Cerularius, Lichudes and Xiphilinus, and nearly 500 letters. The most important of his works have been published by C. Sathas, who has also edited the *Chronographia* in Methuen's series (1899), in his Μεσαιωνικὴ βιβλιοθήκη, iv, 5. On Psellus himself *see* Leo Allatius, *De Psellis et eorum scriptis* (1634); J. E. Sandys, *Hist. of Classical Scholarship*, i, 411 (1906); P. Würthlein, *Rhetorische Studien* (Paderborn, 1919).

PSEUDODIPTERAL, in architecture, a term applied to a temple in which the single row of columns set around the cella is separated from the cella wall by a space equal to the distance between two pairs of adjacent columns, so that the effect is that of a dipteral (*q.v.*) temple with the inner row of the double colonnade missing.

PSEUDONYM, a false or invented name, particularly the fictitious name under which an author produces his work in order to conceal his identity. The same end is gained by publication without any name, or anonymously. The body of works thus produced either without the author's name or under a fictitious name became known as anonymous and pseudonymous literature. Many books affording a key to the identity of the various writers have been published. Though Fredericus Geisler published a short treatise on the subject entitled *Larva detracta*, etc., in 1669, the chief early work was that of Vincent Placcius (1642–99), whose *Theatrum anonymorum et pseudonymorum* was published in 1708, edited by L. F. Vischer; supplements were published in 1711 and 1740.

Other works included *Dictionnaire des ouvrages anonymes et pseudonymes* (1806–09), by Antoine A. Barbier; *Deutsches Anonymen-Lexikon, 1501–1850* (1902–07) and *Deutsches Pseudonymen-Lexikon* (1906), by M. Holzmann and H. Bohatta.

In English, R. Thomas' *Handbook of Fictitious Names* appeared in 1868. *Dictionary of the Anonymous and Pseudonymous Literature of Great Britain*, by S. Halkett and J. Laing, was revised and published posthumously in four volumes in 1882–84. Other English works were W. Cushing, *Initials and Pseudonyms*, 2nd series (1886, 1888), and *Anonyms* (1890); and F. Marchmont, *A Concise Handbook of Literature issued under Pseudonyms or Initials* (1896).

PSEUDOPERIPTERAL, in architecture, a term applied to a building or temple in which the cella or enclosed portion has engaged or attached columns which line with the side columns of the front porch or portico, and thus simulate a surrounding colonnade.

Examples are: the temple of Zeus at Agrigentum in Sicily (late 6th to 5th century B.C.), in which all the columns of the exterior are attached to the cella wall; and the more usual *Maison Carrée* at Nîmes (constructed in 16 B.C.). In certain Roman ex-

amples, such as the temple at Tebessa in Algeria (early 3rd century after Christ), pilasters replaced the engaged columns.

PSICHARI, ERNEST (1883–1914), French author, grandson of Ernest Renan, and son of Jean Psichari, director of studies at the École des Hautes Études in Paris, was killed on the western front on Aug. 22, 1914. He was one of the leaders of the young generation before World War I who sought to "rationalize" war and the defense of their country; he sought to provide the psychological basis for heroic action.

His work is that of an intellectual who must justify the "great sacrifice." In the year before World War I *L'Appel des armes* had a powerful moral effect among young intellectuals. It is the story of a captain in the Algerian army who converts to the military ideal the antimilitarist son of an internationalist, who finds mental peace in military obedience.

This book was followed by *Les Voix qui crient dans le désert. Le Voyage du centurion* appeared as the finished form of this work. In 1917 Jean Psichari presented to the Luxembourg library his collection of 25,000 volumes on mental subjects, in memory of his son Ernest. A second son, Michel, was killed in May 1917.

Bibliography.—Henri Massis, *La Vie d'Ernest Psichari* (1916); L. Aguettant, *Ernest Psichari* (1920); A. M. Goichon, *Ernest Psichari*, etc. (1925).

PSILOMELANE, one of a group of hydrated manganese oxide minerals, with very similar appearances and properties, which are difficult to distinguish. They frequently occur in hard black botryoidal or stalactitic masses with a smooth surface, hence the name from the Gr. *psilos,* smooth, and *melanos,* black. However, they may also be soft and earthy. They are distinctly crystalline, and not amorphous as once supposed. The name "psilomelane" was originally applied to material from Schneeberg, Saxony, which has the formula $BaMnMn_8O_{16}(OH)_4$, and should be restricted to this composition. The other manganese minerals of similar appearance should be referred to as being of the "psilomelane type" until their exact nature is determined. Among these have been distinguished, on the basis of chemical analyses and X-ray photographs, the following species: Cryptomelane, with a formula approaching KMn_8O_{16}, occurring in crystals and cleavable masses as well as in botryoidal form. Cryptomelane is probably the most common of the psilomelane type of minerals. Others are hollandite, with a composition approximately $BaMn_8O_{16}$; coronadite, $MnPbMn_6O_{14}$; rancieite, $CaMn_4O_9.3H_2O$ (?); and lithiophorite, with complex composition, being hydrated and containing lithium and aluminum in addition to manganese. They are associated with other manganese ores and derived from them by weathering. (*See* also Pyrolusite.) (L. S. Rl.)

PSITTACOSIS, an infectious disease endemic among various species of birds, notably parrots and parakeets, lovebirds, doves and occasionally in other species. It is transmitted to man ordinarily as a dust-borne infection from the excreta of birds. This dust is inhaled and occasions in man a pneumonia differing in a number of respects from classical lobar pneumonia. Occasional cases have occurred where the infection has apparently been transmitted from human patients to their attendants or visitors, but this occurrence is rare.

Because of the mechanism of infection it is usual that several persons in one family become infected. The history of the first recorded outbreak, reported from Uster, Switz., in 1879 by Jacob Ritter, is typical. The family kept a number of finches and parrots in the house. On Feb. 26 six small birds were received from Hamburg, Ger. One of these birds died shortly after, and between March 13 and 18 five persons in the family became ill with evidence of pneumonia, and on March 27 and 29 two more persons became ill, one a frequent visitor to the family, the other the person who came in to care for the birds after the family got sick. Three of the seven patients died, and autopsies, revealing a lobular pneumonia, were performed by Eberth.

Clinically the disease is characterized by a hacking cough which produces little or no sputum, by a stuporous or "typhoid" state, by the gradual extension of the pneumonia through the lung, as watched by repeated X-ray examinations, by the rather long (two to three week) duration of the pneumonia and by a long convalescence. In the preantibiotic days mortality was high. Some benefit was reported from the use of penicillin, chloromycetin and aureomycin.

As noted by Eberth, the pneumonia is lobular in character, and in the fatal cases is often confluent and widespread. There is an apparent sequence of congestion and oedema, red hepatization and gray hepatization, but all phases are commonly present in the same lung and even in adjacent areas. This sequence corresponds histologically to a primary exudate of fibrin, red corpuscles, polymorphonuclear leucocytes and epithelial cells, later replaced gradually by large mononuclear phagocytes and epithelial cells. The causative organisms are sometimes found as clusters of small rounded and elongate (cocco-bacillary) rickettsialike inclusion bodies in swollen attached and desquamated alveolar lining cells.

In earlier outbreaks various bacteria had been incriminated as the cause of the disease. In the world-wide epidemic of the winter of 1929-30 the causative organism was almost simultaneously identified as a filterable virus by groups of bacteriologists in Berlin, London, New York city and Washington, D.C., and the observation of the virus bodies as small cocco-bacillary organisms, visible under high magnifications with the microscope, was also simultaneously reported from Berlin (April 5), Washington (April 11) and London (April 12, 1930).

The acute disease in birds was characterized by lesions and accumulations of the organisms in the liver, kidney and intestinal epithelium, which account for the infectivity of the faeces.

(R. D. Le.)

PSKOV, in German, *Pleskau,* a town of U.S.S.R. in the Pskov district of the Leningrad area, in 57° 48′ N., 28° 22′ E., situated on both banks of the Velikaya river, 9 mi. S.E. from Lake Pskov. Pop. (1939) 59,898. The chief part of the town, with its kremlin on a hill, occupies the right bank of the river, to which the ruins of its old walls (built in 1266) descend. The old cathedral in the kremlin has been four times rebuilt since the 12th century; the present edifice (1691–99) contains some very old shrines, as also the graves of the bishops of Pskov and of several Pskov princes. The church of Dmitriy Solunskiy dates originally from the 12th century; there are others of the 14th and 15th.

History.—Pskov, formerly the sister republic of Novgorod and one of the oldest cities of Russia, maintained its independence and its free institutions until the 16th century, being thus the last to be brought under the rule of Moscow. It already existed in the time of Rurik (9th century); and Nestor states that in the year 903 Olga, wife of Igor, prince of Novgorod, was brought from Pleskov (*i.e.,* Pskov). The Velikaya valley and river were from a remote antiquity a channel for the trade of the south of Europe with the Baltic coast. Pskov being an important strategic point, its possession was obstinately disputed between the Russians and the Germans and Lithuanians throughout the 11th and 12th centuries. It became in the 12th century a *prigorod* of the Novgorod republic; *i.e.,* a city having its own free institutions, but included in certain respects within the jurisdiction of the metropolis, and compelled in time of war to march against the common enemy. Pskov had, however, its own prince (*defensor municipii*); and in the second half of the 13th century Prince (Timotheus) Dovmont fortified it so strongly that the town asserted its independence of Novgorod, with which, in 1348, it concluded a treaty wherein the two republics were recognized as equals. Its rule extended over the districts of Pskov, Ostrov, Opochka and Gdov (farther north on the east side of Lake Peipus). The *vyeche* or council of Pskov was sovereign, the councils of the subordinate towns being supreme in their own municipal affairs. The council was supreme in all affairs of general interest, as well as a supreme court of justice, and the princes were elected by it; these last had to defend the city and levied the taxes, which were assessed by 12 citizens. But while Novgorod constantly showed a tendency to become an oligarchy of the wealthier merchants, Pskov figured as a republic in which the influence of the poorer classes prevailed. Its trading associations, supported by those of the working classes, checked the influence of the wealthier merchants.

Its strong walls and its 40 large and wealthy churches bear testimony to the wealth of the inhabitants, who then numbered about 60,000. As early as the 13th century Pskov was an important station for the trade between Novgorod and Riga. A century later it became a member of the Hanseatic league. Its merchants and trading associations had factories at Narva, Reval and Riga, and exported flax, corn, tallow, skins, tar, pitch, honey and timber for shipbuilding. Silks, woollen stuffs and all kinds of manufactured wares were brought back in exchange. In 1399 the prince of Moscow claimed the privilege of confirming the elected prince of Pskov in his rights; and though, 50 years later, Pskov and Novgorod concluded defensive treaties against Moscow, the poorer classes continued to seek at Moscow protection against the rich.

After the fall of Novgorod (1475) Pskov was taken (1510) by Basil Ivanovich, prince of Moscow, and a *voyvode* or deputy was nominated to govern the city. Moscow, at the end of the 17th century, abolished the last vestiges of self-government at Pskov, which thenceforward fell into rapid decay. Near this city the Teutonic knights inflicted a severe defeat upon the Russians in 1502. Pskov became a stronghold of Russia against Poland, and was besieged (1581) for seven months by Stephen Báthory during the Livonian War, and in 1615 by Gustavus Adolphus of Sweden. Under Peter the Great it became a fortified camp. Under the tsarist regime the province of Pskov extended from Lake Peipus to the sources of the western Dwina, and after the 1917 revolution the province of Pskov, though much diminished, remained an administrative unit. In 1927 it was incorporated in the newly created Leningrad area (*q.v.*).

PSORIASIS.—Psoriasis is a moderately common disease of the skin, of great chronicity. It may begin at any age, and a familial history of psoriasis is common. Individuals affected by the disease are ordinarily otherwise healthy; the only exception to this is arthritis in some patients. The lesions of psoriasis are usually characteristic, consisting of sharply outlined dull red patches of varying size, with thickening of the skin, and a heavy rough scale which is silvery or asbestoslike in colour.

Psoriasis has a characteristic distribution over the body in a majority of cases, involving principally the scalp, the elbows, the front of the knees and the trunk. It does not cause loss of hair. Involvement of the nails is quite common, and this may be mistaken for a ringworm infection. The disease varies a great deal in severity and in many patients it will show periodic flareups. In general, nervous tension will make psoriasis worse. There is no regular relation of the disease to any type of diet. Sunlight is usually very helpful, and a considerable variety of local treatments are effective temporarily. Most of the proprietary medicines sold for the treatment of psoriasis contain organic compounds of mercury or various types of tars. Arsenic internally was formerly used in the treatment of psoriasis, but is now rarely employed. X-ray therapy is used with decreasing frequency; it carries definite risks if used in excess. No infectious agent has ever been isolated regularly from lesions of psoriasis, and there is no evidence that the disease is in the least contagious. Compounds such as cortisone or ACTH have been employed successfully in some patients, but are variable in their effects and are justified only in the most severe cases, particularly those with associated arthritis. (D. M. P.)

PSOROSPERMIASIS, a term formerly applied to infection with any one of several groups of Protozoa, including the Cnidosporidia, Myxosporidia, Gregarinida, Coccidia or Sarcosporidia, all of which have in common a resistant spore or cystic stage, which develops in the intestines, liver, kidneys, ureters, musculature or other tissues of the host. (E. C. F.)

PSYCHE, in Greek mythology, the personification of the human soul. The importance, in Platonic philosophy, of love (in the highest sense) as an agent of the soul's progress leads, in art from the 4th century B.C., to representations, allegorical or playful, of Psyche (generally represented as a winged girl, a relic of the old conception of the soul as a bird or insect) in company with Eros (*q.v.*), usually in amatory scenes. The tale of Cupid and Psyche, in the *Metamorphoses* of Apuleius, is interesting as the only ancient fairy tale which is told as such. In it Psyche, the youngest daughter of a king, arouses the jealousy of Venus, who orders Cupid to inspire her with love for the most despicable of men.

Cupid, however, falls in love with her and carries her off to a secluded spot, where he visits her by night, unseen and unrecognized by her. Persuaded by her sisters that her companion is a hideous monster, and forgetful of his warning, she lights a lamp to look upon him while he is asleep; in her ecstasy at his beauty she lets fall a drop of burning oil upon the face of Cupid, who awakes and disappears. Wandering over the earth in search of him, Psyche falls into the hands of Venus, who forces her to undertake the most difficult tasks. The last and most dangerous of these is to fetch from the world below the box containing the ointment of beauty. She secures the box, but on her way back opens it and is stupefied by the vapour. She is only restored to her senses by Cupid, at whose entreaty Jupiter makes her immortal and bestows her in marriage upon her lover.

See O. Waser in W. Roscher, *Lexikon,* iii, 2327 *et seq.* (1924); L. C. Purser, *The Story of Cupid and Psyche* (1910).

PSYCHIATRY is that part of medicine which is concerned with the mental aspects of health and sickness and with the mental and material forces which promote or hinder the healthy functioning of the human being in personal and social ways. Psychiatry differs from other divisions of medicine because of its primary preoccupation with the personality functions. Historically, this differentiation has been heightened by specialization in medicine. The patient, as a person, has by these specialistic trends been lost to view, or dealt with at a rather superficial level, and this fact has contributed to the need for a specialty to deal with the "patient as a person" or the "organism as a whole"—terms by which modern psychiatrists have sought to indicate the subject matter of their branch of medicine.

HISTORY AND GENERAL DISCUSSION

The specialistic differentiation of psychiatry has been influenced and somewhat confused by the historical fact that psychiatry has been slower than other divisions of medicine in the development of effective rational therapy. In the 19th century "psychiatrist" was synonymous with "alienist"—a specialist skilled in the detection and management of insanity, whose main treatment was institutional segregation, with humane custodial care. During the first half of the 20th century, psychiatry grew from a descriptive to a dynamic orientation, with increased therapeutic powers and aspirations. That large division of human illnesses known generically as the neuroses or psychoneuroses has, in many communities, become part of the specialistic field of psychiatry, although in some communities these illnesses still are considered to remain in the specialty of neurology. During the second quarter of the 20th century, child guidance was added to the domain of psychiatry. Emotional reactions and personal maladjustments came to be recognized more systematically than previously as factors in many sorts of disease. This orientation to medical problems, enlarged to include psychodynamic considerations, was designated "psychosomatic medicine." Increased attention to social and environmental factors in medical practice also concentrated attention upon the emotional reactions and attitudes which determine in what way social and material circumstances may influence persons in psychological, physiological and pathological ways. These and other considerations have heightened the desire, in medical education and practice, for a substantial knowledge of human nature, which would be scientifically sound and clinically useful. The development of a fairly teachable and verifiable body of psychodynamic knowledge enabled psychiatry to make considerable headway in meeting this need. Psychiatry was therefore outgrowing the bounds of a specialty of medical practice at mid-20th century and was in the process of becoming, in part, a basic medical science.

In its role of a basic science, psychiatry is intimately related to biology and physiology, since it deals with the integrative functions of the organism. Psychiatry, however, is distinguished from classical physiology and biology because it deals so largely with

interpersonal reactions and attitudes and therefore employs distinctive techniques of interviewing and of biographical study. Theoretically, psychiatry as a basic medical science should be closely associated with the sciences of psychology, sociology and social anthropology, but historically these associations have been rather by accident than by design.

During the 19th century the human brain was intensively studied in the confident expectation that increasing precision in the localization of its functions and increasing knowledge of physicochemical mechanisms would provide a material basis for the explanation of abnormalities of mentation and behaviour. As late as 1910, Sir John Tuke, John Macpherson and L. C. Bruce stated that insanity was "a generic term applied to certain morbid mental conditions produced by defect or disease of the brain," but this should be recorded as a hopeful expectation of that generation of workers rather than as a scientifically established fact. Such brain-anatomical studies of the speech function, for example, met with a fair degree of success in the cerebral localization of lesions causing specific aphasic disorders, but even in this limited segment of personality functions complete explanation by local lesions had not been established at mid-century.

A brilliant succession of German psychiatrists, culminating in Emil Kraepelin, delineated a limited number of presumed specific diseases, such as dementia praecox, manic-depressive psychosis and paraphrenia, for which specific material causes were sought unsuccessfully. When the spirochaete of syphilis was discovered, it was demonstrated to be the cause of meningoencephalitic lesions in a certain proportion of the insane, amounting to about one-tenth or one-twentieth of the admissions to mental hospitals. These cases had previously been classified clinically as general paresis, by reason of the characteristic occurrence of muscular weakness or paralysis caused by lesions in the nervous system. A moderately successful method of treatment of these conditions by malarial inoculations was devised by Julius Wagner von Jauregg of Vienna.

Other types of diffuse lesions of the brain, such as occur in Alzheimer's disease, lead encephalopathy and encephalitis, also provide organic causes of psychotic mental disorder, most common of all being the cerebral lesions of arteriosclerosis and senile degenerative conditions. There is but a meagre correlation between the extent of cerebral damage and the severity of psychotic mental disorder; to a considerable extent, the character and severity of the maladaptive personality functioning associated with organic brain disease is determined by the previous personality. Personality functions are disturbed by toxic conditions, deficiency states and metabolic and endocrine disorders which affect the brain. And yet it remains true, in the majority of psychotic patients and in nearly all neurotic patients, that no physical or chemical explanation can be found in the brain.

Even in some of the psychotic and neurotic conditions in which no lesions of the brain have been found, a measure of therapeutic success has been gained by chemical, physical and surgical measures aimed at the disruption of neural pathways in the brain, temporarily or permanently. In one method a convulsive reaction is elicited by passing a measured alternating electric current briefly through the brain by means of electrodes placed on the scalp. This electroconvulsive therapy has been found particularly effective in interrupting depressive moods. The induction of hypoglycaemic coma by injections of insulin has had a considerable vogue in the treatment of early schizophrenic illnesses. In prolonged agitated states, unresponsive to other treatment, relief is sometimes obtained by the surgical destruction of certain tracts in the frontal lobes of the brain. The rationale for the use of these methods of acting upon the brain had not been clearly worked out at mid-20th century, but, in general, they offered means, crude but sometimes helpful, for modifying the physiological functioning of the brain, and may be integrated into the psychiatrist's strategic plans for promoting better personality functioning.

Adolf Meyer elaborated a clinical approach to mental disorders through the concept of psychobiological reaction patterns, determined by a multiplicity of developmental and environmental factors, as a more realistic and adequate formulation of the clinical facts than the limited assumption of cerebral disease processes. This broadly conceived psychobiological orientation encouraged the integration in the United States of psychological, social and biological lines of investigation in psychiatry.

Introduction of Psychoanalysis.—The potentialities for the psychological understanding of mental disorders were greatly advanced by Sigmund Freud's psychoanalytical investigations of "unconscious" mental processes through hypnosis, free association and dream analysis. (*See* PSYCHOANALYSIS.) In the psychoneuroses, and particularly in hysteria, it was possible by these methods to broaden very greatly the range of memories pertinent to a particular morbid pattern of reaction, to mobilize the emotional or instinctual forces in conflict, and to aid the patient thereby in a more adequate integration of his emotional attitudes, with permanent relief from neurotic symptoms. The therapeutic effectiveness of this method was earlier attributed chiefly to the patient's gain in insight, but further experience served to emphasize the therapeutic importance of the emotional relationship between patient and physician. The term "transference" has been used to designate a special aspect of the patient-physician relationship—the tendency for the patient to repeat toward the physician patterns of emotional attitudes previously held toward father, mother or other persons upon whom he has been emotionally dependent. This repetition is not exact. Indeed, it is precisely by reason of the potential differences that the transference situation may be so handled as to serve as a corrective emotional experience, liberating the patient from the inner tyranny of a maladaptive pattern.

Conceptions fundamental to a psychodynamic understanding of human nature were developed by Freud, who disclosed by his studies the mechanisms of repression, displacement and identification and the related phenomena of projection, conversion and rationalization. His fundamental dynamic concept was that of conflict between opposing forces deep within the personality: on the one hand, instinctual urges or propensities toward the fulfilment of basic biological needs, such as propagation of the species, collectively designated as the "id" tendencies, whose performance promises pleasure and whose frustration means distress; and, on the other hand, the experience of objective hindrances and pressures toward conformity, involving the intelligent postponement or modification of action, and adherence to an ideal of behaviour. The conscious person tends to preserve self-esteem by repression—an active ignoring or distortion of unacceptable experiences or impulses, whereby they become unconscious, but still exert influence upon attitudes and behaviour. Much repression is involved in normal, everyday living, and need not be productive of significant disorder, but in those who lack self-assurance or are poorly integrated there may develop neurotic or psychotic symptoms, or a stilted reaction formation which sets a rather rigid pattern of personality development, not obviously abnormal but unhealthy or unprofitable because so many of the potential forces of the personality are bound up in the maintenance of self-defense.

Certain philosophical and speculative ideas of Freud have also been so often implicated in discussions of psychiatry as to require some comment here. Foremost among them are the libido theory and the postulate of psychic determinism. The universal validity of these assumptions has been considered at times by some as axiomatic for a psychodynamic orientation in psychiatry, but this absolutist attitude does not now generally prevail. With regard to psychic determinism, a strong statement was needed, historically, to challenge effectively the previously prevailing materialistic tendency to limit all causal efficacy to physical forces, as if psychological experience might reflect neural events but could have no effective part in determining subsequent behaviour. It was still being sometimes argued at mid-century, that complete determinism is a necessary postulate for scientific study, in psychiatry and psychology, as elsewhere; but certainly one mode of scientific study is by experimentation, as distinguished from observation, and this distinction would be erased by the assumption of complete determinism. By recognizing a fairly large though incomplete measure of psychic determinism, appropriate respect for the forces of human nature and their modes of operation was gained. Whoever would seek systematically to modify human re-

actions and attitudes, for therapeutic or other reasons, must reckon with whatever degree of faith in psychic determinism or indeterminism is justified by available knowledge and skills; but, as an absolute dogma, determinism may be viewed as one of Freud's philosophical speculations rather than as a foundation of psychodynamic science.

The Libido Theory.—This may be rather loosely but concisely expressed as the assumption that the sexual instinct is the source of biological energy driving human nature. This theory has been, perhaps, the most hotly contested proposition in modern psychiatry. The protagonists of the libido theory developed special dialectic skill in pointing up the personal sources of emotional resistance to their doctrine, and it was not difficult to show that much of the opposition to the libido theory arose from repugnance rather than logic. A great abundance of clinical observations served to illustrate that sexual impulses, and emotional conflicts incident thereto, can be found associated with all regions of the body, and with practically any of the objects and activities intimately concerned in human living. But cumulative clinical studies by psychoanalytic methods led Freud himself to a radical modification of his original view of the role of the sexual instinct in anxiety states. The facts required, for example, the recognition of hostile and aggressive propensities as biological forces, just as fundamental as libido. Aggressive impulses are likewise subject to repression, displacement and other unconscious mechanisms, and hence are as difficult to recognize and trace, clinically, as sexual impulses.

Because such a large proportion of psychoanalytic literature dealt with sex, a widespread impression prevailed that dynamic psychiatry is concerned only with sex. This mistaken notion may be one of the reasons why psychiatry in general is somewhat repugnant to, and therefore neglected by, some persons otherwise well informed and open minded.

Instinct in Behaviour Patterns.—The post-Darwinian emphasis upon the biological nature of man gave a special importance to instinct in the formulation of basic concepts of human nature. The emphasis upon instinct was somewhat excessive and also confusing. In the fields of general biology and psychology the concept of instincts took a somewhat different course of development from what it did in the psychoanalytic literature, with resulting misunderstanding. Biologists and psychologists in general found it convenient to study instincts as behavioural patterns whose biological utility lay in the aptness of a rather specific innate pattern of behaviour for the achievement of a definite biological goal. In this sense there is but little in human behaviour to label instinctive. Psychologists and social anthropologists contributed impressive evidence that human behaviour is patterned chiefly by social custom. In the psychoanalytic literature the primary useful implication of the term instinct was not the specific behaviour pattern, but the drive or urgency toward the biological goal. Instinct is, in this usage, an innately prompting motivational force rather than a stereotyped instrumental pattern. This difference in the use of the term "instinct" impeded mutual understanding. It became possible to avoid some confusion and controversy by the invention of an adjective form "instinctual," rather than "instinctive," to connote this special motivational implication. *Instinctive* behaviour patterns may be more or less readily identified by observation; *instinctual* motivation must be inferred by the interpretation of behaviour. The difficulties of interpreting the biological motivations involved in human behaviour are very real, and it is doubtful if there would have been much progess in the development of skilful interpretation in this field without persistent detailed study of individual patients, including the adaptive meaning of symptoms, the intensive biographic study of personal issues in relation to pathological reactions, the disclosures obtained by hypnosis and free association and other clues to the unconscious aspects of mentation. The difficulties of such interpretive study of motivation are indeed so great that it might never have proceeded far without the special stimulus of the therapeutic goal—the combination of the desire of a patient in emotional distress to work through to some peace of mind, and the therapeutic enthusiasm of the physician. It has been for these reasons that the basic advances in a psychodynamic science of human nature have been made under medical rather than academic auspices. The emotional satisfactions and frustrations involved in therapy have, however, somewhat impeded scientific progress in this fundamental field of psychiatry by arousing considerable emotionalism and sectarian animosity in the discussion of psychodynamics. No general synthesis found universal acceptance.

It is possible, nevertheless, to present in the following paragraphs a broad sketch of what may be called a general psychiatric view of elementary psychodynamic principles, without attempting to point up or to iron out divergences from Freudian psychoanalysis or other special doctrines.

Psychodynamic Principles.—The primary psychopathological condition is anxiety. In ordinary speech one is said to be anxious when in disturbing suspense about some uncertain event. Although we speak of anxious situations, this is a figure of speech. Situations are not anxious; it is a person who is anxious, and the muscular tensions or even tremors which characterize the state of anxiety indicate that person's impulse to activity, which is being checked. Anxiety is closely related to anger and fear. The primitive root words imply constriction or choking in all three experiences. Constriction of the chest or throat is for many persons the most distressing feature of anxiety. In the experiences called anger or fear, there is some object or person or situation offering a fairly clear-cut point of focus for decisive reaction. Anxious situations are typically those which offer no feasible focus of decisive reaction, either fight or flight, or in which such reactions are inwardly prohibited or suppressed. In addition to tensions and tremulousness in the voluntary musculature, anxiety is also characterized by sweating, flushing or pallor, rapid or uneven heart rate, disturbances of gastrointestinal function and other indications of excitation in the autonomic nervous system.

Anxiety, in some measure and duration, may be considered a useful biological function, mobilizing the resources of the organism for sudden violent activity. Many anxious situations cannot, however, be resolved satisfactorily by any outburst of activity. Indeed one's appreciation of the situation is often somewhat befuddled, and the urge to activity may result in restless agitation or some rather aimless action which nevertheless affords a certain relief from intolerable tension. Clinically speaking, anxiety *per se* is seldom presented as the chief complaint by those driven by it to seek medical relief. The most common presenting complaints are specific effects of tension such as headache, backache, tremor or insomnia, or the physiological disturbances such as indigestion, excessive perspiration or palpitation of the heart; and the complaint is frequently misinterpreted by the patient as a sign of organic disease. Commonly, too, the patient has only an obscure understanding of the background of dissatisfaction from which have arisen the impulses involved in the anxiety reaction, especially if those impulses are incompatible with the way of life to which he or she is officially dedicated by custom and choice.

In the simpler cases, the psychotherapeutic aspect of the psychiatrist's treatment of anxiety states consists in helping the patient resolve this obscurity by a more complete and adequate review of the total situation, including facts and impulses which may have been obscured by mental mechanisms of repression or displacement. Granted that the patient is fairly free of pathological personality trends, and enjoys therefore a considerable freedom of spontaneity and self-confidence, such a clarification of issues may put him in a fair position to work out a practical solution of his situation or an acceptable compromise with what may be unalterable.

It happens not infrequently, however, that such a patient has not the full employment of mature attitudes adaptable to the real life situation, by reason of immature development or some hindering personality trend. The maladaptive personality patterns which thus prevent the therapeutic resolution of anxiety may, by the same token, predispose the patient to repetitive anxiety attacks. Some of the maladaptive patterns are particularly difficult to overcome permanently, because they offer a sort of solace and a mitigation of the anxiety state, by relieving the patient's sense of responsibility. Such, for example, are the obsessive-compulsive

pattern, the hysterical conversion reaction and the paranoid pattern.

Understanding of the genesis of maladaptive personality patterns or morbid personality trends depends upon an appreciation of the social nature of human living. Exactly the same statement can be made regarding excellent patterns and trends, but at mid-century these had not yet received the same intensive study because their fortunate possessors do not have particular incentives to submit themselves to exhaustive study. The better patterns are nevertheless of great interest and importance to the psychiatrist, for it is by their development and exercise that his patients make the most satisfactory recoveries and adjustments in life.

The most significant features of a person's environment are other human beings, for in human societies it is through interpersonal co-operation that people satisfy even the most elementary biological needs, such as food, shelter and propagation of the species; yet other persons can also be most frustrating and disturbing. Interpersonal co-operation is mediated through interpersonal sentiments or attitudes, which are as definitely the instrumentalities of human living as are the tools and skills of a person's occupation. A person's organized system of interpersonal attitudes may be said to constitute his personality—the aspect which he presents to others and the means by which he establishes and maintains relationships with others. Into the formation of these sentiments or attitudes go whatever instinctual propensities characterize man as an animal, with individual innate variations in force, direction and sensitivity, together with the effects of individual interpersonal experiences by which these propensities have been shaped into patterns conforming more or less to the generally established pattern of his culture, as modified in its impact upon the individual person by the special characteristics of parents, siblings and other agencies of acculturization. The formative years of life do present a succession of impersonal problems, in play and in work, through which capacities are stimulated and perfected, but, more significantly, these educative play problems and work problems are embedded in social settings, and the child's personality is shaped by the development of acceptable modes of adaptation in this social milieu. Satisfaction and gratification are as much social rewards as they are products of objectively successful individual effort, since they depend upon one's gaining success through behaviour, which, while spontaneous, is also in a pattern which gains and maintains the respect and affection of others. One's personality development, and particularly one's sense of security and personal worth, are strongly influenced, therefore, by the character and consistency of the social milieu of one's formative years. Some cultures, and some homes, operate automatically to arouse and cultivate individualistic aggressiveness; others through communal ceremonials cultivate even-tempered moderation and well-poised social participation. No culture provides completely uniform homes, no home brings exactly the same attitudes to bear on each of the children, and nature provides a considerable diversity of innate propensities; hence any culture affords a variety of personality patterns.

Concerning some of the pathological variants it may be said that antisocial personalities are commonly products of "bad" homes—broken homes or those permeated with hostility; obsessive-compulsive personalities are commonly products of "good" homes—good in the sense of stability and conformity but in which affection is weak and acceptance is conditional upon correct performance; hypochondriacal patterns are commonly modelled upon an example of invalidism in the home, or are cultivated by the overprotective solicitude of parents. Yet all such statements are but crude approximations, exceptions are numerous, and one of the main principles of modern psychiatric study and treatment is to conduct an individualized study of each case adequate to reveal the main recurrent theme or issue of dissatisfaction and conflict, to assess the individual's unused potentialities for dealing with this issue and to evoke a well-founded and self-assured mode of resolving the issue more satisfactorily. This thematic method of psychiatric study is what distinguishes psychodynamic psychiatry from the preceding stage which was essentially descriptive.

(J. C. Wn.)

SYMPTOMATOLOGY: SOMATIC SYMPTOMS

A wide variety of bodily changes, many of them productive of troublesome symptoms, has been found to occur in response to life situations. These somatic disturbances are often accompanied by special emotions or feeling states, but they may occur in the absence of awareness of emotional conflict. The individual, finding himself in an adverse situation, may repress his feelings and be unconscious of emotional stress. Bodily changes which occur in the absence of emotional display have often been found to be more extensive than otherwise.

Many of the bodily changes which occur in response to situational stimuli are not symptoms in the sense that they are disturbing. For example, the accelerated flow of saliva which accompanies pleasurable thoughts of eating is painless, purposeful and, as a reaction to a situational stimulus, would not be looked upon as a symptom. Blushing and weeping are other commonly observed but less agreeable bodily changes which occur because an individual finds himself in a special situation. Blushing and weeping would also not ordinarily be construed as symptoms. Other equally familiar somatic changes might, however, because they are accompanied by disagreeable sensory experiences. The wave of nausea which often accompanies fear, rapid heart action, trembling, sweating of the hands or urinary frequency are examples of such symptoms. Despite the common occurrence of these phenomena which quite obviously represent bodily changes occurring in response to situational stimuli, there has been a general lack of awareness of their implications, and of the possible relation between situation and disease. It is, therefore, of special interest that recent evidence indicates that serious disturbances in bodily functioning occur in response to life situations, which may lead to incapacity or even death.

Almost any of the bodily organs or organ systems may participate in disturbances which occur in response to threats to the integrity of the organism. All these patterns of reaction are not clearly understood, but certain of them appear to have some significance as defensive mechanisms. Tears, for example, appear to serve no function when they are shed in reaction to a bereavement or humiliation. When the same mechanism is invoked, however, as a defense against local assault by noxious fumes or dust, tears are clearly recognized as a useful device for washing away the offending substance and protecting the eyes of the threatened individual.

Tears constitute only a part of a widespread defensive pattern of a person, invoked not only in response to local threats but also in adverse life situations productive of anxiety and conflict. The defensive pattern is one of shutting out and washing away. It is characterized by partial or intermittent closing of the eyelids, tears, swelling of the membranes of the nose with obstruction of the air passages and increased nasal secretion, sneezing, coughing and often constriction of the throat, oesophagus and bronchi which may give rise to inability to swallow and difficulty in breathing with asthmatic wheezing. When such widespread bodily changes are transitory they cause little inconvenience to the subject. When sustained, however, as is often the case when situational conflicts are unresolved, they may lead to serious disease. The nasal obstruction, for example, impairs drainage and allows microorganisms located in the nose to invade the tissues and establish infection in the nasopharynx, sinuses or elsewhere along the respiratory passages.

Other serious physiologic disturbances occurring during situational stress have been recognized in the gastrointestinal tract. Constrictions in the oesophagus just proximal to its entrance into the stomach have been demonstrated. A tightness in the chest, not unlike that which accompanies coronary artery disease, or more intense burning pain, may occur.

The behaviour of the stomach has been studied in some detail during various emotional states and life situations with regard to appearance, blood supply, motor activity and secretion. Interest in this subject was given impetus by the famous studies of William Beaumont on Alexis St. Martin, a French fur trader who acquired a permanent opening into his stomach because of an accidental gunshot wound. Among his classic observations, Beau-

mont noted that the appearance of his subject's stomach varied with his mood. Later, I. P. Pavlov measured in the stomachs of dogs changes in the secretion of gastric juice brought about by situations productive of conflict. Later Walter B. Cannon described disturbances in digestive and motor activity as well as secretion in animals during crises. Studies were also made on a man whose stomach was accessible to view and who provided an unparalleled opportunity for the study and recognition of the influences of situational stimuli on that organ of the human body. This subject's rather volatile emotional life provided special opportunities for investigation. In general, in the various studies conducted, it was found that in response to situations which gave rise to feelings of fear, disgust or dejection the stomach became pale and inactive and secreted relatively little acid. This state of the stomach was often accompanied by feelings of fullness in the upper half of the abdomen and nausea. On the other hand, it was shown that life situations which gave rise to feelings of conflict with anxiety, hostility and resentment were accompanied by opposite changes in the stomach; namely, engorgement of the mucous membrane with blood, increased motor activity and accelerated secretion of acid. In this state the stomach wall was found to be relatively fragile. Minor insults caused injury with the formation of small bleeding points and erosions. In this state, too, the pain threshold in the stomach was found to be greatly lowered. (*See* PAIN, SIGNIFICANCE OF.) Thus, when a state of sustained overactivity and engorgement prevailed in the stomach, heartburn and localized pain in the upper half of the abdomen commonly occurred. There is considerable evidence to indicate that the changes in the stomach which occur during such pernicious emotional states set in motion a chain of events which leads to peptic ulcer.

Lower in the gastrointestinal tract, changes in blood flow and motor activity in the colon have been observed to occur under circumstances of situational stress and it is thought that these disturbances form the basis for the development of colitis of various types.

Like the gastrointestinal, the cardiovascular system commonly participates in patterns of bodily reaction to situational threats. Rapid heart action and disturbances in rhythm give rise to palpitation and occasionally cardiac pain. Transitory high blood pressure with all its attendant symptomatology has also been induced experimentally during discussions of emotionally charged situations. There is some evidence to indicate that serious sustained hypertension may occur in reaction to situational stress.

Alterations in blood flow through the kidneys have also been demonstrated experimentally during variations in emotional state. If a sustained reduction in blood flow occurs, a mechanism is provided which may contribute to the development of hypertension.

Disturbances in the contractile state of peripheral blood vessels may also give rise to symptoms as in the case of cold hands and Raynaud's disease, in which circulation to the hand is reduced below the requirements of local tissue metabolism. During an attack the hands become pale, blue and painful and finally red as the attack of vascular constriction subsides.

Symptoms arising elsewhere in the body have been shown to occur in response to situational stimuli but at mid-20th century had been studied less thoroughly than those mentioned. Changes in salivary flow appear to have some importance. Subjects with unexplained halitosis were found to display a marked diminution in salivary secretion which thus impaired the normal washing effect of saliva in the mouth.

Skeletal muscle tension prevailing in any of several parts of the body frequently gives rise to troublesome symptoms. The familiar "wryneck" is an example of such a disturbance. Many troublesome pains in the back which may lead to serious incapacity have been traced to sustained contraction of spinal muscles occurring as part of a reaction to a situational threat or dilemma. It is likely that other painful conditions of the extremities have a similar origin.

Fever, elevation of the white blood cell count, skin disorders, disturbances in vision and, indeed, in almost any of the bodily functions may occur as part of a reaction to situational threats.

Most common among symptoms which are related to life situations and emotional state is headache and by far the greatest proportion of headaches occur in response to problems of situational adjustment. Two separate mechanisms have been described. One is responsible for tension headaches and the other for migraine. Tension headache is usually characterized by a dull ache, persistent and nonpulsatile, located most often in the occipital region and associated with slight local tenderness and stiffness of the neck. Tension headache is caused by sustained contraction of underlying muscles whose products of metabolism accumulate between the muscle bundles and stimulate pain nerve endings there. The tension may spread around the head producing a painful sensation of bandlike constriction. Tension headache occurs in reaction to situational conflict and most characteristically occurs in association with feelings of emotional tension.

The headache of migraine is usually more intense than tension headache. It arises as a result of overdilatation of arteries, mainly of the scalp, with resultant stretching of their walls by the pulsating column of blood which they contain. Migraine characteristically occurs among conscientious, perfectionistic people who relax poorly. They have been called "stress addicted" because of their compulsive need for striving and adherence to standards.

More strictly psychiatric disorders may be marked by any of the above symptoms and symptom patterns attributable to alteration of body physiology. If a patient has an especially low threshold for reaction to pain or if, because of some conditioning experience, the painful part has acquired special symbolic significance to the individual, he may overreact to minor physiologic disturbances and become incapacitated by disturbances which would go unnoticed by the average subject.

In addition to the serious physiologic disturbances described above as occurring in response to difficulties of situational adjustment and the overreaction to minor disturbances, it appears likely that certain somatic symptoms which accompany psychiatric disorders are entirely "imaginary," having their origin above the segmental levels in the central nervous system. The bodily delusions which accompany psychoses appear to be disturbances of this type, as do the puzzling losses of bodily function which characterize hysteria. Evidence on this point, however, is far from complete. It is largely based on the fact that the distribution of hysterical anaesthesias, for example, often does not correspond to the arrangement of the neurons within the nervous system; on the fact that reflex activity may be undisturbed in an instance of hysterical paralysis in which all voluntary power is lost; and on the fact that from a total disability sudden complete recovery may occur either spontaneously or under hypnosis.

There are few psychiatric disorders which are not accompanied by some somatic symptoms or disturbances. The body usually participates prominently in efforts of the organism to adjust to its environment. Thus, when depression settles on the individual's thinking and emotional reactions, not only are his mental processes slowed but his whole body is likely to become slowed and he may display a paucity of skeletal movements as well as depressed visceral function with, for example, diminution in salivary secretion leading to halitosis and diminution of the motor activity of the intestines leading to constipation.

Somatic symptoms are a part of psychiatric disease just as the body is a part of the organism and hence shares in its reactions to environmental forces. (*See* also NEURASTHENIA.)

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PSYCHOLOGICAL DETERMINANTS: DYNAMIC PSYCHIATRY

The principles of psychological motivation revealed by the study of the mental processes of the patient, and the application of these principles in modern psychotherapy, are usually referred to as "dynamic psychiatry." This approach to the problems of neu-

rosis and psychosis is primarily concerned with the adaptations of an individual to his emotional needs, to the realistic and cultural demands of his environment and to the stresses imposed by relationships with other people.

The technical principles, discoveries and concepts of dynamic psychiatry developed phenomenally during the 20th century, and were influenced throughout by psychoanalysis (*q.v.*). But though there are many diversities of technique, as well as theory and objective, among those who specialize in dynamic psychiatry, all have in common one basic principle unique in medicine—the study of the ideas and other subjective experiences of the patient. Much of the human psychic life is for everyone a private world, consisting of daydreams, secret loves, secret hates and secret fears, and the study of these elements of mental life is the raw material, the empirical basis, of dynamic psychiatry, this modern contribution to psychopathology and to treatment.

Concepts in Dynamic Psychiatry.—*Adaptation.*—The cardinal concept of dynamic psychiatry is that all reactions of the human organism serve the basic need to secure an optimal adaptation to internal and external stresses. Such a perspective creates a revolutionary attitude to psychotic and neurotic problems. Whereas descriptive psychiatry is concerned essentially with the diagnosis and classification of abnormalities, the techniques of dynamic psychiatry repeatedly demonstrate that apparently harmful mental symptoms or modes of behaviour are in fact adaptations to forces unknown to the patient. The arbitrary differentiation of "abnormal" as contrasted with "normal" (or "sick" as contrasted with "healthy") consequently dwindles in significance, and the therapeutic problem becomes the question of why psychotic adaptations necessitate a tragic limitation of social function, and neurotic adaptations, almost by definition, involve suffering and failures.

Dynamic psychiatry assumes that the potentiality for a great variety of psychological needs and social patterns varies in each individual in accordance with his individual physiology and inherited endowment, and that development involves the activation and suppression of these potentialities by environmental influences, especially those of infancy and childhood.

The environment is a major component of those stresses to which the individual must adapt. Indeed the ability to create situations compatible with gratifying interpersonal relations is one of the major problems of life and a major criterion of mental health. Environmental problems include those of social status and class, convention, ethics and group morality, economic problems, problems of school and vocational adjustment, relationships with friends, family and other members of the community. Besides the more concrete societal institutions, there are the cultural attitudes, especially conventional standards of behaviour, religious dogmas, criteria of success and failure, all the mores and manners of a society which offer many variable possibilities of social adjustment in a complex civilization. What is acceptable in one culture or its subdivisions is unacceptable in another, and what is socially significant and impelling for one individual is unimportant to another.

Psychiatric methods which emphasize predominantly the social aspect of adaptation are occupied chiefly with the conscious and rational elements of human behaviour. For social stresses are reflected and consciously recognized in the more superficial types of introspection, in the self-conscious awareness of inferiority feeling and in phantasies that fundamental personality problems can be relieved by a new vocation or habitation, or even by the ever-prescribed rest cure, whose results are notoriously ephemeral. The limitations of social psychiatry in therapy are a result of the fact that repeated failures in social adjustment are usually the consequence of the basic internal conflict rather than its cause. This is especially true of adults, whose social relationships and problems are determined to a great extent by the healthy and neurotic components of the personality itself. The younger the individual, the more true is the statement that he is reacting to excessive environmental difficulties rather than involuntarily creating them. Consequently the psychiatric importance of the immediate environment as a primary factor is greater in children than it is in adults, while in infancy the stresses imposed by a milieu over which the individual has utterly no control approach 100%.

Conflict.—Adaptation is largely a process of resolving various conflicts between intrinsic and extrinsic stresses experienced by the individual. There are the social conflicts discussed above, in which the individual must adapt strong impulses of his own to those of other people or to his culture. But there are many other basic types of conflict. There are conflicts between the need to be dependent and independent, to be both dominant and submissive, and those resulting from love and hate of the same person. There are conflicts resulting from dual reactions to the same stimulus; for example, the feeling that the physical manifestations of sexuality are both desirable and disgusting. Another important group consists of the conflicts between the need for various forms of pleasure and the moral feelings. Consideration of conflicts between what one wants and fully conscious moral codes only scratches the surface; for many basic conflicts are shown by modern psychiatry to involve a guilt which is not consciously recognized. Most important of all, in the experience of modern psychiatrists, are the conflicts between adult desires and attitudes and needs of childhood which still press for gratification.

Repression; Emotion and Motivation.—A major reason why a basic conflict, or one of the components of a conflict, is unrecognized by the individual himself is the process known as "repression." This consists of the exclusion of a motivating memory or phantasy from consciousness. Study of repression by special methods shows that "maladjustments" and neurotic symptoms are themselves resultants of this adaptive process. For repression spares the individual an experience still more painful than the symptom itself, especially the emotion of anxiety and its derivatives, apprehension and guilt.

Repression affects more than ideas; it also often excludes from conscious experience the emotion associated with ideas which can produce a conflict. This was a basic discovery, for emotion is regarded by dynamic psychiatry as the primary factor in motivating psychological and social adaptations. It is emotion which impels us to act, or to want to act, in certain ways; ideas have no effect without feelings. Emotions are the representations of physiologic processes in the autonomic nervous system; they are the subjective components of biologic needs which impel the human organism to strive for various pleasure-yielding goals. Primitive emotions are, however, modified by environmental influences, especially those of infancy, which predispose the individual to conflicts. The empirical task of the dynamic psychiatrist therefore resolves itself into studying those groups of ideas (complexes), and especially the phantasies, through which alone he may identify the true meaning of the individual's emotional demands, his drives and the conflicts which have undergone repression.

Fixation and Regression.—Techniques for investigating phantasy material show that many repressions are significant because they involve not only the emotions activated by immediate experience but also situations originating in the past, often the remote past of infancy and childhood. This is explained by the fact that some emotional situations were not originally resolved by satisfying behaviour, but by repression. Such complexes are said to represent "fixations" to immature types of imagery and emotional need. In other cases the crucial conflict is in the present, but is avoided by unconscious replacement of the current conflict by a more immature pattern, a mechanism termed "regression." Both fixation and regression show why much of the motivation of maladjustments is inexplicable to the rational mind; conscious introspection in terms of logic and the realities of the present cannot account for phenomena motivated in these ways. Thus, "rationalization," or the effort at logical explanation of emotionally motivated reactions, becomes a fruitless mental labour and fails to achieve its purpose of solving an emotional problem.

Character Patterns.—The effects of the conflicts, fixations and repressions of some patients are more apparent in patterns of conduct productive of suffering and frustration than in the symptoms and inhibitions which result from simple repression. Each neurotic behaviour pattern is characterized by compulsiveness so that an endless amount of reasoning with oneself will not and cannot cure

the inevitability of reacting in certain ways unacceptable to other individuals and groups. Many other character patterns are not neurotic, but the less rigid characteristics of an individual's own way of adapting himself to others; these unneurotic traits are less compulsive and more modifiable than neurotic patterns, but they too are products of developmental influences and comprise the total means at the disposal of the individual for adapting successfully and with flexibility to variable situations.

The Integrated Personality.—Emotion, drive, conflict and their consequences are not, however, the only elements affecting adaptation. A basic need to function effectively determines how well the individual can organize co-ordinated responses to all stresses, and the more effectively integrated the personality, the more subordinated crucial conflicts are to conscious intention and reason and to the demands of the present and the expectations of the future. Mature integration results from a long process of growth, in which the innate development of physiologic processes, learning and the successful nonrepressive solution of emotional demands at various levels of maturity all play conspicuous roles. Pathological failure of the integrative functions is most conspicuous in psychoses, where gross failures of integration make adaptation to adult society impossible. They may also be severely impaired in problems of character and behaviour, and are always impaired to some extent by any neurotic symptom or tendency.

Psychological Ontogeny: *Development.*—All these facts and concepts which distinguish dynamic psychiatry—adaptation, conflict, fixation and regression, immaturities of character and integration—led to special knowledge of the development of personality and interpersonal relationships, and of its role in maladjustment. Only through understanding why and how an individual's personality was formed and modified at various levels of development does one attain an adequate understanding of his psychological motivation and social patterns. All human beings are immature in certain ways, the more neurotic conspicuously so; everyone is still at times a little boy or little girl seeking to find the satisfaction denied his childhood wishes, failing to adapt to all his conflicts maturely. Dynamic study of the abnormal mind and character has therefore led to basic discoveries of the nature of the normal child and his problems, and of vital aspects of his emotional development. These results have manifold ramifications in pedagogy, social hygiene, preschool psychology, anthropology, sociology and medicine. Dynamic psychiatry learned much about psychopathology, therapy and the aetiology of some organic diseases; but above all it learned that personality is built on the emotional experience of the past. People do not "grow out of" the unsolved problems of childhood—they encounter them and reproduce them again and again in forms no longer recognized for what they are. The more painful or socially futile adaptations become the objectives of the psychiatrists who approach therapy as primarily a problem of the dynamic understanding of what deeply affects the individual's modes of solving his conflicts and meeting the world of other people. (I. Hk.)

TREATMENT

Psychotherapy.—Psychotherapy is a term used in two ways; *i.e.*, (1) as a semitechnical name for all homely common-sense aids to wise and peaceful living, and (2) as a technical term for those specific methods of treatment which take up where the simpler remedies fail, and attempt to eliminate those compulsions which force people in the face of their own better judgment to live unhappily and unwisely.

In the first sense, psychotherapy is as old as human culture, and includes every effort to shape human thought, feeling and behaviour, whether by education, precept or example, by command or exhortation, by reason and logic or emotional inspiration, by distraction and diversion, by stern discipline or by indulgence and deliberate escape, by punishments and rewards, by direct material relief or by other subtler alterations in the external environment. Finally it includes the influence on the individual of such cultural forces as religion, music, the arts and literature. Such aids have always been used by wise parents, clergymen, teachers and social workers. They are in no sense new: the Greeks in their healing temples used music and occupational therapy as adroitly as does the modern hospital. Nor are they a psychiatric discovery. They are important aids to normal development and education; and while they require patience, tact, intuitive sympathy and practical wisdom, they require little technical psychiatric knowledge, because they are not the specific tools by which neurosis as such is cured. No matter how imaginatively they are used, no matter how much sympathy, intuition, firmness and common sense are employed in their application, these aids by themselves can never resolve the ultimate source of discontent in human life; *i.e.*, the neurotic conflicts which every adult inherits in greater or lesser degree from his own infancy and childhood.

Yet these simple components of psychotherapy perform several useful functions. In the first place, they are a practical test of the severity of a neurosis. Where they succeed, their success proves that the roots of the disturbance were superficial. On the other hand, where after persistent use they fail, their failure proves that the neurosis is more deep-seated. This self-evident fact is often overlooked; and patients, their families and their physicians often blame themselves for the loss of time involved in giving a fair trial to simple measures. Such self-reproaches are justified only when such efforts persist too long in spite of repeated failure, usually out of a prejudice against turning to more precise psychiatric help.

Second, the homely psychotherapeutic methods often exercise an important palliative function, by teaching a patient how to live with some measure of comfort within the limits imposed by an uncured neurosis. In itself this often gives enough relief from mental suffering to constitute a valuable contribution both to the patient and to his family.

Third, these remedies provide an invaluable foundation for deeper treatment. A severe neurosis often causes such complete disorganization in a patient's life that he can turn neither to work nor to play for gratification and self-esteem. For such a patient, intelligent guidance may find healthy activities which in turn may make it possible for him to go through prolonged treatment without breaking down.

Fourth, concurrently with these general introductory measures, the psychotherapist must often undertake considerable emotional re-education. In essence this consists of a careful effort to increase a patient's tolerance for his own instinctual needs, for jealousies which are born in family stress and for the hostilities, fears and guilts which arise out of such conflicts. In this aspect of treatment, group methods may at times be particularly effective.

There are limits, however, to what can be achieved by such direct education, and, when it is pushed too far, patients may reject truths about themselves which are quite obvious to others, because of the fear and guilt which these truths evoke. The essential task of psychotherapy as a science is to remove from the patient's mind those barriers which make it impossible for him to recognize the obvious. Before these barriers are removed, no one *can* tell a patient much of anything; once the barriers are gone, no one *need* tell him.

This fundamental principle of psychotherapy runs counter to much of what is naïvely called common sense; and since even experienced psychiatrists frequently violate this rule, it is small wonder that physicians, nurses, laymen, clergymen, educators and parents are constantly stubbing their toes against it. They offer a patient or relative excellent arguments, reassurance, consolation or sound corrective advice, and then wonder why he agrees verbally yet fails to act on their precepts, or even reacts with panic or rage or depression, instead of with the relief, reassurance and encouragement that had been anticipated.

Yet, if wisely used, even such failures as these need not be without value. They are wasted and even dangerous only when the deduction that should be drawn is rejected, and the psychotherapist stubbornly and perhaps with angry impatience persists in his blunt technique of confrontation. If, on the other hand, he realizes that the patient's seeming recalcitrance arises from deep-rooted unconscious resistances, and if he modifies his technique accordingly, then he has taken a first step toward the eradication of those resistances and of the unconscious obligatory pat-

terns of behaviour which constitute the core of the ubiquitous neurotic component of human nature.

These references to an essential core of the neurotic process, and to a ubiquitous neurotic component in human nature, imply that an understanding of the nature of psychotherapy requires some comprehension of the nature of the neurotic process which scientific psychotherapy aims to combat. Therefore it is necessary to describe more precisely what is meant by neurotic as contrasted with normal. What are the essential differences between neurotic and normal actions, thoughts and feelings? Their differences are found not in the kind of behaviour, not in its legality or illegality, its responsibility or irresponsibility, its social or antisocial values, its rightness or wrongness, its statistical frequency or its conformity to social customs, not in whether or not it seems to make sense, but solely in the nature of the psychological forces which determine and control it. For instance, to stand on one's head in the middle of a street is normal behaviour when it is done to pay an election bet or as a hazing stunt; but the same act is neurotic if it occurs in obedience to an unconscious inner compulsion. Similarly, to wash our hands is normal, but not if it has to be done hundreds of times each day under the whiplash of a blind compulsion, which leaves the patient haunted by a fear that his hands are still dirty. Many such examples could be given, all adding up to the same conclusion; namely, that the difference between normal and neurotic lies not in the act but in the purposes served. And here the significant difference is whether the motivating forces are predominantly conscious or unconscious.

There is conclusive experimental and clinical evidence that every event in human behaviour is the product of motivating forces in which conscious and unconscious processes are mixed together in varying proportions. In such a mixture the conscious purposes are alterable by experience. They respond to reason and exhortation, to successes and failures, to rewards and punishments. As a consequence, behaviour in which conscious purposes play a major role is flexible, adapting itself readily and usefully to external realities. On the other hand, the unconscious purposes in human motivations behave as though they were deaf and blind. Life seems to exert little influence on them. They are not spurred by success, nor deterred by pain and defeat, nor altered by argument, reason or exhortation. Consequently, behaviour which is determined by a preponderance of unconscious purposes is rigid, inflexible and poorly adjusted to external reality. It is this component of human nature which limits our ability to learn either by our own experiences or by the experiences of others.

The second major characteristic of neurotic behaviour arises from the fact that the symptomatic acts and feelings to which unconscious forces give rise never succeed in discharging the psychic energies which are bound up in these unconscious purposes. As a result, in addition to being rigid and inflexible, neurotic behaviour is blindly repetitive and insatiable. This then is the essence of what is meant by the neurotic component of human nature. In widely varying degrees it is found in every human being; and it is against this aspect of human behaviour that scientific psychotherapy is directed; *i.e.,* against those intricate unconscious forces which produce that which is rigid, inflexible, insatiable and repetitive (to wit, "neurotic") in human conduct. It is evident, therefore, that these unconscious forces must inevitably be blind and deaf to the homely common-sense measures which constitute the simple art as contrasted with the intricate science of psychotherapy.

What tools have we, then, by which these obligatory unconscious purposes can be altered? In essence, the goal of all such therapeutic techniques is to reduce the influence of unconscious mechanisms in human life, partly by bringing them under conscious control, and partly by giving some form of adequate discharge to their stored-up energies. The aim is to achieve freedom not merely from superficial symptomatic disturbances, but from the underlying and unconscious sources of neurotic symptoms. Whether this is attempted by accepted psychoanalytic technique, or by such derivatives as analysis under hypnosis or under chemical sedation, the emancipation of the patient requires that in some measure he recapture and relive those past experiences in the course of which the disturbing unconscious purposes were laid down.

This is never easy. Psychiatry had to learn that human beings are very reluctant to revisit the painful and forgotten past, and that patients must be brought carefully and slowly along this path. The importance of recapturing the past was understood by the end of the 19th century, but not its difficulties. Consequently at that time it was attempted by direct suggestion or by impressively commanding the patient to remember, sometimes with the patient in full consciousness, sometimes when he was under hypnosis. This method was soon abandoned, however, because with many patients it failed, while it forced others into premature recovery of material for which they were unprepared, with the result that instead of therapeutic responses, explosive and sometimes disastrous emotional reactions occurred. Therefore, direct exhortations and commands were gradually replaced by the psychoanalytic technique, in which free associations were used to explore the deeper interconnections between psychological processes. In turn this led to a recognition of the fact that certain powerful emotional forces are set in operation in every psychotherapeutic relationship, forces which came to be known as "the transference." It was given this name because the relationship between the patient and the therapist is a mosaic in which many of the feelings which the patient experiences with respect to the physician are feelings which he originally had in earlier and intrinsically more important relationships, and which are now reactivated and re-experienced as though they were about the therapist. The psychotherapist thus becomes in reality a sample drawn at random from a human grab bag, whom the patient has unwittingly vested with special emotional importance, so that he comes to represent all the phantasies with which the patient unconsciously distorts his view of the people who inhabit his world. Therefore the study of such transferred feelings of fear and anger and indifference and affection gradually throws light on a patient's relationship to the world at large. Psychotherapy consequently includes not merely a study of free associations, but also of the fluctuations in the emotional attitudes of the patient toward the therapist. Such transference phenomena are universal; but in psychotherapy the meaning of the transference is brought to the surface and clarified, and the relationship is actively manipulated to further the therapeutic process.

By means of these two weapons (*i.e.,* the study of free associations and of the transference relationship) the patient's conscious and unconscious psychological processes are explored. The material covered ranges over the patient's entire life, from earliest infancy to current years, and includes without prejudice or preference his past and current life, his phantasies and his dreams. Any such painstaking search must of necessity proceed slowly, especially since violent emotional obstacles to the search constantly have to be overcome in the process.

Other levers with which psychotherapy exerts an influence on the underlying neurotic process can be summarized as follows:

1. The transference relationship exercises a powerful modifying influence upon the harsh, unconscious, self-condemnations and self-rejections which dominate much of that which is neurotic in human personality. This therapeutic influence is exercised largely through the passive listening attitude of the therapist, which is far more permissive and reassuring in its implications to the patient than any amount of active argument can be. Indeed active reassurance often serves merely to kindle doubts about the therapist, whereas his patient silence creates in the patient's mind doubts of the validity of his own self-condemnation.

2. In the same way, the transference forces gradually undermine the authority of the condemning parental images which are hidden deep in the unconscious psychological processes of every patient. In the therapeutic process these rigid parental images are slowly replaced by more tolerant, permissive and mature judgments. The literal taboos of childhood give way to the qualified judgments of maturity, until the patient is enabled to build up a conviction of his own right to feel, think, speak and finally act.

3. In this gradual process, the therapist's interpretations play a critical role; but the way in which the patient utilizes these

interpretations depends on the extent to which the self-condemning attitudes have been modified through the relationship that has been created. When it is successful, interpretations lead gradually to the recovery of memories, to the reliving of the past and to the discharge of residual effects which had been stored up from the past.

4. This process is what is called the acquisition of insight: insight, first, into the fact of illness; second, into the inescapable limitations of the life with which the patient is confronted; third, into unconscious conflicts and drives; and, finally, into the sources of these conflicts. At mid-century, much remained to be discovered about the psychotherapeutic effect of insight—how and why it sometimes exercises a profound therapeutic function, and why it sometimes fails; but much experimental work was being done.

Many efforts have been made to clarify and accelerate the psychotherapeutic process; *e.g.*, by systematic use of hypnagogic reveries, exploration of free associations under hypnosis, study of free associations under various types of medication and artificial induction of dissociated states, with spontaneous or artificially induced regressions to younger ages. All these experiments shed new light on psychotherapy, and provided grounds for hope that the process would in time be accelerated. The value of these methods in the treatment of war neuroses and of other acute neuroses had been demonstrated.

Chemopsychotherapy.—Chemical aids to psychotherapy have received considerable interest and attention. In theory their origins reach back to include the use of many forms of sedatives to produce deeper and more prolonged sleep at night or relaxation of emotional tension in the daytime. To this was added an investigation of the use of large doses of sedatives to produce a state of prolonged and nearly continuous sleep lasting for days or even weeks. This was first tried in certain Swiss mental hospitals, but dropped into disuse because of uncertain results, until it was tried again in the treatment of the more acute disturbances of World War II, disturbances which were complicated by states of profound exhaustion.

Chemical agents as aids to psychotherapy took on a more specific objective; namely, to make it possible for the patient to revisit deeply disturbing experiences, while in a state of consciousness so altered that it can be likened to a kind of emotional anaesthesia. When successful, this enables the patient to explore painful memories freely, sometimes with less suffering but sometimes with an alarmingly violent emotional explosion. Under certain circumstances such volcanic eruptions seem to exercise a significant therapeutic effect. This type of experience is variously called "narcoanalysis," "narcosynthesis" or "abreaction," and has played a considerable role in the treatment of the acute upsets induced by the exceptional strains of modern warfare. It must be borne in mind, however, that in appropriate patients the same goals can be achieved under simple hypnosis, or even with direct interview techniques without either hypnosis or chemical sedation. Furthermore, the same results have been achieved using a wide variety of chemical agents, so that no claims for specificity seem to have any validity. Consequently, it is uncertain just how essential is chemical sedation or the induction of any states of partial dissociation or of altered consciousness. All this was still subject to investigation at mid-20th century, and no dogmatic statements about methods were justified. It could only be said that there existed a body of clinical experiences and of experimental work in this area which gave grounds for hope that chemical aids might produce modifications of customary therapeutic techniques, which would not only shorten the duration of psychotherapy but increase its depth and efficacy.

One other way in which chemicals have been used as an aid to psychotherapy should be mentioned; namely, to produce a temporary interference in the metabolic processes in the brain. This has been done by the use of insulin to produce lowering of the blood sugar, or by certain convulsant drugs, such as metrazol, or by electrically induced convulsions. All these manipulations are followed by what is called a "twilight state" (*i.e.*, an altered state of consciousness) which can sometimes be utilized for the exploration of important and relevant historical material which is difficult of access when the patient is fully conscious, and which can be used to evoke emotional discharges which are of significant therapeutic value.

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Mental and Emotional Disturbances of Childhood.—The term mental disorders when applied to children creates impressions coloured by knowledge of adult mental disturbances. It is important to break away from this orientation to gain perspective of the childhood period and understand the important differences between the nature of emotional disturbances in children and adults. While adult disorders usually reflect the turmoil of the growing-up period, the individual carries that problem more in himself. The child, being in the formative period, presents mental or personality disorders that involve basic relationships, and other individuals, particularly parents, are a part of the problem. This means that mental disorders in children are, in the main, relationship disturbances, and both diagnostic and treatment procedures must be built around this essential fact. The main exception is found in the organic disturbances such as juvenile paresis, the sequence of encephalitis, toxic and gross endocrine disorders, etc. Here we see the direct effects of structural changes influencing behaviour and, while basic relationships colour the symptom picture, they are secondary in their effects.

This section deals with the disorders of children that arise from the process of growing up. In the essential relationships, particularly in the family, the drama of growth unfolds. Parents initiate and influence this process and a child in responding to them finds how he can be an individual and learn at the same time how he can be a part of a group. Understanding this normal growth process is essential to understanding and treatment of the mental disturbances that emerge in children attempting to solve the dilemmas universally inherent in growing up.

Normal Growth Process.—This life drama always unfolds in the setting of relationships created by adults and usually within the structure of a family. Here a man and woman create from their own life experiences the roles of father and mother guiding the growth steps of a child they have created. Out of their separate individualities a new individual gets started on a life journey. The father and mother give this new individual his biological equipment, but they also provide him with the social setting in which he discovers how to use his biological potentialities. Through his own experiences the child awakens to the universal reality that he is a separate individual in a family that defines in varying ways the kind of individual he can be.

The Dilemma of Growth.—The parents soon discover that the child is not a mechanism that automatically responds to their desires—they become aware of the individuality of the child created by their own will and from their own biological equipment. He begins to assert his own ideas and express his own feelings. Sometimes these responses are in harmony with what is required, sometimes they are in conflict. Early in the life of the child, and on through the life process, emerges a dilemma the

solution of which determines the degree of mental health in the individual. For the child this dilemma can be stated this way: How can he develop his individual self with uniqueness and with a will of his own and acquire, at the same time, a social self enabling him to feel he is like others and that he belongs to a group? How can he fit into the world that has a preconceived standard for him and at the same time gain a sense of value about himself as a different and unique individual?

The parents also have an important dilemma: How can they exercise the essential moulding influence and at the same time support and encourage the individual difference in the child? How can they encourage independence to emerge from the dependence a child must have on them?

The social forces in the culture and the biological forces in the individual operate throughout life—sometimes in harmony, frequently in conflict. Society limits individuality and the individual asserts himself against these limits. Yet it is clear that a healthy child, in becoming an individual feels both his differences from and similarity to others in his group. The culture draws its vitality from the creative contributions of its individual members. There is little enduring vitality in a society when everyone feels he must be like everyone else. On the other hand there would be chaos if every individual made being different from everyone else his primary objective.

These considerations are basic in understanding the varied emotional disturbances arising in the childhood period. There are several types of disorders which arise from the conflicts that flourish in this formative period.

Mental Disturbances Involving Aggression.—The capacity for assertive and aggressive action is normal in all protoplasm and is essential for survival. In the human being the need to bring this essential quality into harmony with social realities reaches its highest development. Many mental disturbances in children are rooted in the process of adjusting their own drives to the defining and limiting requirements society places upon them. As a sample situation illustrating a serious clash between these forces, a parent seeks help for her eight-year-old boy who "yields to no authority" and "will take nothing from anyone." These brief statements epitomize a serious deadlock between a boy who was asserting his individuality against all social controls represented by parents and school. This problem flourished in a family atmosphere charged with emotional tensions. The mother, explosive in her disciplinary efforts, had developed a highly protective relation to this boy. While admiring the assertive quality in the boy, she was frightened over the crescendo of community anger created by his flagrant definance of all authority. Out of her great fear she sought to maintain her control, and her explosive threatening accentuated the boy's struggle to assert himself against the controls he needed but could not use.

The nucleus in this problem is the common one in the over-aggressive and defiant behaviour patterns of children. The assertive capacity has a totality in early life, but under the guiding authority of a parental relationship breaks up into more partial patterns allowing for both a "yes" and a "no" response. The child, such as this boy, who maintains the negative reaction in a total way, allows no balance between yielding and assertion essential for a friendly relation to authority.

Problems Involving Withdrawal.—The boy just described was in open rebellion against all social controls. Even more serious mental disturbances develop when all this aggressive force is encapsulated and held in. Such a child withdraws into himself and allows little communication of feeling that is essential for any healthy relationship. With such reactions the child becomes silent and withdrawn, gives out very little and resists taking much from anyone. He builds from within, but in the process maintains an isolation that allows little healthy growth. A common description of him is, "I never know what he is thinking or feeling."

The first reaction describes the common pattern of the delinquent, who seeks to grow up on his own terms and against the demands of others. The second reaction describes the more neurotic and even psychotic child, who draws away from relationships and who seeks to nourish himself only from his own resources. Both reactions, however, represent efforts to solve the dilemmas of growth; *i.e.*, how individuality can be maintained in a reality that includes relationships to other individuals.

Problems Involving Overconformity.—Overconformity to social patterns, always seeking to be what others want him to be, allowing only "goodness" to be revealed in behaviour, never risking anything spontaneous—these are forms of behaviour indicating a fear of being an individual and seeking to perpetuate the infantile period by remaining an irresponsible precipitate of the parental pattern, with minimal motivation to allow the emergence of individual difference. In a sense these behaviour patterns emerge from an aggressive and controlling effort to make others carry a life force. They represent efforts to avoid the risks of being an individual and separating the child from the more cloistered setting of infancy. "I don't want to grow up" is the theme song of such a child, usually accompanied by the parental theme song of "I am afraid to let him grow up."

All growing up involves separation and differentiation. A parent presents life to a child and provides the setting in which the child can take hold of living and, in doing so, relinquish the parent and move gradually into a life that is his own. Many parents hold onto their responsibility and avoid risking the child to life. In such protected parental relations this more parasitic type of development can flourish. The child is denied the support and stimulus he needs to achieve a sense of value about being an individual in his own right. Common mental disturbances in such children are manifested by such symptoms as excessive shyness and overt anxiety, and various psychosomatic disturbances such as bed-wetting, lack of appetite, speech disorders, etc., resulting in a double distortion—normal functions of the organism are interrupted and feelings are disguised and diverted from reality. In the latter disorders, the repressed feelings accentuated by this pattern of self-development are expressed by physical symptoms.

A group of mental disturbances is rooted in certain organic deficiencies. Prominent in this group are those based on inadequate biological equipment to meet the demands of the modern world. The mental defective belongs to this group, and society has to find ways and means of helping these less adequate individuals find their place so as to utilize the potentialities they have. They need more protection, particularly during formative years.

It is important to recognize that many mental defectives make a normal adjustment to life. More make this adjustment where parents and teachers adjust their feeling and thinking to an acceptance of their limitations, thus helping them to a fuller development of what they have.

Schools have made progress in this direction by providing educational facilities designed to develop the special but limited capacities of mental defectives. This is a particularly hard adjustment for a parent, especially if the intellectual level of the family is above that of the child. Frustration and discontent can easily arise where a child of limited capacity is pushed to levels of accomplishment beyond his ability. The important fact that should be basic in social planning for this group is that normality can be achieved when we fully realize that normality for any child is the adjustment to and utilization of capacities he has.

Development of the Child Guidance Clinic.—There is little value in understanding the nature of mental disturbances in children unless this understanding is built into therapeutic procedures. With the exceptions noted, these mental disorders are rooted in the essential relationships, and the helping process must provide the opportunity for both child and parent to participate. Both are involved in the problem; both must be included in a solution involving change in both parent and child.

The modern child guidance clinic has built a structure based on the unique nature of the childhood period. It provides the opportunity for both child and parent to have growth experiences to break up the unhealthful elements in their relationship and to move together toward a healthier way of living together as individuals—one the parent, the other the child. The professional skills of psychiatrist, social case worker and psychologist are interwoven to provide this type of service. The focus is on the problem in a child for which a parent has sought help. The helping

process must include the participation of both parent and child, because the problem for which help is needed is rooted in their living together.

Child guidance clinics have had their greatest development in the United States and have made significant contributions to the understanding and treatment of childhood disturbances. These advances were possible because the clinics developed a professional method of utilizing and integrating the skills of the psychiatrist, social case worker and psychologist into a service designed to help a parent and a child. (F. H. An.)

WAR NEUROSES

Any individual, even the most normal, may develop this type of neurosis. Every man has his breaking point, since neuroses are reactions of persons predisposed to respond in an individual manner to a particular quantity of a meaningful stress. Individuals previously psychoneurotic, the psychologically immature, the withdrawn asocial person and the overcompensated tough psychopath succumb more quickly and develop more severe neuroses than do the relatively stable. Although psychiatric selection can weed out the most obvious candidates for war neuroses, objective techniques are not available for accurate and rapid selection of a mass of men; hence the only test of fitness for combat is combat itself. Psychiatric therapy administered during every phase of induction, training and into combat reduces mental stress and lessens the likelihood of psychiatric casualties.

The symptoms of war neuroses are varied, depending on the individual personality and the type and quantity of precipitating stress. Previously overt or latent neurotics react as they had in the past. The acute war neuroses are manifested by direct or indirect evidence of free anxiety. When anxiety is severe it is evidenced by a terror-stricken appearance and, often, behaviour as in a panic. Victims are tremulous, stuttering or mute, and become startled at the slightest sound. Excessive sweating, increased heart beat, dilated pupils and other signs of fear are obvious. Some men become infantile in physical regressions into simian or infantile postures and attitudes, often unco-ordinated, enuretic and drooling. In the milder states of anxiety the subject may be temporarily stuporous, restless, sleepless and without appetite. Catastrophic nightmares of battle awaken these men from their fitful sleep. Most of the anxious patients have considerable amnesia for their traumatic experiences. Many soldiers react with less obvious manifestations of anxiety but with hysterical paralyses, deficits of sensation, convulsive seizures, wobbly gait or loss of a special sense such as sight or hearing. The most frequent disturbance is manifested by functional breakdowns of the internal bodily organs and are experienced as abdominal pain, nausea and vomiting or diarrhoea, cardiac pain and irregular cardiac rhythm, or headache. A few latently psychotic soldiers develop a full-blown malignant psychosis such as schizophrenia. Others become temporarily psychotic, with pathological suspiciousness or loss of comprehension of present reality; recovery is rapid on removal to safety. Very few malignant and permanent psychoses develop, but many depressions result from a feeling of failure to carry on, from men thinking that they have not done enough or have been in some way responsible for the death of a fellow soldier through an act of commission or omission.

Among the important causative factors for these neurotic reactions are physical and emotional depletion and fatigue. Therefore, the first step in treatment is a short stay in an exhaustion centre for rest, warmth, good food and encouragement. If recovery is not effective in a few days the neurosis has become resistant or fixed, and the soldier is evacuated to a hospital where special psychiatric therapy is prescribed. This consists of techniques to uncover the intellectual or emotional amnesia and assist the patient to master his anxieties and conflicts. Return to combat is rarely successful at this level, so that reclassification for noncombatant duty is the usual outcome; if therapy is ineffective the soldier is evacuated home.

Many soldiers returned home for rotation develop signs of war neuroses for the first time. They react to a loss of the solidarity of their combat group, to feeling of guilt at leaving their units, to the letdown of their powers of defense and to a general depletion of their psychological resistance. Others returning in a depleted state are unable to master the problems of readaptation to civilianlike army life at home or to the responsibilities of their families. These delayed war neuroses are manifested by regressions into infantile behaviour patterns, by visceral disturbances, by depressive moods and by aggressive and hostile reactions to persons in authority and civilians.

Identical reactions are often delayed until problems of civilian existence are confronted after discharge from the armed services. Too many demands for adaptation on a psychologically depleted or regressed individual, and insufficient gratification, are important factors in these late breakdowns. Hence social, housing, economic and job difficulties in a period of reconversion are responsible for many war neuroses in veterans of combat.

For neurotic veterans the principles of therapy are gratification of dependent needs, uncovering and ventilation of individual psychological conflicts, stimulation to independence and a satisfactory and unfrustrated outlet for the mature drives. To this end, ambulatory scientific psychotherapy in the patient's own social setting rather than hospitalization is effective. (*See* also *Psychotherapy* above.) (R. R. G.)

SOCIOLOGICAL ASPECTS OF PSYCHIATRY

Legal and Institutional.—No specialty of medicine has so many points of tangency with the law as does psychiatry, the specialty which deals with interpersonal relations. To a large extent, although the approach is different, the subject matter of law and of psychiatry is the same thing—that is, people, and how they conduct themselves.

Nearly all legal actions involve the conduct of individuals, and where individual contact is involved there may be deviations from normal. The psychiatrist may be involved in the question of the state of mind of one who has left a will, made a contract, suffered injuries resulting in mental disorder, who is seeking the annulment of a marriage, or who is accused of having committed a crime. Many of these problems will be dealt with under other headings. There is one phase, however, which should be expanded here—namely, the laws relating to the enforced detention in mental hospitals of persons suffering from psychiatric disorders.

The mentally ill have been with us as long as history has been recorded. It is only in modern times, however, that much has been done about them by the state. The first English institution was the Bethlehem hospital (later corrupted to "Bedlam"), established by a monastic order about the middle of the 14th century; public institutions were a much later development. In the United States, no institutions for the care of the mentally ill were available before the Pennsylvania hospital, Philadelphia, Pa., took in a few patients of this sort in 1756. The first public mental institution was opened in Williamsburg, Va., in 1773. Even as late as the beginning of the 19th century, these institutions were entirely custodial and protective. They were places where the "furiously mad"—those who were menaces to the peace and welfare of the community—were confined. There was very little concept of treatment, and the institutions were called asylums—that is, places of refuge. Thanks to the activities of William and Samuel Tuke and John Conolly in England and of Dorothea Lynde Dix in the United States in the first half of the 19th century, the number of institutions grew amazingly, as did their population. In England, all mental hospitals, public and private, come under the board of control, and the laws relative to the admission of patients are enacted by parliament rather than by the local communities. Consequently, a high degree of uniformity is found in the admission and hospital practices in England. The tendency there has been to keep admissions relatively informal.

In the United States the care of the mentally ill has consistently been considered a function of the several states. As a result, there are 49 separate jurisdictions and 49 potentially differing types of commitment procedure. About 97% of the patients are in public institutions, and the private hospitals are usually under some form of state licensing or supervision.

The tendency in the United States, in the earlier days of the

country, was to keep admissions relatively simple. Usually the order of a judge was necessary to send a patient to a mental hospital and to detain him therein, but the procedure was not complicated. Indeed, many of the states permitted patients to be sent to a hospital upon the certificate of a physician at the request of the guardian or family, just as one is sent to a general hospital today. Beginning about 1870, there developed a tendency to resort to jury trials for the determination of the need of care in a mental hospital, despite the undesirable effect of this procedure on the patient. By mid-20th century, however, only one state required a jury trial for commitment; there were 11 others in which a jury trial may be held at the discretion of the judge. In 26 of the states there might be a hearing before a magistrate after an examination by two or more physicians. In four other states there is a proceeding before a board or commission, with a judge as chairman.

In at least 10 states, a patient might be sent to a mental hospital for a short period on the written request of a police officer or physician, and in 34 states, the patient who is clear enough to understand what he is doing may make application for his own admission, on a voluntary basis, being at liberty to leave when he gives the required written notice. The essentials of the procedure, then, are that there be a medical examination and opportunity for a hearing before a magistrate. The federal constitution does not guarantee jury trial for any but criminal proceedings, and the disadvantages of such trial far outweigh the imagined protection to the patient.

The order of commitment, when issued, permits the hospital to receive the patient and detain him so long as he requires care. In a number of states, the commitment as such does not deprive the patient of his civil rights. Theoretically, at least, it is solely a justification for detention. The laws relating to mental hospitals are designed to protect the rights of the patient, not only to prevent improper commitment, but to ensure humane care in the institution. Patients may have access to legal counsel and may write under seal to certain state authorities if they have complaints. The more populous states have supervisory boards or commissions which inspect the hospitals and see that the laws and regulations are enforced.

Release comes from the head of the institution, under such conditions as he may lay down when the patient's condition warrants. In the case of persons charged with crime, or convicted, the patient is returned upon recovery to custody of the legal authorities if proceedings or a sentence is still pending. The patient, if he feels aggrieved, may always have recourse to the courts by petition for a writ of habeas corpus.

There are special provisions for the commitment of the feebleminded; this group differs from the mentally ill in that they suffer only from a defect of development. Most of them are educable in the community, but a small proportion requires institutional procedures and rigid regimes. In four U.S. states at mid-century there was a provision for the commitment of sexual psychopaths, so-called—that is, those persons who are menaces to the community by reason of their uncontrollable sexual impulses, but who, at the same time, are not considered legally "insane." There were four states, also, with laws providing for the commitment of the so-called defective delinquent—that is, the feeble-minded person who has serious criminal tendencies.

Much more might be said on the question of the enforced detention of the mentally ill for care in mental hospitals. There are, however, many other legal aspects of mental disorders which should be mentioned. Many actions are brought which involve personal injury. Some of these come under the category of workmen's compensation cases, but most of them are actions in tort. In general, it may be said that if a person suffers damages at the hands of another who is mentally ill he is entitled to damages, even though the one inflicting the injury is not capable of comprehending what he is doing at the time. A far more frequent type of case is that in which it is alleged that, as a result of shock or physical injury resulting from an accident, the plaintiff has developed a mental disorder of some sort, very frequently a neurosis. Again, if there was a dereliction of duty on the part of the person who caused the injury, the injured individual is entitled to damages if he can show that he has the disability alleged.

Another type of case is that involving wills in which it is alleged that the testator at the time of making the will was not of sound mind or did not have what the law refers to as "testamentary capacity." English and U.S. law, in general, requires for testamentary capacity that one making a will shall have the ability to know the facts necessary to qualify him for that purpose, to understand that he is engaged in devising his property to others, to understand in a general way the nature and position of his property and to bear in mind those who are naturally entitled to consideration in the distribution of his estate. The law is inclined to take a narrow view of the nature of the incapacity and the symptoms shown and may be said to lean over backward in protecting the rights of the testator. For example, even though it is well recognized by psychiatrists that delusions, in general, show serious mental disorder, the law is inclined to require proof that the delusion of the testator directly affected the disposition of the property. Another psychiatric problem is that of the use of so-called undue influence; in this case, the law recognizes that the enfeeblement of old age may render a testator unduly subject to blandishments or threats in a way which, though not constituting "insanity," is recognized as abnormal.

With relation to the marriage state, it is generally held that if a person is so deranged or defective mentally that he cannot appreciate the nature of the marriage relation and its duties and obligations, his marriage may be annulled by the court upon his petition. To give relief to the sane spouse, a number of U.S. states enacted legislation entitling the spouse to receive a divorce if the patient has been suffering from mental disease and confined in a mental hospital for a stated number of years, and is certified to be probably incurable. The sociological aspects of this type of legislation are certainly open to question, as are the medical ones.

It is in criminal cases that the so-called plea of insanity achieves its greatest degree of notoriety, a notoriety which is out of all proportion to the frequency with which the defense of insanity is urged. There is a widespread impression that many criminals plead insanity in an attempt to escape the consequences of their crime, and that this "insanity" which is alleged is often of a very tenuous and unsubstantial nature. Such few cases of this sort as arise achieve publicity out of all proportion to their frequency.

Ever since about the 14th or 15th century, English law has recognized that one of the elements of crime is the so-called *mens rea,* or guilty mind, and that mental disorder may exist to such a degree as to negative this element, in which case the defendant is entitled to an acquittal by reason of insanity. The rule in force in England, and in most of the states in the U.S., was laid down in the McNaghten case in England in 1843, and has often been criticized by psychiatrists as being out of line with modern psychiatric points of view. The test, known as the "right and wrong" test, is essentially that the party accused must have been labouring under such a defect of reason from disease of the mind as not to know the nature and quality of the act he was doing, or if he did know it, that he did not know he was doing what was wrong. It is emphasized that this knowledge must extend to the very act in question and not to right and wrong in general. One of the principal defects of the so-called McNaghten rule is that it deals only with the cognitive aspects—that is, knowledge as to right and wrong, a knowledge which may superficially be retained in the face of obvious mental disorder. An attempt was made to correct this defect in a number of U.S. states, by the introduction of what is known as the "irresistible impulse" test, a recognition of the volitional or conative aspect of action, as opposed to the cognitive. This was a distinctly U.S. innovation, but of equal age with the "right and wrong" criterion. It was specifically rejected by the English and most of the U.S. courts, in spite of its being far more nearly in line with modern psychiatric views.

A person acquitted by reason of insanity must be committed to a mental hospital unless he can prove that he has since recovered, and presumably detained until it is shown that he has recovered. It has always been the rule of the common law both

in England and in the United States that no person who is unable to make a rational defense should be put on trial. If serious doubt arises as to the mental condition of the defendant before or during the trial, that doubt must be resolved before the trial is allowed to go on.

These are some of the types of situations in which psychiatry comes into close contact with the law. It will be seen that, in all of them, the psychiatrist plays a part, usually as a witness. This raises an interesting question as to opinion evidence, and the manner in which scientific information should be conveyed to juries and judges in the course of trials. A great deal of criticism has been levelled at the so-called expert witness on the grounds that he is unscientific, biased or even venal. The rules of procedure certainly tend to prevent the expert from presenting a scientific statement, and the manner in which he is presented certainly makes him a partisan, however much he may strive to be impartial. Finally, the hypothetical question as used can hardly be expected to present a fair picture of the situation under consideration. The Commissioners on Uniform State Laws drafted an expert testimony act, which was submitted to all the states, with the purpose of overcoming, if possible, the objections existing in the field of expert testimony. Massachusetts led the way, from 1921, under the Briggs law by having an automatic mental examination of defendants in certain types of criminal cases, this examination being an unbiased one. The trend was certainly, in cases of all sorts, toward a more free use of court-appointed experts who at least could come into court as impartial advisers on a scientific question. Courts recognized more and more their need of information concerning the mental state of parties to cases.

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Cultural.—During the second quarter of the 20th century there was a growing recognition of the need for combining the findings and the concepts of psychiatry, especially of psychoanalysis, with those of sociology and cultural anthropology. This joint or integrated approach, called the psychocultural approach, offers a conception of the emergence of personality in a cultural setting which gives many insights into personality development and character structure and also a better understanding of social order.

The cultural emphasis, in this approach, recognizes that all over the world different groups of people have faced the same persistent life tasks—coming to terms with the environment for food, shelter and protection, maintaining order in group life and regulating human behaviour for social order. Each group has attempted the solution of these life tasks in terms of its basic assumptions and beliefs about nature and man, and has accordingly developed a symbolic cultural world which it imposes upon nature and upon man.

Everywhere people are living in these cultural worlds which they maintain by teaching the young to see, think, believe, act and feel according to their traditions. Thus people, as organisms, exist in the geographical world of nature, but they live in their symbolic cultural worlds, using the rituals and symbols, the tools and techniques, the ideas and the language and patterned conduct prescribed by tradition. Upon these traditions they have established their social order, with their institutions and formal practices, such as barter and sale, contracts, courtship, marriage and divorce, law enforcement, litigation, voting and other forms of political, economic and social activity and interpersonal relationships.

Each individual, growing up in a cultural group, will learn these prescribed patterns with greater or less fidelity to the modal way of acting, thinking and feeling, thereby developing the basic character structure of his group. Thus the members of each group will exhibit the regularities of behaviour and the persistent patterns that give rise to and maintain social order. Moreover, each individual will share much the same beliefs and ideals, and, as a member of the group, will therefore be concerned with the same "problems," personal and social, which these traditional beliefs and practices create and the social order regulates.

The psychiatric emphasis in this approach, while recognizing the coercive role of traditional patterns upon the individual, stresses the idiomatic way in which each individual receives and accepts these traditions. It sees the individual child, with his unique heredity, undergoing the process of being culturized and socialized, but learning his own peculiar version of all these required patterns of believing, thinking, speaking, acting and feeling. It especially emphasizes the emotional or affective reactions of the infant and child to the many deprivations, frustrations, coercions and punishments by which the parental demands and prohibitions are imposed. It also stresses the child's attachment to and dependence upon the parents as the dominant influence in his socialization.

The psychiatric emphasis is therefore upon the idiomatic or idiosyncratic expression of traditions by each individual who may be viewed as building up a private world of his own, according to what life experiences have meant to him and how he has felt toward his parents and other adults during the years of childhood and adolescence. The clinical orientation of psychiatry has been focused largely upon the warped, twisted, often distorted personalities which emerge from these early experiences, burdened with persistent affective reactions of anxiety, guilt and resentful hostility. These persistent feelings find more or less disguised outlets in the socially sanctioned institutions and rituals of politics, economics, professional activities and the arts, or in the antisocial actions called crime and delinquency. When these feelings are too severe to be expressed in these overt activities by an individual who has not been able to take over the cultural traditions successfully, they may give rise to mental disorders; then the individual can no longer conform to the prescribed norms of action, speech and beliefs, and so he lives wholly within his private world.

The individual personality may be viewed as emerging from these early life experiences of being inculcated with traditions, as he surrenders his physiological autonomy for social control of his functional processes—food, elimination and sex—learns to curb his impulses and his expression of emotions and accepts the culturally defined world of human relations which he translates into his own idiomatic conduct.

The psychocultural approach offers a promising way of reconciling the observed regularities and organized activities of social order with the observed variations and distortions of individual conduct, beliefs and feelings. It therefore provides a way to escape from the traditional dichotomy of society versus the individual and the older belief in complicated, often mysterious, social forces. It also rejects the survivals of ancient animism known as psychic mechanisms and similar inaccessible, subjective intrapersonal processes for the conception of an organism learning to live in a culturally patterned environment. (L. K. FR.)

Mental Hygiene.—In a narrow and precise sense the term "mental hygiene" is applicable only to that body of knowledge that bears upon the maintenance of mental health. However, the term has come to be used more loosely to cover practices that are designed to maintain mental health in which the body of knowledge correctly included in mental hygiene is applied (applied mental hygiene). Even more broadly, the term "mental hygiene" has been applied to the promotion of improved care and treatment of the mentally sick, and sometimes even to the provision of such care (psychiatry).

Mental hygiene, strictly speaking, is a part of the field of hygiene, and as such includes the facts and theory pertinent to adequate human living; that is, survival, productiveness and satisfaction. In earlier formulations, hygiene was concerned with those problems and threats to health that came from disorders or diseases of the tissues and organs of man, but by the second decade of the 20th century it began to be better recognized that health is dependent not only upon the way man's tissues and organs behave and what they experience, but upon the way man himself behaves and the way he experiences life as a person. The distinction between physical hygiene and mental hygiene is fairly

clear. The former has to do with the adequate functioning of the parts of man, such as a tissue (*e.g.*, mucous membrane), an organ (*e.g.*, the lung) or a system (*e.g.*, digestive system). The latter is concerned with man as a person (a member of a family or neighbourhood, a worker, a churchgoer, etc.).

Many scientific fields, both biological and physicochemical, contribute to the content of mental hygiene as well as of hygiene as a whole. This contribution comes not only from the more formal sources, such as laboratories, but from the everyday practice of those professions that have to do with the problems of people, such as medicine, education and social work. Mental hygiene has not been formulated into as precise principles as has physical hygiene. This is in part because of its later development, but also because the conditions under which tissues and organs live and the threats with which they are confronted are much more fixed and consistent. Their physical surroundings remain fairly constant and their climate remarkably uniform. With man himself, however, the environment within which health must be achieved is extremely variable, and even health itself is subject to different criteria as a man's milieu varies. What would be considered healthy behaviour of a person in one part of the world, living under one set of customs, becomes unhealthy in another.

Mental hygiene has to do with the enhancement of human effectiveness and the guidance of developing habits and attitudes so that they may be useful in the world in which the person must live. This does not mean a rigid moulding of a person to the average of the culture in which he lives. It means rather the development of a capacity to deviate from that norm sufficiently to take the best advantage of his talents, and, at the same time, to keep within the bounds of what society will permit, or perhaps even appreciate.

The scope and content of mental hygiene is consequently determined by those important things that influence mental health. For one thing, mental health is affected by the degree of integrity of the body. If it is diseased, or defective, the prospects of good mental health are more limited; and, vice versa, mental hygiene is concerned with the influence of unsound mental health upon bodily function and disease. Mental health depends upon the way the infant and child are prepared for and introduced to the obligations, restrictions and relationships within the family and later the community; upon the way his deviations which may not only be normal but real assets are handled; upon the respect shown for his strengths and weaknesses in educating him, and upon the mental health of his teachers; upon the way his philosophical quandaries and religious inclinations are dealt with and guided; upon the way his work life harmonizes with his ambitions, interests and talents; upon the opportunity given him through play and recreation to dispose harmlessly of destructive inclinations and to organize those that can be creative.

Mental hygiene is concerned with data that help to solve or to remove the cause of ineffective worry and anxiety. It recognizes the greater productivity and reliability of intelligence that operates free of emotional bias, yet at the same time it recognizes the role of emotional factors in effective action. Basic is its principle that behaviour is caused and so is subject to understanding and modification. This gives to mental hygiene an astounding breadth, and in fact it has sometimes been adversely criticized because of this breadth. But this breadth is inherent in the objective and is not a matter of arbitrary decision. This fact of great breadth further determines the wide extent of the professional sources from which data and experience are drawn in order to make up the body of knowledge in the mental hygiene field.

This breadth also determines the hands into which fall the responsibility for applying mental hygiene. Doctors, teachers, social workers, nurses, judges, probation officers, ministers and many others become the agents of mental hygiene. An inspection of the objectives of all these groups reveals the fact that at best they aim toward advancing the capacity of those they serve for survival, productivity and satisfaction. Insofar as one of these professions fulfills its objectives, it is serving as an agency of mental hygiene. Each of these agencies, of course, has its own special emphases, techniques and sphere of problems. At many points these interests overlap. But insofar as they employ a common body of knowledge, terminology and objectives, they tend to see themselves as part of a community of effort directed toward mental health. They see themselves, therefore, as dependent on other professions and not legitimately isolated. The content of mental hygiene affords a bridge between them.

While, broadly defined, mental hygiene includes both the treatment and prevention of disease, it is the former that has received the greater attention. This is because the handling of mental disease includes the more emergent problems, because there is better definition of the steps to be taken and more experience with the application of effort. Also the failure of government to provide adequately for humane custody and for the treatment of the mentally ill often results in intolerable treatment of patients. Physical abuse, unnecessary restraint, lack of cleanliness, poor nutrition, insufficient clothing, to say nothing of neglected medical care, are the lot of the mentally ill very generally. There is great variation in the quality of care given the mentally ill from country to country and place to place, but even the best service leaves much to be desired.

It was in fact the neglect of the mentally ill that initiated the field of mental hygiene. Many reformers arose to press for better care of the mentally ill. Among the better known toward the end of the 18th century were P. Pinel in France, W. Tuke in England and B. Rush in the United States. But all these men were speaking to a society that was not yet ready to give the mentally ill the form of humane treatment that they promulgated. There were advances and losses, but a foundation was laid to which later leaders could point. Dorothea Dix, a half century later, took up the cause and strove both in the United States and Great Britain for the provision of adequate hospitals in place of the existing forms of detention. She was eminently successful, but achievements were still in advance of society.

Clifford W. Beers, in the early 20th century, found society much readier to concern itself with the proper care of the mentally ill, and medical science had advanced to a point where better treatment was possible. Modern mental hygiene was spearheaded primarily by the initiative and energy of Beers. Beers had been a patient in a mental hospital for about three years when he conceived the idea of devoting his life to the improvement of the care of the mentally ill. An autobiography, *A Mind That Found Itself*, was the opening gun of this effort after his recovery.

In 1908 Beers founded the Connecticut Society for Mental Hygiene, the first organization in this field, and in 1909 the National Committee for Mental Hygiene (now the National Association for Mental Health) for the United States as promotional agencies. Many other states in the United States and other countries in all continents subsequently organized such associations. About 1930 the International Committee for Mental Hygiene was formed under which congresses were held in 1930 and 1937. A third congress in 1948 resulted in a reorganization into the World Federation for Mental Health, which now operates with a regular staff. The World Federation is consultant to the World Health organization, the United Nations Educational, Scientific and Cultural organization and the Economic and Social council. A fourth congress was held in 1951 in Mexico City. In addition, some professional associations in the medical, educational and other fields formed their own mental hygiene committees.

The preventive phase of mental hygiene is most frequently only relatively preventive; that is, it is designed to prevent more serious problems of mental health by dealing with simpler problems at their beginnings. Thus, child guidance clinics have been established to deal with the behaviour of deviations of children. Truly preventive mental hygiene, however, is inherent in the functions of other fields. The prevention and early treatment of syphilis is mental hygiene, for one mental disease is caused by syphilis; likewise is the development of better food habits, especially in regions where pellagra is prevalent, for some mental disease is caused by pellagra. Help by social agencies to families experiencing or threatened with disorganization is mental hygiene, for problems of neurosis and psychopathic personality frequently grow out of family disorganization. For similar reasons, careful selection and training in mental hygiene of teachers, ministers,

doctors, social workers, nurses and other professions dealing with people in need or in trouble; attunement of school curricula and other work with children to their potentialities; prenatal work with parents, especially in anticipation of the first child; and careful evaluation and allocation of workers in the industrial field are samples of activities that enhance and safeguard mental health.

The positive phase of mental hygiene focuses not on prevention of disease but on raising the level of healthy living. It begins with the fact that talents of people differ. Not only is productiveness the result of working in keeping with one's own talents, but satisfaction and happiness are to a considerable degree feelings that come from using one's talents. Positive mental hygiene is, at the same time, both preventive and curative. It is the root of occupational therapy. It reconciles what the person does with what he enjoys doing. It enhances his wholeheartedness about his activities, which is the opposite of the conflicting and mixed feelings that are often found behind mental ill health.

Special opportunities for furthering positive mental health are found in the school, where the curriculum can be adjusted to the individual needs of the child, and in industry, where employment can be similarly individualized. There are also ministers who help those whom they are counselling to work out the religious formulations and interpretations that are peculiarly valuable to the individual. Some colleges have maintained mental hygiene personnel for the guidance of students, the tendency being to relieve such personnel of administrative or disciplinary responsibility so that the student may be free to seek help on any phase of life that may be troubling him. Industry is coming slowly to appreciate the fact that employee morale and satisfaction is greatly dependent upon the quality of executive and supervisory staff. World War II likewise revealed the fact that mental breakdown in combat is directly related to the quality of officer leadership. (G. Ste.)

PSYCHICAL RESEARCH. Psychical research is the experimental study of the supernormal faculties (real or supposed) of human personality. The word "supernormal" is merely an equivalent for "not recognized by general scientific opinion" and is free of all implications of "supernatural." The function of psychical research is to collect and weigh all the available evidence for and against all such supposed faculties, to the end that they may either be accepted by general scientific opinion, or may be rejected.

Psychical research is actually a special case of general research in human psychology. The subject matter of psychical research has included such debatable phenomena as telepathy, clairvoyance, precognition, dowsing and divination, hypnosis and evidence for the hypothesis of survival after death.

The Society for Psychical Research, founded in 1882 in England, assumed an active part in carrying out experiments and in collecting evidence concerning these phenomena. Similar societies were founded in other countries, particularly the United States. No real progress was made regarding the establishment of these hypotheses after the founding of the societies, with the exception of the problem of hypnosis. Hypnosis became a recognized tool of the clinical practitioner of medicine. The collection of evidence as to the reality of telepathy, clairvoyance and precognition is unusually difficult and fraught with problems of experimental design and execution.

It is customary to divide the phenomena of psychical research into two classes, "mental" and "physical." If a table is moved without the application of any force known to science, that is a "physical phenomenon." If a medium in trance gives information outside his normal knowledge, that is a "mental" phenomenon; there is nothing necessarily supernormal in trance speaking; the supernormality is to be found, if anywhere, in the content of the words spoken. If, however, the information is given through a trumpet floating in the air at a distance from the medium, that is both a physical and a mental phenomenon. The main problem of psychical research continues to be the collection of scientifically acceptable evidence under controlled experimental conditions.

Poltergeists (a German term meaning "racketing spirits") constitute the principal type of spontaneous physical phenomena. The word is used to describe those allegedly frequent cases of strange noises, movements of furniture and breakage of crockery which are inexplicable to the inmates of the houses where they occur. Cases of this kind have been recorded for many hundreds of years and from all parts of the world, civilized and barbarous.

Poltergeist cases show a remarkable degree of uniformity in spite of their wide distribution in time and space. It can almost invariably be shown that there is some particular agent or person whose presence is essential for the production of the phenomena. Although a second agent may assist in their production, the phenomena cease at once if the principal agent is removed. The agent is usually a person of some marked mental or physical abnormality, often a girl in her "teens," less often a boy of the same age, and only rarely an adult. In some cases there is obvious trickery, easily discoverable by any fairly good observer; in others the trickery is so cleverly done that only a skilled investigator can find it out. In a few cases, trickery does not seem to be an adequate explanation of the facts, assuming these to have been accurately reported. It may be that the same motives as those for flag-pole sitting and other instances of public notoriety are involved in these strange occurrences. The problem is whether the undoubted existence of fraud (usually "hysterical fraud") in many other cases justifies the assumption that the same factor has operated in the unexplained residue. This controversy remains very much where it was left many years ago because of the paucity of adequately recorded cases in later years.

The physical phenomena have also been investigated experimentally in the séance-room. Under these conditions, limitations are placed upon the experimenter's mode of observation by the medium to such an extent that the evidence obtained from such experiments is practically useless. The investigator of séance-room phenomena soon discovers that the limits within which he is permitted to experiment are extremely narrow, that the subject matter of his proposed "experiments" (the medium) dictates most of the crucial conditions of the investigation, and that for all practical purposes he is merely a passive observer.

Two kinds of physical phenomena have received considerable study, telekinesis and teleplasm (also called ectoplasm). Telekinesis is the alleged movement of objects without the application of any physical force known to science. Its history dates back to the early days of spiritualism. Teleplasm is a "substance," extruded from the medium's body, which either may be wholly invisible, visible but amorphous, or may take the form of a complete human figure, apparently endowed with energies of its own.

For telekinesis pure and simple it should be relatively easy to formulate methods of control adequate to prevent deception without being harassing to the medium. Telekinesis would rest on a firm basis if it were certain that in all cases where positive results are reported, the conditions of control stated in the reports have, in fact, been continuously exercised throughout the sittings. But telekinesis has become very closely associated with teleplasm. The substance is reported to possess at different times such contradictory properties as to make extremely difficult the task of formulating conditions for sittings where its production is anticipated. Too delicate to endure even the lightest touch, but strong enough to shift heavy weights; sometimes so sensitive to light as not to be able to endure even the dim glow of a red lamp, at other times so insensitive as to be capable of being photographed by flashlight; how is the researcher to plan conditions in advance, when he cannot know in which form this substance may appear?

The mental phenomena of psychical research consist, for the most part, in some form of "supernormal cognition," that is, knowledge shown by a percipient of matters which he has no normal means of knowing. ("Percipient" is here used, for lack of a better word, to include not only percipients or "receivers" in telepathy, but automatists of all kinds, trance mediums, etc.). The supernormal knowledge may relate to another person's thoughts, or to events distant in time or space; it may arise spontaneously, so far as the percipient is concerned, or as the result of deliberate attempts on his part. A percipient may be in the normal waking condition, asleep, entranced, or in a state of slight dissociation produced by crystal gazing or other similar devices. Telepathy is defined as supernormal knowledge derived from another person's mind. Clairvoyance is defined as all manifesta-

tions of supernormal knowledge not so derived, for example, a capacity to see distant events and scenes without the intermediary of sensory information.

Supernormal cognition in some form is the most generally accepted phenomenon of psychical research, although there is no general agreement among psychologists as to the existence of the phenomenon. The evidence for it is impressive in quantity, but unimpressive in the quality of objective experimental control of the numerous sources of error which may invalidate the results obtained in experiments. The British Society for Psychical Research was responsible for the collection of many so-called spontaneous cases of supernormal precognition particularly of apparitions of dying or recently dead persons, seen by friends who were at a distance, and who had no normal reason for anxiety. Edmund Gurney, Frederic Myers and Frank Podmore, who analyzed the results [*Phantasms of the Living* (1886)] came to the conclusions: (1) that such apparitions occurred too frequently to be explicable by chance coincidence (elaborate statistics were given in support of this conclusion); (2) that, in the majority of cases, the most probable explanation was the transmission of an impression from the mind of a dying man to the mind of his friend, which is externalized in the form of a "subjective hallucination," rather than existing as any semimaterial wraith. The major difficulty with weighing the evidence collected from such spontaneous instances is that the experimental control desirable to eliminate fraud, collusion and other sources of error is not present because of the very character of the evidence—it is spontaneous, therefore uncontrolled and uncontrollable.

Experiments in thought transference (telepathy) have been conducted for many years in most civilized countries. The conditions of the experiments have been very diverse. Sometimes the percipients have been in a normal waking condition, sometimes in hypnosis; sometimes in the same room or house as the agent, sometimes at a distance of many miles, or even in a different country. The subject matter has also varied greatly. Attempts have been made to transfer impressions of numbers, simple or complex diagrams, the suit and value of playing cards, landscapes or pictures, incidents from books and imaginary scenes.

In experiments with numbers or a pack of cards it is possible to make a statistical computation of the degree to which the results exceed chance expectancy. In experiments with diagrams, scenes and incidents, of course, no such precise computation of theoretical probability is possible. There seems to be general agreement that experiments should be conducted using material to which standard probability statistics may be applied in order to establish a conclusion that results beyond the level of chance expectancy were produced.

Where agent and percipient are in the same room, the possibility of the use of extraneous sensory cues such as visual or auditory signals must be taken into account. Numerous experiments both in the field of psychical research and in experimental psychology have fully demonstrated that it is possible for the subject to use such cues and yet be incapable of reporting on their presence or absence.

One of the most important sources of error in experiments on telepathy and also on clairvoyance arises from the suggestibility of the experimenter in recording the results of guesses made by the percipient. The presence of this error has been established by actual inspection of records.

Even though agreement among scientific observers has not been reached regarding the hypothesis of telepathy, some individuals have considered possible ways in which the supposed telepathic impressions might operate. It has, for example, been supposed that telepathic impressions pass first from the agent's conscious to his subliminal mind, then from his subliminal mind to that of the percipient, and finally emerge from the percipient's subliminal mind to consciousness.

Psychometry is the name given to supernormal knowledge of the past history or associations of objects handled by mediums.

Precognition is the term applied to alleged instances of supernormal knowledge of future events. The outbreak of World Wars I and II and the use of the atomic bomb set a large part of the public in all countries hunting up old prophecies to see whether any of them fit. Some were found to fit quite well after they had received a little judicious interpretation. Precognition, if it is a genuine phenomenon (considerable disagreement exists as to its genuineness), does not fit very easily the previously mentioned hypothesis regarding telepathic transmission.

Most persons become convinced of survival after death even before considering the evidence furnished by psychical research; for them the question is finally settled one way or another by revealed religion or their interpretation of the facts of biology and physiology. Progress toward the establishing of a scientific basis for either belief or disbelief in survival after death remains notably lacking. The alleged evidence obtained from spiritualistic mediums and other especially "gifted" individuals did not receive general acceptance by those trained in the scientific rules of fact-finding. Psychical research has, in general, been conducted by amateurs who are unfamiliar with the necessary controls of experimental procedure involving the human organism. The history of psychical research is full of observations and experiments in which erroneous conclusions were drawn because of the absence of necessary experimental control. One need only mention the case of Clever Hans, a horse reputed to have human powers of reasoning and communication. Psychological research into the claims made for the capacities of this animal revealed that it was responding to involuntary cues provided by its trainer. When the trainer was removed from the vicinity of the animal, it no longer exhibited a remarkable capacity to add, multiply and spell.

Research in experimental psychology had not, by mid-20th century, revealed other sensory mechanisms than those described in modern textbooks of psychology and physiology. Electrophysiological research on "brain waves" had demonstrated that these electrical phenomena of the brain occur at such a low power level that firm attachment of electrodes to the scalp of the patient and several thousand-fold amplification are required in order to detect the presence of the "waves." The hypothesis that these electrical disturbances may be propagated from person to person in some unknown way had no support.

By way of summary, reference should be made to the necessary practical tests of the validity of telepathy, clairvoyance, precognition and survival of the dead. For example, the stock market represents an institution which could be very profitable to anyone gifted with telepathy, clairvoyance or precognition. Many legal cases could be more expeditiously and rightly settled if communication with the dead could be obtained. The work of law enforcement agencies could be much more precise and rapid if telepathy, clairvoyance and precognition were among the abilities of even a very few persons. It should be further mentioned that, from time to time, large sums of money have been set aside as a prize to any person who will, to the satisfaction of the members of a scientific committee, produce any supernormal human mental phenomena under the conditions of control that the scientific boards must insist upon. (*See* PARAPSYCHOLOGY.)

(W. H. SA.; J. L. KY.)

PSYCHOANALYSIS. In the years 1880–82 a Viennese physician, Josef Breuer (1842–1925), discovered a new procedure by means of which he relieved a girl, who was suffering from severe hysteria, of her various symptoms. The idea occurred to him that the symptoms were connected with impressions which she had received during a period of excitement while she was nursing her sick father. He therefore induced her, while she was in a state of hypnotic somnambulism, to search for these connections in her memory and to live through the "pathogenic" scenes once again without inhibiting the affects that arose in the process. He found that when she had done this the symptoms in question disappeared for good.

This was at a date before the investigations of J. M. Charcot and Pierre Janet into the origin of hysterical symptoms, and Breuer's discovery was thus entirely uninfluenced by them. But he did not pursue the matter any further at the time, and it was not until some ten years later that he took it up again in collaboration with Sigmund Freud. In 1895 they published a book, *Studien über Hysterie,* in which Breuer's discoveries were described and

an attempt was made to explain them by the theory of *catharsis*. According to that hypothesis, hysterical symptoms originate through the energy of a mental process being withheld from conscious influence and being diverted into bodily innervation (*conversion*). A hysterical symptom would thus be a substitute for an omitted mental act and a reminiscence of the occasion which should have given rise to that act. And, on this view, recovery would be a result of the liberation of the affect that had gone astray and of its discharge along a normal path (*abreaction*). Cathartic treatment gave excellent therapeutic results, but it was found that they were not permanent and that they were dependent on the personal relation between the patient and the physician. Freud, who later proceeded with these investigations by himself, made an alteration in their technique, by replacing hypnosis by the method of free association. He invented the term *psychoanalysis*, which in the course of time came to have two meanings: (1) a particular method of treating nervous disorders and (2) the science of unconscious mental processes, which has also been appropriately described as "depth psychology."

Subject Matter of Psychoanalysis.—Psychoanalysis finds a constantly increasing amount of support as a therapeutic procedure, because of the fact that it can do more for certain classes of patients than any other method of treatment. The principal field of its application is in the milder neuroses—hysteria, phobias and obsessional states—but in malformations of character and in sexual inhibitions or abnormalities it can also bring about marked improvements or even recoveries. Its influence upon dementia praecox and paranoia is doubtful; on the other hand, in favourable circumstances it can cope with depressive states, even if they are of a severe type.

In every instance the treatment makes heavy claims upon both the physician and the patient: the former requires a special training, and must devote a long period of time to exploring the mind of each patient, while the latter must make considerable sacrifices, both material and mental. Nevertheless, all the trouble involved is as a rule rewarded by the results. Psychoanalysis does not act as a convenient panacea (*"cito, tute, jucunde"*) upon all psychological disorders. On the contrary, its application has been instrumental in making clear for the first time the difficulties and limitations in the treatment of such affections.

The therapeutic results of psychoanalysis depend upon the replacement of unconscious mental acts by conscious ones and are operative in so far as that process has significance in relation to the disorder under treatment. The replacement is effected by overcoming internal resistances in the patient's mind. The future will probably attribute far greater importance to psychoanalysis as the science of the unconscious than as a therapeutic procedure.

Depth Psychology.—Psychoanalysis, in its character of depth psychology, considers mental life from three points of view: the dynamic, the economic and the topographical.

From the first of these standpoints, the dynamic one, psychoanalysis derives all mental processes (apart from the reception of external stimuli) from the interplay of forces, which assist or inhibit one another, combine with one another, enter into compromises with one another, etc. All of these forces are originally in the nature of *instincts;* that is to say, they have an organic origin. They are characterized by possessing an immense (somatic) persistence and reserve of power (*repetition-compulsion*), and they are represented mentally as images or ideas with an affective charge (*cathexis*). In psychoanalysis, no less than in other sciences, the theory of instincts is an obscure subject. An empirical analysis leads to the formation of two groups of instincts: the so-called "ego instincts," which are directed toward self-preservation, and the "object instincts," which are concerned with relations to an external object. The social instincts are not regarded as elementary or irreducible. Theoretical speculation leads to the suspicion that there are two fundamental instincts which lie concealed behind the manifest ego instincts and object instincts; namely, (*a*) Eros, the instinct which strives for ever closer union, and (*b*) the instinct for destruction, which leads toward the dissolution of what is living. In psychoanalysis the manifestation of the force of Eros is given the name *libido*.

Pleasure-Pain Principle.—From the economic standpoint, psychoanalysis supposes that the mental representations of the instincts have a cathexis of definite quantities of energy, and that it is the purpose of the mental apparatus to hinder any damming up of these energies and to keep as low as possible the total amount of the excitations to which it is subject. The course of mental processes is automatically regulated by the *pleasure-pain principle*, and pain is thus in some way related to an increase of excitation and pleasure to a decrease. In the course of development the original pleasure principle undergoes a modification with reference to the external world, giving place to the *reality principle*, whereby the mental apparatus learns to postpone the pleasure of satisfaction and to tolerate temporarily feelings of pain.

Mental Topography.—Topographically, psychoanalysis regards the mental apparatus as a composite instrument, and endeavours to determine at what points in it the various mental processes take place. According to the most recent psychoanalytic views, the mental apparatus is composed of an *id*, which is the reservoir of the instinctive impulses; of an *ego*, which is the most superficial portion of the id and one which is modified by the influence of the external world; and of a *superego*, which develops out of the id, dominates the ego and represents the inhibitions of instinct characteristic of man. Further, the property of consciousness has a topographical reference; for processes in the id are entirely unconscious, while consciousness is the function of the ego's outermost layer, which is concerned with the perception of the external world.

At this point two observations may be in place. It must not be supposed that these very general ideas are presuppositions upon which the work of psychoanalysis depends. On the contrary, they are its latest conclusions and are in every respect open to revision. Psychoanalysis is founded securely upon the observation of the facts of mental life, and for that very reason its theoretical superstructure is still incomplete and subject to constant alteration. Second, there is no reason for astonishment that psychoanalysis, which was originally no more than an attempt at explaining pathological mental phenomena, should have developed into a psychology of normal mental life. The justification for this arose with the discovery that the dreams and mistakes (*parapraxes*, such as slips of the tongue, etc.) of normal men have the same mechanism as neurotic symptoms.

Theoretical Basis.—The first task of psychoanalysis was the elucidation of nervous disorders. The analytical theory of the neuroses is based upon three ground pillars: the recognition of (1) *repression*, (2) the importance of the sexual instincts and (3) *transference*.

Censorship.—There is a force in the mind which exercises the functions of a censorship, and which excludes from consciousness and from any conscious influence upon action all tendencies which displease it. Such tendencies are described as "repressed." They remain unconscious, and if the physician attempts to bring them into the patient's consciousness he provokes a *resistance*. These repressed instinctual impulses, however, are not always made powerless by this process. In many cases they succeed in making their influence felt by circuitous paths, and the indirect or substitutive gratification of repressed impulses is what constitutes neurotic symptoms.

Sexual Instincts.—For cultural reasons the most intensive repression falls upon the sexual instincts; but it is precisely in connection with them that repression most easily miscarries, so that neurotic symptoms are found to be substitutive gratifications of repressed sexuality. The belief that in man sexual life begins only at puberty is incorrect. On the contrary, signs of it can be detected from the beginning of extrauterine existence; it reaches a first culminating point at or before the fifth year (early period), after which it is inhibited or interrupted (latency period) until the age of puberty, which is the second climax of its development. This double onset of sexual development seems to be distinctive of the genus *Homo*. All experiences during the first period of childhood are of the greatest importance to the individual, and, in combination with his inherited sexual constitu-

tion, form the dispositions for the subsequent development of character or disease. It is a mistaken belief that sexuality coincides with "genitality." The sexual instincts pass through a complicated course of development, and it is only at the end of it that the "primacy of the genital zone" is attained. Before this there are a number of "pregenital organizations" of the libido—points at which it may become "fixated" and to which, in the event of subsequent repression, it will return (*regression*). The infantile fixations of the libido are what determine the form of neurosis which sets in later. Thus the neuroses are to be regarded as inhibitions in the development of the libido.

The Oedipus Complex.—There are no specific causes of nervous disorders; the question whether a conflict finds a healthy solution or leads to a neurotic inhibition of function depends upon quantitative considerations; that is, upon the relative strength of the forces concerned. The most important conflict with which a small child is faced is his relation to his parents, the *Oedipus complex;* it is in attempting to grapple with this problem that persons destined to suffer from a neurosis habitually fail. The reactions against the instinctual demands of the Oedipus complex are the source of the most precious and socially important achievements of the human mind; and this probably holds true not only in the life of individuals but also in the history of the human species as a whole. The superego, the moral factor which dominates the ego, also has its origin in the process of overcoming the Oedipus complex.

Transference.—By transference is meant a striking peculiarity of neurotics. They develop toward their physician emotional relations, both of an affectionate and hostile character, which are not based upon the actual situation but are derived from their relations toward their parents (the Oedipus complex). Transference is a proof of the fact that adults have not overcome their former childish dependence; it coincides with the force which has been named *suggestion,* and it is only by learning to make use of it that the physician is enabled to induce the patient to overcome his internal resistances and do away with his repressions. Thus psychoanalytic treatment acts as a second education of the adult, as a correction to his education as a child.

Within this narrow compass it has not been possible to mention many matters of the greatest interest, such as the *sublimation* of instincts, the part played by symbolism, the problem of *ambivalence,* etc. Nor has there been space to allude to the applications of psychoanalysis, which originated, as we have seen, in the sphere of medicine, to other departments of knowledge (such as anthropology, the study of religion, literary history and education) where its influence is constantly increasing. It is enough to say that psychoanalysis, in its character of the psychology of the deepest unconscious mental acts, promises to become the link between psychiatry and all of these other fields of study.

The Psychoanalytic Movement.—The beginnings of psychoanalysis may be marked by two dates: 1895, which saw the publication of Breuer and Freud's *Studien über Hysterie,* and 1900, which saw that of Freud's *Traumdeutung.* At first the new discoveries aroused no interest either in the medical profession or among the general public. In 1907 the Swiss psychiatrists, under the leadership of E. Bleuler and C. G. Jung, began to concern themselves in the subject, and in 1908 there took place at Salzburg a first meeting of adherents from a number of different countries. In 1909 Freud and Jung were invited to the United States by G. Stanley Hall to deliver a series of lectures on psychoanalysis at Clark university, Worcester, Mass. From that time forward interest in Europe grew rapidly; it showed itself, however, in a forcible rejection of the new teachings, characterized by an emotional colouring which sometimes bordered upon the unscientific.

The reasons for this hostility are to be found, from the medical point of view, in the fact that psychoanalysis lays stress upon psychical factors, and, from the philosophical point of view, in its assuming as an underlying postulate the concept of unconscious mental activity; but the strongest reason was undoubtedly the general disinclination of mankind to concede to the factor of sexuality such importance as is assigned to it by psychoanalysis. In spite of this widespread opposition, however, the movement in favour of psychoanalysis was not to be checked. Its adherents formed themselves into an international association which survived World War I, and by 1926 there were psychoanalytic societies in Vienna, Berlin, Budapest, London, Switzerland, the Netherlands, Moscow and Calcutta and two in the United States. There were psychoanalytic polyclinics in Vienna, Berlin and London, and several training institutes were in process of organization. At that time, too, three journals were the official organs of the societies on the continent and in England: the *International Zeitschrift für Psychoanalyse, Imago* (concerned primarily with applications of psychoanalysis to nonmedical fields) and the *International Journal of Psychoanalysis.* (S. Fr.)

Bibliography.—J. Breuer and S. Freud, *Studien über Hysterie* (1895); Freud, *Traumdeutung* (1900), *Zur Psychopathologie des Alltagslebens* (1904), *Drei Abhandlungen zur Sexualtheorie* (1905), *Vorlesungen zur Einführung in die Psychoanalyse* (1916). Freud's complete works have been published in Spanish (*Obras completas*) (1924) and German (*Gesammelte Schriften*) (1925); the greater part of them has been translated into English and other languages. Short accounts of the subject matter and history of psychoanalysis will be found in: Freud, *Über Psychoanalyse* (the lectures delivered at Worcester, Mass.) (1909), *Zur Geschichte der psychoanalytischen Bewegung* (1914), *Selbstdarstellung* (in Grote's collection *Die Medizin der Gegenwart*) (1925). Particularly accessible to English readers are: A. A. Brill, *Psycho-Analysis* (1922); E. Jones, *Papers on Psycho-Analysis* (1923); S. Ferenczi, *Theory and Technique of Psychoanalysis* (1927).

Controversial Literature: Karen Horney, *New Ways in Psychoanalysis* (1939) and *Self-Analysis* (1942); Clara Thompson, "Penis Envy in Women," *Psychiatry,* 6:2, p. 123 (1943); Erich Fromm, "Sex and Character," *ibid.,* 6:1, p. 21 (1943), "Selfishness and Self Love," *ibid.,* 2:4, p. 507 (1939) and "Faith as a Character Trait," *ibid.,* 5:3, p. 307 (1942); Franz Alexander and Thomas French, *Psychoanalytic Therapy* (1946); Franz Alexander, "Psychoanalysis Revised," *Psychoanalytic Quarterly,* vol. 9, p. 1 (1940), *Our Age of Unreason* (1942) and "Indications for Psychoanalytic Therapy," *Bulletin of the N.Y. Acad. of Med.,* 20:6, p. 319 (June, 1944).

Discussion of Controversial Viewpoints: Robert Waelder, "The Problem of Genesis of Psychical Conflict in Earliest Infancy," *Internat. Jour. of Psychoanalysis,* vol. 28, p. 406 (1937) and "Present Trends in Psychoanalytic Theory," *Bulletin of the Menninger Clinic,* vol. 8, p. 1 (1943); Fritz Wittels, "Neo-Adlerians," *Am. Jour. of Sociology,* vol. 15, p. 433 (1939); Ludwig Jekels, "Psychoanalysis and Dialectics," *Psychoanalytic Review,* vol. 28, p. 228 (1940); Ernest Jones, "Review of Alexander's 'Our Age of Unreason,'" *Internat. Jour. of Psychoanalysis,* vol. 24, p. 90 (1943); H. Hartmann and E. Kris, "The Genetic Approach in Psychoanalysis," *Psychoanalytic Study of the Child,* vol. 1 (1946). (S. Fr.; X.)

Later Developments.—The above article appeared in 1926. It was written by Freud and translated by Ernest Jones. Except for the omission of certain general topics to which Freud alludes, it represents clearly the status of psychoanalytic theory at that time.

The 26 years between 1926 and 1952 were marked by an uninterrupted expansion of psychoanalytic activity in England and the United States. Before the nazis came into power there were active psychoanalytic societies in the U.S.S.R., Japan, Italy, France, Czechoslovakia and Hungary, as well as Germany and Austria; but with the eruption of fascist-nazi governments most of these societies were suppressed, many of their scientific leaders were killed in concentration camps, and all who could escape migrated to other countries. An effort was under way in the post-World War II period to rebuild these societies, their training institutes and their clinics.

At the end of 1951 there were in the United States alone 12 psychoanalytic societies, with a total active membership of more than 500 physicians, and more than that number in training in institutes recognized by the American Psychoanalytic association. There were two societies in South America, one in Australia, one in the British Isles, two in the Netherlands, two in France, a society in India, one in Sweden, one in Switzerland, one reopened in Austria and one in Hungary. What had happened to the two societies which formerly existed in Japan was still a question.

During the totalitarian period the continental journals were suppressed, but in the same period several additional psychoanalytic journals came into existence. Among these were the American *Imago,* the *Psychoanalytic Review,* the *Psychoanalytic Quarterly, Revue française de psychanalyse, Revista de Psicoanálisis* (Argentina) and one in Italy; and such closely related journals as *Psychosomatic Medicine* and *Psychiatry.*

Implicit in Freud's 1926 article are the lines along which both theoretical and technical developments were to occur in the subsequent years. These can be outlined in general terms as follows:

1. The topographical schema of psychological organization, which Freud then emphasized, gradually dropped into a position of relatively less importance. This was largely a result of the influence of Freud's own later writings, in which his attention shifted to more dynamic problems. (*See* Freud, *Hemmung, Symptom, und Angst* [1926; translated into English in 1936, under the title *Problem of Anxiety*]; also Anna Freud, *The Ego and the Mechanisms of Defence* [German, 1936; English, 1937].)

2. The role of anxiety and of the conscious and unconscious defensive measures which the ego utilizes in dealing with instincts and anxiety came to occupy a central position in analytic thinking.

3. These developments were related to a growing interest in the psychoanalytic study and treatment of the child. Starting with the early reports of Freud, Hug-Hellmuth and Jung, child analysis was systematically developed by Anna Freud, Melanie Klein and others, especially in Vienna and London. (*See* Anna Freud, *Einführung zur Kinderanalyse* [1927]; Melanie Klein, *Psycho-Analysis of Children* [1932].)

4. Special problems concerning female sexuality became objects of intensive investigation by Freud, Ernest Jones, Helene Deutsch, Jeanne Lampl-de Groot, Ruth Mack Brunswick, Sandor Rado, Karen Horney and others.

5. Psychoanalytic theory and technique were applied increasingly to the study of organic physiology and pathology. These studies of the interrelationship between organic and psychic processes are exercising a profound influence on medical education and on the everyday practice of surgery and internal medicine. (*See* Edward Weiss and O. S. English, *Psychosomatic Medicine* [1943]; Flanders Dunbar, *Emotions and Bodily Changes* [1935] and *Psychosomatic Diagnosis* [1943]; "Psychosomatic Medicine Monographs"; and the files of the journals *Psychosomatic Medicine* and the *Psychoanalytic Quarterly*.)

6. Psychoanalytic technique and theory have come into wide use in field work in anthropology and sociology: Geza Roheim, Margaret Mead, B. Malinowski, Abram Kardiner, J. Dollard and others.

A survey of certain of these and of other developments will be found in Freud's *New Introductory Lectures on Psycho-Analysis* (1933).

Areas of Controversy.—It is instructive to look back on the controversies which have revolved around psychoanalytic theory and technique. Early schisms occurred over such issues as the basic role which Freud ascribed to biological instinctual processes in human psychology. Jung moved away from this in a direction which was in essence mystical. Otto Rank reverted to an 18th-century facultative will psychology. Alfred Adler placed an unbalanced emphasis on an artificially isolated power drive. Of necessity these viewpoints entailed a rejection of psychoanalytic technique as well as theory, and the supporters of these psychologies did not designate their theories as psychoanalytic, but used various other names (individual psychology, analytical psychology, etc.) to distinguish them from Freud's psychoanalytic psychology. None of these three early separations resulted in the development of a systematic school of theory, technique, experimentation or instruction. The result was that their adherents were gradually disappearing.

More recent controversies are over details of theory or technique and do not lead to a complete departure from the parent stem. The leaders continue to subscribe to the main body of psychoanalytic thought and to look upon themselves as psychoanalysts. Although their right to do so is disputed by some, it is significant that they prefer to be known as "neo-Freudians," rather than as "anti-Freudians."

The more valid among the controversies current at mid-20th century focus on such questions as the definition of instincts, details of libido development and the relative importance of infancy, puberty and adolescence in the genesis of neurosis; and on such technical issues as the duration and continuity of treatment and the handling of transference phenomena. Certain specious issues are often interwoven confusingly with these legitimate issues, however. Some of these are reminiscent of the ancient battles over heredity versus environment, and take the form of polemics over what is called a "genetic" *versus* a "cultural" origin of neuroses, as though it were possible to isolate the influence of the one from that of the other. Such pseudo-controversies are scientific catchpennies, and because they are devoid of meaning quickly disappear.

Disagreement is essential to the growth of any science. In the state of psychoanalysis at mid-century one might deplore only a tendency on the part of some critics to broadcast theoretical concepts widely to a lay public before they have been sufficiently tested. This creates a furor of verbal disagreements and makes it difficult to maintain an atmosphere of quiet objective research. It seemed doubtful, however, that any of the issues which were in dispute at that time would lead to the development of new schools or to such schisms as occurred in earlier years.

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Influence on Literature and Art.—The two principal figures in the history of psychoanalysis and modern art were Sigmund Freud and Carl G. Jung. Of Freud's work, the most important for literature and the other arts were *The Interpretation of Dreams* (1900), *Three Contributions to the Theory of Sex* (1905), *Beyond the Pleasure Principle* (1920) and a number of the essays and papers in *The Collected Papers of Sigmund Freud* (the English translation published 1924). Conspicuous for their influence on the arts among these last were such essays as "The Dynamics of the Transference" (vol. ii), "Turnings in the Ways of Psychoanalytic Therapy" (vol. ii), "The Moses of Michelangelo" (vol. iv), "The Relation of the Poet to Day-Dreaming" (vol. iv) and "The Unconscious" (vol. iv). The work of Jung best known to modern writers and artists included *Psychology of the Unconscious* (1916), *Psychological Types, or The Psychology of Individuation* (1920), *Modern Man in Search of a Soul* (1931) and several essays which attempted to explain the psychology of art; of these, his "Psychology and Poetry" (which appeared in *Transition*, translated by Eugene Jolas, in 1930) is perhaps best known. A number of other pioneers in the establishment of psychoanalysis in the 20th century contributed to the very large body of work on psychology and the arts. Most of these followed through suggestions made originally by Freud and Jung, but they also investigated more exhaustively subjects that were for the most part only peripheral to the major interests of the two leading spokesmen for the field. Among these psychoanalysts who were interested in the application of their disciplines to the arts and to criticism were Wilhelm Stekel, Otto Rank, Ernest Jones and Charles Baudouin. The most important works of these men were Rank's *The Incest-Motive in Poetry and Legend* (1912), Jones's *Hamlet and Oedipus* (1910 and 1949) and Baudouin's *Psychoanalysis and Aesthetics* (1924). In addition, there were numerous critics whose analysis of the arts was strongly marked by their preoccupation with psychoanalysis and psychiatry: among them the most influential were Herbert Read, Kenneth Burke, Frederick C. Prescott and Maud Bodkin. Psychoanalytic investigations of the lives of writers and artists were responsible for a large body of additional work. Freud himself contributed to this kind of writing in his *Leonardo da Vinci: A Psychosexual Study of an Infantile Reminiscence* (1910) and in his essay "Dostoyevsky and Parricide" (English translation published in *Partisan Review*, fall, 1945). In both cases, Freud attempted to find in the work of

the artists evidence that would help toward an understanding of their "psychic life." Biography, following upon the suggestions contained in these contributions and others, as well as the great body of clinical investigation, developed a special approach toward the arts, in which the work of art was related to and explained in terms of the artist's psychological history. Conspicuous examples of this form of psychobiography were René Laforgue's *The Defeat of Baudelaire: A Psycho-Analytical Study of the Neurosis of Charles Baudelaire* (1931), Saul Rosenzweig's "The Ghost of Henry James" (in *Character and Personality*, Dec. 1943), Edmund Wilson's biographical studies of literature (many of them contained in *The Wound and the Bow*, 1941), Joseph Wood Krutch's *Edgar Allan Poe: A Study in Genius* (1926) and Van Wyck Brooks's biographies of Mark Twain (*The Ordeal of Mark Twain*, 1920) and Henry James (*The Pilgrimage of Henry James*, 1925).

The question of the influence—of the degree of it and of all the peculiarities of its nature—is as complex as the influence itself is varied and widespread. There were writers and artists who professed to have and sometimes had a great knowledge of psychoanalysis and who worked in terms of a direct recognition of its value for their art. These included most of the surrealists, some of whom (like André Breton) had had actual experience as analysts, and other writers who (like Ludwig Lewisohn, Georg Groddeck, H. R. Lenormand) spoke of psychoanalysis with varying degrees of accuracy and conviction. Of Lenormand's plays, beginning with *Le Mangeur de rêves* (1922), those which presented tragedy based chiefly on psychoanalytic knowledge of character included *L'Homme et ses fantômes* (1924), *Asie* (1931) and *Pacifique* (1937); all these works reflect wide and accurate acquaintance with the discipline and the conclusions of psychoanalysis, though Lenormand objected to their being labelled "Freudian." Also included in this first group of writers was Thomas Mann, who not only knew and greatly respected the work of Freud, but was also extremely judicious in his application of this knowledge to his fiction. In an essay on "Freud's Position in the History of Modern Thought" (1928; included in *Past Masters, and Other Papers*, 1933), Mann applauded Freud for his intelligent concern with the psychic life as well as his wish to find new sources of cure and therapy. One of Mann's first uses of his wide acquaintance with psychoanalysis was in the novel *The Magic Mountain* (1924), but here the reference to psychoanalysis is mixed with a generous and eclectic use of many other kinds of knowledge and speculation—notably the philosophies of Arthur Schopenhauer and Friedrich Nietzsche. That he remained objective concerning the advantages of analysis for modern society was abundantly indicated in such remarks from the novel as this made by the character Settembrini: "Analysis as an instrument of enlightenment and civilization is good, in so far as it shatters absurd convictions, acts as a solvent upon natural prejudices, and undermines authority. . . . But it is bad, . . . in so far as it stands in the way of action, cannot shape the vital forces, maims life at its roots. . . ." (*The Magic Mountain*, Thomas Mann, p. 283 Mod. Library Ed.; A. A. Knopf, Inc., N.Y., 1927.) In his fictional reconstruction of the biblical story of Joseph, Mann quite deliberately made use of the speculations of both Freud and Jung concerning the value of myth and its symbolic recurrence, through a racial (or "collective") unconscious. Mann's fiction showed the skill of an intellectually disciplined mind whose application of psychoanalysis, as well as of other knowledges, never allowed it to dominate but made it serve the original aesthetic form and subject.

The knowledge of psychoanalysis also led modern novelists to establish the analyst himself as an important fictional personage, sometimes available to satirical observation (as in Waldo Frank's novel *The Bridegroom Cometh*, 1938), sometimes placed in a crucial role as adviser and "physician of the soul" (as in Lewisohn's *The Island Within*, 1928) and sometimes credited with providing the means of a novel's resolution (as in Arthur Koestler's *Arrival and Departure*, 1943). The substance and content of psychoanalytic disclosures (or their equivalents in the artist's imagination) often dominated the content of works of literature. Reliance upon the revelations of the subconscious mind was conspicuous in such works as the fiction of Anaïs Nin; surrealist poetry, prose and painting; Groddeck's *Der Seelensucher* (1922); F. Scott Fitzgerald's *Tender Is the Night* (1934); Conrad Aiken's *Great Circle* (1933), *King Coffin* (1935) and much of his poetry (particularly *The Coming Forth by Day of Osiris Jones*, 1931); and both the poetry and fiction of Dylan Thomas. Notable for its literary approximation of clinical analysis was the novel by Italo Svevo (Ettore Schmitz) *La Coscienza di Zeno* (1924; translated as *The Confessions of Zeno*, 1930), in which the narrative is presented as a continuous self-analysis by the hero.

A second group of writers and artists included those who undeniably showed the influence of psychoanalysis but who resisted the labels "Freudian" and "psychoanalytic." These people gained prominence in literature and art in one of two ways: either they formulated their own theories of the unconscious and other psychoanalytic concerns in an effort to disprove Freud or to discount his values; or their work followed the lines and treated of the material with which psychoanalysis was largely concerned without having derived from a study of it. An important opponent of psychoanalysis was D. H. Lawrence; his novel *Sons and Lovers* (1913) interested psychoanalysts and critics who found a direct influence in its presentation of familial problems. Lawrence's reply was to repudiate psychoanalysis as too narrowly and harmfully scientific; but in the energy of his protest lay an earnest of the contribution made by psychoanalysis to his thinking. In a great number of letters and essays, Lawrence attacked both Freud and Jung, though he gave a qualified approval of another analyst, Trigant Burrow. His principal long attacks on psychoanalysis were *Psychoanalysis and the Unconscious* (1921) and *Fantasia of the Unconscious* (1922). In these works, Lawrence accused psychoanalysis of putting a false and debilitating emphasis upon scientific probing and examination which not only misunderstood the vital sources of human action but helped to defeat human vitality and tended to reduce the "life forces" to objects of intellectual curiosity. These reflections were associated in a large portion of Lawrence's writings of every kind with a general attack upon modern rational and intellectual life, as well as with his repudiation of the mechanistic, life-defeating impact of modern industry upon human vitality. Other writers offered in their work tempting opportunities for critics who wished directly to attach the label "Freudian" to them, but in large part rejected it or confessed to an ignorance of the disciplines that had allegedly influenced them. Among these writers were Sherwood Anderson and Eugene O'Neill; particularly in some of the latter's plays (especially *Mourning Becomes Electra*, 1931) there is abundant evidence of his realization of psychoanalytic techniques and discoveries, though O'Neill himself denied any direct line of influence. Franz Kafka was a special case: many of his writings show a line of relationship to his own familial circumstances, revealed especially in "Letter to My Father"; but, while critics did quite successfully exploit that relationship, Kafka's work derived from a complex of other influences which made a too-simple psychoanalytic explanation misleading. (See *The Kafka Problem*, edited by Angel Flores, 1946).

The final kind of influence concerned the role which psychoanalysis played in a number of the major preoccupations of modern writing and art. Psychoanalysis could rightfully claim a share in the motivating influence upon the release (of literature chiefly, but of the other arts as well) from the restraining and inhibiting cultural and traditional limits of taste and decorum which had fairly well held until the end of World War I. In the literature following upon the conclusion of that war (and sometimes antedating it) a greater frankness concerning sexual relationships, familial and infantile sources of perversion and inversion, and the fact of perversion itself became a dominating characteristic. In this connection, the clinical studies begun by Freud and revealed in *Three Contributions to the Theory of Sex* and other places had a rather important voice, though by no means an exclusive one; the work of other psychologists, of sociologists and anthropologists was equally important, and the general impact of the war served as a primary cause of the release of inhibitions among artists regarding the treatment of these matters. What psychoanalysis did was immensely to extend and partly to provide phraseology for the discussion of sex matters or for their dramatization in works of literature. The attitude toward psychoanalysis on this level of influence was often largely undiscriminating, amateurish and ignorant. The principal terms and the popular notions of psychoanalysis were used over and over again in the popular and semipopular literature of the 1920s, as the Marxist and pseudo-Marxist ideas found their way into the work of the 1930s. The catalogue of works which reflected this type of influence is very great; the use of psychoanalysis was sometimes very shrewd, sometimes quite mistaken and misleading and often merely the result of a desire to be fashionable. In one way or another the work of the following writers showed the widespread impression made by psychoanalysis upon the modern world: Floyd Dell, Max Eastman, Maxwell Bodenheim, Conrad Aiken, Susan Glaspell, Evelyn Scott, Waldo Frank, F. Scott Fitzgerald, Carl Van Vechten, May Sinclair, J. D. Beresford and Aldous Huxley. In the work of most of these, psychoanalysis was little more than incidentally acknowledged, or was used merely as a form of intellectual small change. In the 1940s psychoanalysis penetrated even further into the public consciousness and became one of several sources of material, plot, explanation and motivation in the cinema or in novels written at least partly with an eye to an adaptation to cinema production.

The actual study of psychoanalytic influence on modern literature and art contains many varied problems. In the first half of the 20th century at least, the influence was often haphazard and incidental, and art borrowed from it a means of confusing its terms and its disciplines. Until the time of World War I, the career of psychoanalysis had been largely handicapped by a considerable rejection of it as a valid psychology. The writer or artist, aware of a significant new contribution to human knowledge, even in the early years, was both distrustful and confused concerning its actual value for him. New terms, discoveries, emphases (or extensions of original terms) served to confuse him further. In addition, the sources of information from which the artist was able to draw were often quite remote in both nature and quality of precision from the original; as psychoanalysis became popular, numerous books, essays, editorials, conversations and amateurish "games" served often to give portions of "information" or vagrant notions of what psychoanalysis was actually doing. This variety of circumstance accounted for the vast majority of errant and erroneous uses of what was, when separated from its accurate source, mostly a fashionable mode of discourse, or a jargon.

For those who considered psychoanalysis seriously and with some accuracy, it made substantial contributions in at least three separate areas of creative work. The first of these was the study of the un-

conscious itself—often quite aside from the psychoanalytic purpose for making that study. The pioneering influence in this connection was Freud's *The Interpretation of Dreams*. His investigation of the "dream work" had a profound and widespread effect upon the arts, especially as it gradually made available to artists certain information concerning the "behaviour" of the unconscious. The dream not only provided an extension of the uses to which the various languages of the arts might be put; it also suggested a range and a new reordering of symbolism which could be applied in varied ways to literature and art. In literature, the technique known as stream-of-consciousness writing was greatly extended through adaptations or applications of Freud's original suggestions. A considerable range of literary styles was made possible as a consequence, as well as new departures in the structure of novels, plays and poems. The popularity of this method was largely the result of the great success of James Joyce's *Ulysses* (1922), imitated in a great number of the novels which followed its publication. *Ulysses* was followed by *Finnegans Wake* (first published in part as "Work in Progress" in the magazine *Transition,* 1927 to 1929; as a book, 1939), a much more elaborate and exhaustive exploitation of the literary resources of psychoanalysis, in combination with many other disciplines, knowledges and techniques available to the erudition of its author. Other applications of the information about the unconscious made available to the arts included the so-called "automatic writing" of the surrealists, especially of André Breton, Louis Aragon, Philippe Soupault, René Crevel and Paul Éluard. These artists, and others, did not confine themselves, however, to a mere simulation of mental disorders in their work; it did remain close to what the founders of surrealism thought were their psychoanalytic origins. Breton's definition of surrealism, given in the *Manifestes du surrealisme* (1924) established both the nature and the limitation of their work: "Pure psychic automatism by which it is intended to express, verbally, in writing, or by other means, the real process of thought. Thought's dictation, in the absence of all control exercised by the reason and outside all aesthetic and moral preoccupations." (André Breton, *Manifestes du surrealisme,* p. 46; Éditions du Sagittaire, Paris, 1924). In its later development, the sponsors of surrealism acknowledged that such work could easily be confined to a too narrow and repetitious form of creation and proposed (in Breton's essays and in those of Nicholas Calas) to free themselves from the limits of psychoanalytic descriptions of the unconscious. This independence of the limits of clinical psychoanalysis was much less true of surrealist painting (Max Ernst, Yves Tanguy, Salvador Dali and others), which for the most part continued to realize pictorially and without much variation the desires resident in the unconscious.

The second most conspicuous contribution made by psychoanalysis to modern literature and art had chiefly to do with the re-examination and exposition of human behaviour and the motives underlying it. This revision of view, involving as it did much attention to a person's sex life and his relationship to his parents from infancy on, did much to encourage both illuminating and wildly erroneous changes in the explanation of motive. In fiction and drama it encouraged a certain boldness in the presentation of issues hitherto generally suppressed in literature. Many of the explanations offered in novels and plays were naïvely crude or overly simple. So too the extensions of psychoanalysis found in biography were marked often by crude and simple applications to speculative readings of their subjects.

The range of information concerning such mental disorders as were available, to novelists and dramatists especially, increased as the techniques of psychoanalysis expanded and theorists multiplied. Earlier fiction of the 1920s often remained content to speak superficially of "repressions," "neuroses" and "free association" and to narrate visits to psychoanalysts as part of a social fashion. As familiarity with psychoanalysis increased, the use of it became more "professional" in its efforts to achieve clinical exactness. The novels, dramas and motion pictures of the late 1930s and of the 1940s demonstrated much detailed knowledge of psychiatry and a willingness to exploit its opportunities for characterization and melodrama. An early example of literature engaged in such exploitation is Fitzgerald's *Tender Is the Night,* whose major theme depends upon the risk taken by a promising young American psychoanalyst when he marries his patient, and is thus forced to call increasingly upon his reserves of nervous and moral energy until both are completely exhausted. The novel revealed a considerable acquaintance with the terminology, practices and techniques of the clinic and the sanitarium, and some skill in appropriating them to the problems of a novel's form and structure.

The third contribution is largely the work of Jung. The difference between his influence and Freud's can best be explained by reference to their differing explanations of the term "libido." Freud had used this term to designate sexual energy; Jung preferred to expand its definition. Linked with this fundamental difference of interpretation was the much greater emphasis Jung put upon what he called the "collective unconscious," which has been described as "the precipitate of humanity's typical forms of reaction since the earliest beginnings." (J. F. Jacobi, *The Psychology of Jung,* p. 8; Yale University Press, New Haven, Conn., 1943.) The role of the artist became extremely important for Jung; he was considered a form of priest of the "collective unconscious" because he relates the conscious life of his fellows to its archetypes in the unconscious. This view of the unconscious and of its availability to art and literature had no small influence upon 20th-century writers and artists. It was one of several germinal theories which stimulated a great critical interest in myth and mythology. Among the critics whose interpretations of literature showed its influence were Maud Bodkin (*Archetypal Patterns in Poetry,* 1934), Elizabeth Drew (*T. S. Eliot: The Design of His Poetry,* 1949) and Richard Chase (*Quest for Myth,* 1949). Jung's influence served in a way to counteract Freud's rather narrow view of the artist and the tendency of his followers to analyze art in terms of the artist's psychic nature. Jung was in a much larger sense concerned with the act of creation and with its significance as a restatement and reshaping of recurrent mythical themes.

At the halfway mark of the 20th century, the usefulness of psychoanalysis for criticism and its influence upon the artist had grown much more complex and varied than at the beginning. New explorations of Freud and Jung continued to appear, as well as a considerable number of studies by psychoanalysts of the arts, by critics of psychoanalysis and psychiatry. In literature especially, the groundwork of psychoanalytic knowledge was accepted as familiar to the majority of both artists and critics.

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(F. J. HN.)

PSYCHOGALVANIC REFLEX. The term psychogalvanic reflex (P.G.R.) was first used by Veraguth to describe the change in electrical properties of the human body (or any living animal body) in response to nocuous (emotional) stimuli. The terms "galvanic skin reflex," "skin constrictor reflex" and "sweat secretion reflex" have been used synonymously. This reflex is usually demonstrated in one of two ways. (*a*) Electrodes connect the hands directly to a galvanometer. When the subject is stimulated by a pin prick, threat of injury, etc., the galvanometer, after a latent period of about two seconds, will show a deflection indicating a change in the difference of potential between the two hands. This rises to a maximum within two to ten seconds and subsides in about the same time. (*b*) The human subject forms the fourth arm of a balanced Wheatstone bridge electrical circuit. On stimulation the galvanometer will deflect as described above. In this case, the deflection indicates a change, usually a decrease, in the ohmic resistance of the body.

This phenomenon was first described by Vigouroux (1879). It remained, however, for Veraguth (1909) to draw the attention of a large scientific audience to the psychogalvanic reflex. The physics of the "reflex" is still a matter of dispute. According to Gildemeister it is the result of a change in conductivity of the human body which is dependent upon polarization of the membranes of the cells of the skin, so changing the cellular permeability to different ions. The anatomical control of the psychogalvanic reflex has been shown to lie in the sympathetic nervous fibres which lead to the smooth musculature of the walls of sweat glands and capillaries. Any stimulus resulting in activity of the sympathetic division of the autonomic nervous system will consequently result in changes in tonicity of the involuntary musculature of the skin surfaces of the body which are shown by the secretion of sweat, changes in circulation, local skin temperature, etc. This combined action leads in turn to variations in electrical conductivity (psychogalvanic reflex).

Psychologists have, for a long period, been interested in this phenomenon, particularly following the suggestion of Binswanger (1907) that *only* emotional stimuli elicit the reflex. This view has been held by many subsequent investigators. The work of Radecki (1911) and later of Aveling questions the validity of this assumption. It is probable that the psychogalvanic reflex is elicited most frequently by nocuous stimuli, but that it is not specific to "emotional" situations.

The reflex has found application in many fields of research. Otologists have used it to detect the feigning of deafness in dubious cases. Psychoanalysts have used the phenomenon together with word association tests as a means of discovering

hidden complexes. Many investigators have made use of the psychogalvanic reflex for the demonstration of individual differences in emotionality. There seems to be fairly good evidence that such differences may be established in this fashion. Psychiatrists have made use of the reflex in differential diagnosis of organic and functional orders.

Attempts toward the practical application of the reflex as an indicator of emotional stability of men who were applying for positions in hazardous occupations have not met any great success.

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(C. LA.; X.)

PSYCHOLOGICAL TESTS. A psychological test may be described as a measurable sampling of an individual's performance on a standard task. "Test" is also used to designate the printed form or other instrument used in the testing process. Sampling implies that the person's test performance is taken as typical of some aspect of his usual behaviour, which we call a trait or an attitude; or, if he has been motivated to do his best, some aspect of his performance at its maximum; *i.e.*, some ability. Tests are often called scales, indicating that they measure and describe a single psychological variable in terms of some kind of quantitative unit; but not all psychological measuring scales are tests (*e.g.*, rating scales, or those used in laboratory experiments); it is customary to restrict the term "test" to some performance measure of individual differences, and the branch of psychology which deals with them and the results obtained by their use is called differential psychology (*q.v.*).

Historical Development of Tests.—Individual differences in mental performance were first scientifically studied in the 1870s and 1880s by Francis Galton, who endeavoured to demonstrate mental inheritance by making estimates of the abilities of distinguished (and other) fathers and sons and establishing the relationship between family strain and ability. His associate and successor, Karl Pearson, developed a method of measuring such relationships by means of the coefficient of correlation, a technique which came to be of primary importance in test research and standardization. In the late 1880s J. M. Cattell, inspired by Galton's work and trained in experimental methods under Wilhelm Wundt, devised a series of performance tasks he called mental tests, and with them he and his associates obtained objective measures of several mental processes such as association, memory span, reaction time, perceptual discrimination of various kinds, etc.; however, no one was able to demonstrate high correlation between scores on these tests and any measures of school ability. The first successful test of school aptitude was the general intelligence test of Alfred Binet, who at Paris in 1905 assembled and used a series of problem-solving tasks, differing from Cattell's in that they measured complex rather than elementary operations, including the "higher" processes of abstraction and generalization. These tests Binet soon organized into a mental-age scale which he used effectively in predicting pupils' school success or failure. The Binet tests were soon translated and widely adopted; several U.S. revisions appeared, most used of which have been those of Frederick Kuhlmann (1912, 1922) and L. M. Terman, whose Stanford revision appeared in 1916 and was revised in 1937.

During World War I group tests of intelligence were administered to about 1,750,000 men, and the decade of the 1920s witnessed a rapid multiplication of intelligence and special aptitude tests as well as of educational achievement tests and their widespread adoption in education and industry for purposes of predicting success in school and employment. That decade brought also the development of attempts to measure traits of personality other than abilities, by means of questionnaires, performance tests, rating scales and other devices. During the 1930s test workers both in laboratories and in practical service became increasingly critical as to what tests actually measure, not merely how consistently they do it. This attitude led to refinements of statistical techniques of test construction and standardization, to increasingly numerous validation studies and to the development of factor analysis techniques (first suggested by C. E. Spearman in 1904), by means of which the various mental functions involved in tests of general intelligence and other traits can be identified with some assurance. Thus, when World War II began, psychologists were prepared to put into use many kinds of tests on a large scale for selecting the special aptitudes needed in various branches of the military, naval and air services.

The number and variety of kinds of psychological tests are very large. One bibliography of psychological tests and rating scales listed 4,279 such instruments, classified under 85 categories. In terms of the functions measured, psychological tests can be grouped into three broad classes: (1) tests of aptitudes, either general or specialized; (2) tests of achievement or proficiencies, educational, vocational or other; and (3) tests of other personality traits, attitudes and interests.

Aptitude Tests.—Aptitude tests differ from proficiency or achievement tests in that the latter measure the outcomes of formal education or occupational training while the former measure potential abilities, untrained except through incidental practice and experience or prerequisite background education. Aptitudes vary in inclusiveness from tests of highly specialized functions, such as cancelling all a's on a page or speed of tapping with a stylus, to comprehensive tests of abstract or mechanical intelligence. Special aptitude tests are most extensively used in employee selection and placement, in detecting peculiarities or defects in sensory, motor or intellectual capacity and in experimental research on the nature and organization of abilities. At first such tests were commonly designated by the kind of mental condition or process presumably involved, such as colour blindness, auditory acuity, controlled association (opposites, genus-species, etc.), memory span, imagery, reasoning or hand coordination; but the later tendency was to designate them by the kind of operation involved, pitch discrimination, assembling, form board, tapping, arithmetical problems, series completion or other, or else by their proposed use, such as clerical aptitude, reading readiness, lathe operation or medical aptitude. Aptitude tests may employ simple equipment such as a list of questions or arithmetic problems, or a page of pied type for cancelling a's, or relatively elaborate apparatus for testing some complex mechanical aptitude.

When a rating on general level of ability rather than special aptitudes is desired, several different tests may be combined into a scale which purports to measure general intelligence or general mechanical aptitude. The latter type is represented by several tests, some paper-and-pencil tests, some performance tests, which endeavour to get at some general organic capacity more fundamental than the various special motor skills. Unfortunately, agreement as to the definition and nature of "mechanical aptitude" has been lacking, with the result that some tests emphasize one ability, some another, including such varied things as motor dexterity, comprehension of mechanical principles, acquaintance with a variety of mechanical devices, facility in visualizing shapes or movements, numerical skill, etc. Consequently, while such tests have been used with considerable success in vocational guidance and selection, they have yielded lower correlations than are desirable, both with one another and with such external criteria of mechanical aptitude as are available.

Individual Intelligence Tests.—General intelligence tests are known also as tests of abstract or verbal intelligence, mental alertness and scholastic aptitude. They may be individual (given to one subject at a time) or group tests. The former include tests of the Binet (mental-age) type and performance (nonverbal, manipulative) tests. In any Binet-type scale the tests are grouped as to degree of difficulty. Thus, the Revised Stanford-Binet had 122 test items grouped into 20 levels of difficulty, 6 being placed at each half-year or year level from age two up to three superior adult levels, except for eight at the average adult level. The nature of the tests is suggested by the following examples: (1) Year V: defining orally (by description, classification or use) 2 words from a standard list of 45, copying a square, repeating a standard sentence from memory; (2) Year X: reading and summarizing a paragraph, telling what is absurd

about a picture, naming 28 words in one minute; (3) average adult: transcribing into a simple code a short message, defining 20 words from standard list, stating differences between two abstract words. The mental age which the subject achieves is computed by totalling the credits for all tests passed (or presupposed), usually at the rate of two months' credit each. A given mental age is defined as the level of test performance which is median or normal for children of that age. The intelligence quotient, popularized by Terman although originally suggested by William Stern, measures rate of mental growth, and is obtained by dividing the mental age by the chronological age (omitting decimal point). If a 10-year-old has a M.A. of 10, his I.Q. is 10/10 = 100; if his M.A. is 8, his I.Q. is 8/10 = 80; if his M.A. is 12, his I.Q. is 12/10 = 120. Thus, 100 I.Q. designates exact normality, I.Q.s above 100 indicate degrees of brightness above average and I.Q.s below 100 indicate degrees of dulness below average. An I.Q. of 70 or below is usually regarded as indicating some degree of mental deficiency. Since an individual's I.Q. does not usually vary greatly from year to year, it affords a basis for predicting his probable future achievement; its value for school placement is therefore apparent. Because the average individual's performance does not increase beyond the average adult level in the scale (approximately mental age 15), 15 is arbitrarily taken as the chronological age in computing the I.Q. of an individual above that age.

Performance scales, such as the Pintner-Paterson, Grace Arthur and others, were originally designed for illiterates, non-English-speaking and the deaf (for whom language is highly artificial); they employ such nonverbal material as form boards, dissected pictures, mazes, picture completions and sequences and painted cubes to be arranged to form given designs. The Bellevue-Wechsler scale for adults combines five verbal tests with five performance tests; this and other performance scales yield point scores, although mental ages and I.Q.s can be computed by the use of tables. Special scales have also been devised for testing the blind, partially sighted and those otherwise handicapped.

Group Intelligence Tests.—The earliest group intelligence tests were the Army Alpha (for literates) and Beta (for illiterates) used in World War I. In World War II these were replaced by the Army General Classification test. Group testing previously had been assumed by most psychologists to be too unreliable a method for successful use, but after 1918 it quickly achieved popularity and many group tests were standardized not only for adults but for use in colleges and high schools and in elementary and primary grades. For the last-named, nonverbal tests (which do, however, use oral directions) are provided, using pictures, designs, mazes, etc., to be marked as directed. Some scales, such as the Kuhlmann-Anderson, provide a graded series from infant to adult level, so that scores at successive testings can be directly compared. Other tests have endeavoured to encompass the entire age range in one test, but usually at some sacrifice of reliability. Verbal group scales brought into popularity so-called "objective" questions, which are answered by checking the correct one of a number of answers, hence called the "best-answer," "multiple-choice" or "recognition" type of question, or in some other way recording an answer that is unambiguously scored right or wrong independently of scorers' variable judgments. Typical of such questions are the following:

What is related to a cube in the same way in which a circle is related to a square? (underline one) *Circumference, Sphere, Corners, Solid, Thickness* (analogies test).

The opposite of treacherous is . . . (underline one) *Friendly, Wise, Brave, Cowardly, Loyal* (opposites test).

If a strip of cloth 24 in. long will shrink to 22 in. when washed, how many inches long will a 36-in. strip be after shrinking?——— (arithmetical reasoning).

On the two blanks write the two numbers that should come next: 2 3 5 8 12 17 — — (number series completion).

A number of devices have been provided to facilitate the administering or scoring of tests and thus extend the range of their usefulness. The cyclical or spiral form, instead of grouping items of the same kind, follows one or two examples of one kind by one or two of another kind, so that each type recurs several times in the scale, usually at a more difficult level; this is also called the self-administering type, since it can be given by an untrained examiner. Quick-scoring or self-scoring devices on several tests permit wrong answers to be quickly distinguished from right without recourse to laborious item-by-item scoring; while machine-scored answer blanks, separate from the test booklets, are extensively used when a number of tests have to be scored.

Most group tests have a time limit such that none or at most very few of a group can solve all problems within that time, thus preventing accumulation of many undifferentiable high scores. Such tests therefore measure not only mental power but also speed. Most Binet tests, on the other hand, are untimed; hence they measure power and only slightly speed.

Primary Abilities.—One of the most hotly debated questions has been that of the nature of general intelligence (*q.v.*). Is it, as some have held, merely the overlapping area of the many highly specialized abilities involved in more complex performances? Or is it, as Spearman argued, a single, common factor (symbolized by *g*) which is a component of many tests, always combined with some special *s* factor? Spearman devised a special correlation analysis for supporting his view and for demonstrating the presence or absence of the *g* component in a group of tests. This *g* he postulated as a special kind of energy which is used in discerning abstract relationships and drawing inferences. Later a third intermediate view was developed; namely, that there are besides *s* factors a number of "group factors" or "primary abilities" less inclusive than Spearman's *g* but more general than the identical elements of the first-mentioned view. By multiple factor analysis of tables of intercorrelations between tests, the number of factors which will account for these correlations can be ascertained, and by examining those tests which are heavily or lightly loaded with a given factor, its psychological nature can be identified with some assurance. Among the primary abilities there have been identified verbal comprehension (V), number facility (N), space visualization (S), word fluency (W), perceptual speed (P), inductive thinking (I), memory (M) and some others with less certainty; a number of these abilities have already been further analyzed into less general factors. No assumption was made as to the psychophysiological nature of these factors. General intelligence, in this view, is a name given to one or another combination of primary abilities, and the fact that some intelligence tests do not correlate more highly than they do with others is in large part because different tests emphasize different abilities. Thus, performance scales which are heavily loaded with form board and other spatial tests will emphasize the S factor; while a highly verbal test will be heavily loaded with V and W factors; and still another may have a large proportion of N. As an outcome of these analyses, tests are available which measure separately the primary abilities in relatively pure form, thus giving better knowledge of just what is being tested than is obtainable from an inclusive general intelligence score or mental age.

Proficiency or Achievement Tests.—Tests of proficiencies, also called achievement tests, are intended to measure outcomes of systematic education and training in school or occupation toward a conventionally accepted pattern of skill or knowledge. There are other fields in which definite proficiencies are sufficiently recognized, such as sports and the fine arts, so that informal if not formal achievement testing is practised. Some writers make a distinction between psychological tests and educational tests; but this distinction is one of practical convenience rather than of method or even of functions measured, for both kinds of test employ common principles in their construction and standardization, while both inherited capacity and practice influence the scores on all kinds of tests.

Only the principal types of educational achievement tests and their functions will be enumerated here. They are: (1) subject tests, in reading, language usage, arithmetic, geography, writing, algebra, chemistry, Spanish and a score of other school subjects, are available literally by the hundreds; they may yield point scores or a "reading age," "arithmetic age" and the like; or (2) several subject tests may be combined into an achievement battery for measuring general school proficiency either in point scores or "achievement ages" and perhaps "accomplishment quotients" (AA/CA); some achievement batteries are available for use either as such or broken up into subject tests; (3) classification or placement tests are subject tests standardized for the uses indicated by the names; (4) promotional tests cover a limited scope, usually one topic or unit of instruction or a term's work in the subject; (5) instructional tests are planned as teaching and study aids; (6) diagnostic tests are designed to reveal special difficulties, such as "borrowing" in subtraction, in order to facilitate corrective instruction; (7) survey tests, used in school surveys for evaluating the work of schools and school systems instead of individual pupils, are usually briefer and cover the fundamental subjects only. Besides these types of achievement tests, special types of scholastic aptitude are measured by (8) readiness tests (usually reading readiness) for first-grade pupils and (9) a variety of subject aptitude tests, such as foreign language, music, mechanical or fine arts, or at preprofessional levels, for law or medicine, to predict a student's fitness for undertaking the study of these subjects.

Tests of occupational achievement are exemplified by the more than 100 trade tests standardized during World War I to aid in selecting the most proficient men for the civilian occupations represented in large army cantonments, such as typist, telegraph operator, stationary engineer, sheet metal worker, truck driver, etc. They were of three types, question, picture-question and performance, and their scores classified men into expert, journeyman, apprentice and novice grades of skill. These tests were not used extensively in civilian life because industries large enough to need tests in selection routine seldom hire craftsmen skilled in these broad trade categories; instead, they employ specialized workers, often trained on the job, and hence selected by means of aptitude tests. Some large firms do, however, maintain their own trade-test departments for constructing, standardizing and administering proficiency tests for their highly specialized operations.

Personality Tests.—The first test of traits of personality other than abilities to attract general professional attention was the Downey Individual Will-Temperament test in 1919. Using as material the changes in handwriting under varying stimuli and instructions, it yielded profile scores on a dozen motility traits. It did not enjoy long popularity because of its low reliability (which was due to brevity of the component tests) and low correlation with trait ratings; but it did stimulate activity in this field of testing. Several other performance tests were used chiefly for research purposes, for measuring honesty, co-operation, inhibition, aggressiveness, persistence, dominance and other traits. But most of the attempts to measure traits of personal

adjustment have employed schedules or inventories, lists of questions to be answered "yes" or "no," such as, "Do you often feel lonesome even when others are around you?" "Do you often feel just miserable?" The prototype of these inventories was the Woodworth Personal Data sheet, for measuring neurotic symptoms, begun but not actually used during World War I. Special forms of questionnaire, for measuring neurotic tendencies, introversion-extraversion, ascendance-submission, school, family, home or personal adjustment, and several multiphasic inventories in which several traits can be measured at once by using separate scoring keys for each trait have been published and extensively used. Since these instruments are personal reports rather than tests, their value is limited both by the subject's ability and his willingness to give a true and competent report about himself; and they have, in general, considerably lower statistical reliability (and hence validity) than have ability and achievement tests. They have proved fairly helpful in clinical diagnosis and vocational guidance, more so than in employment and other situations where the subject feels he has something at stake in choosing how he shall respond.

A special type of adjustment test that acquired wide clinical use was the projective method, of which there are several examples. They are based on the principle that a subject, responding to an unstructured stimulus situation, will "project" his own feelings and attitudes into his response. They employ standard words, pictures or other materials, and the subject is given only very general directions, such as, "Give the first word that comes to mind," or "What might this (ink blot or cloud picture) be?" or "Tell me a story about this picture" or "Make anything you like" (with these paints, modelling clay, toys). The word-association tests of C. G. Jung and of Grace H. Kent and A. J. Rosanoff, the ink blots of the Rorschach test, Stern's cloud pictures, the pictures in the Murray Thematic Apperception test, the psychodrama (of J. L. Moreno and others, in which the subject dramatizes with the aid of others his own problem situation), finger painting, toy objects and dolls, and play therapy are among the vehicles of self-expression which give opportunity for the subject to reveal, sometimes unwittingly, his own problems and ambitions. Most projective tests have not been quantitatively scaled, or only incompletely so, and are diagnostic devices rather than measuring instruments.

A variety of verbal-response instruments has been devised for measuring directional sets toward particular goals or objects, designated as attitudes, opinions, interests, values, etc. Opinions about particular social policies, propositions or groups have been measured by checking agreement with one or more of a list of varied opinions to which scale values have been assigned by the "method of equal appearing intervals" (Thurstone attitude-scale technique) or by expressing degree of agreement or disagreement with a proposition (Likert technique). These have been used chiefly in social research as to what attitudes are held and how they are changed. The measurement of vocational interests has been undertaken by means of several tests, best known of which was that of E. K. Strong, Jr., which consisted of 400 items to be checked *like, dislike* or *indifferent;* and the degree of resemblance of an individual's pattern of interests to the pattern found characteristic of each of the 30 or more standard occupational groups is taken as a measure of his interest in (but not necessarily aptitude for) that occupation. Nonvocational interests and values were measured by the Kuder Preference record, the Allport-Vernon Scale of Values and other devices. The Allport-Vernon yields a profile showing the relative strength of six "values": the theoretical, economic, aesthetic, social, political and religious. These instruments have found their principal use in personal and vocational guidance.

Units of Measurement.—Measurement implies representation of a selected variable along a linear scale divided into units of equal magnitude. In psychological measurement, defining and equating these units presents peculiar difficulties. The simplest procedure is to count each problem solved or each question correctly answered (or, in adjustment tests, "favourably" answered) as one point and total them to obtain the point score. Or, in case of speed tests, the time required to perform the task or the amount accomplished in a given time can be taken as the measure. Such point scores are of course somewhat arbitrary, for items vary in difficulty and importance; and various methods have been proposed for differential weighting of items. Any "raw score," moreover, varies in significance from test to test, so it is necessary to provide norms or comparison scores in order to evaluate an individual's test performance. The simplest norm is the mean score of a standard comparison group, which must be large enough (several hundred cases, preferably) to be statistically stable and typical of the population it is taken to represent, ordinarily a particular age group, occupational group or school grade. To permit more precise interpretation, quartile, decile or centile norms are often provided.

Raw scores are often supplemented or replaced by some kind of derived or equivalent score, either mental age or some form of dispersion score. A mental age, since it is the median test performance of a given age group, incorporates norms directly into the age units, as do also the various educational or achievement ages. This practice is feasible so long as the ability measured increases with age. But since the average person's intelligence-test performance ceases to improve after 15 ("average adult level"), mental ages above that do not conform to the definition but are arbitrary scores; although on the Revised Stanford-Binet they yield I.Q.s of approximately the same significance as in earlier years. Consequently, many psychologists hold that mental ages and I.Q.s of the more intelligent half of the adult population are logically unsound, and should be replaced by some kind of dispersion score.

Dispersion scores describe an individual by defining his position somewhere along a representative distribution of scores when arranged in order from low to high. His centile score (commonly called percentile rank, or P.R.) is the percentage of the comparison group whom he equals or surpasses; thus a P.R. of 75 means that he equals or excels 75% of the group, while the remaining quarter surpass him. But since in any normal group psychological test scores tend to pile up in the middle of the range and become decreasingly frequent toward either extreme (the normal probability or Gaussian distribution), equal differences in P.R. do not at all ranges mean equal differences in test performance; for this reason it is sometimes denied that P.R.s are "units." This objection is avoided by the use of the standard score, based not on rank but on actual scores. The standard score is expressed as a fraction or multiple of the standard deviation unit of the dispersion (one S.D. or sigma is the square root of the sum of the squared deviations of each individual score from the mean score). A person whose score is exactly at the mean of the group does not deviate from it, hence has a standard score of 0; one who scores one sigma below the mean has a standard score of −1.00, and in a normal population his P.R. would be 16, since a range of ±1 S.D. includes approximately 68% of the population (16 P.R. to 84 P.R.). Thus, a single derived score both states and interprets a test score.

Test Construction and Standardization.—Constructing and standardizing a test is much more than merely choosing the kind of task to be performed and devising questions or problems; that is only a first step. In addition: (1) Many details of construction have to be worked out, tried and revised, items must be evaluated and those discarded which do not contribute to the desired differentiation, time limit set, verbal directions and mode of presentation of material formulated, scoring instructions worked out, key prepared, etc. (2) A well-standardized test must also have known reliability, as high as possible; that is, it must be demonstrably self-consistent in measuring whatever it measures; to this end self-correlation procedures are employed. (3) A well-standardized test must be provided with adequate norms, as previously described; it often happens, however, notably with educational achievement tests, that the test administrator prefers to compute his own local norms rather than use published norms. (4) Finally, a test cannot be considered thoroughly standardized until something about its validity is known; *i.e.*, what it actually tests or what it is good for, as indicated by a reasonably high correlation between scores and some independent criterion of whatever characteristic it is thought the test will discriminate or predict—a question which obviously can never be completely answered.

To say a test has high validity means that it correlates well with one of three types of criterion: (1) some accepted measure of the trait or ability the test purports to measure, usually some kind of rating of a group of subjects on that trait; (2) some other test already assumed to be a valid measure of the trait, which merely pushes the problem back upon the earlier test and ultimately back to the first type of criterion (thus, many early group tests were announced as valid tests of intelligence because they correlated well with Binet mental ages, whose validity as a measure of intelligence can also be questioned); (3) some criterion of the actual effectiveness of the test in making desired discriminations or predictions. Inasmuch as the first two criteria hinge on what raters mean subjectively by a given trait name and take into account when they make ratings on it, the increasing tendency is to disregard trait names and test titles and rely on the last-named type of criterion—school records, industrial production records or other concrete evidence of achievement or character.

The validation of already standardized tests for a given purpose (such as selecting employees or soldiers for a particular job) is an application of the third type of criterion named. It constitutes a well-established experimental procedure which may be briefly summarized in the following eight steps: (1) analysis of the operation to determine its psychological characteristics and requirements; (2) choosing, devising or adapting presumably suitable tests for experimental tryout; (3) selecting a group of suitable experimental subjects (those for whom some criterion measure is available or can later be obtained); (4) obtaining efficiency criteria on those subjects (production record, scholarship record, efficiency ratings or other); (5) obtaining scores of those subjects on all tests to be experimentally evaluated; (6) correlating each set of test scores with criterion measures; (7) selecting (and perhaps combining) those tests showing best correlation; (8) setting critical scores on those tests, for selection or rejection, and using those tests with their critical scores in selecting or rejecting candidates.

Uses of Psychological Tests.—As already indicated, psychological tests have found a wide variety of practical uses in many areas of activity. The diversity within a single field is suggested by the following partial list of uses of aptitude tests in schools and colleges: pupil classification and placement; as aids in selective admission; diagnosing causes of failure or substandard performance; homogeneous sectioning of classes by ability to facilitate effective instruction; educational and vocational guidance; recommending for employment or for admission to higher institutions; selection for special responsibilities or special treatment. The uses of different kinds of educational achievement tests have already been summarized. But in addition to

their practical uses, psychological tests have come to be hardly less important as tools of fundamental research on theoretical problems in psychology, social sciences and even physiology, typical of which are the following: course of mental growth and decline in both general and special functions; evaluation of the relative role of hereditary and social determinants of ability and personality; measurement of effects on individual abilities, traits, and attitudes of various organic, physical or social changes; evaluation of group differences in ability and temperament between different races, nationalities, sexes, age groups, socio-economic classes, etc.; analyzing the nature of mental organization and the interrelations between mental functions.

Psychological tests were no longer thought of by informed observers at mid-20th century as in the fad stage, although they were and always would be in the experimental stage. Nor are they devices which can successfully be applied by anybody, regardless of professional training and qualifications. Tests can be and often are misused and misinterpreted by those who lack sufficient psychological training and insight to appreciate their meanings and limitations, and to be able to interpret single test scores wisely in the light of other relevant facts about the personality of the individual being examined. The administration and interpretation of tests, and even more their construction and standardization, are professional undertakings, requiring extensive and intensive professional training; they are no tasks for amateurs.

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PSYCHOLOGISM, in philosophy, is the view that problems of epistemology (that is, problems relating to the validity of human knowledge) can be solved satisfactorily by the psychological study of the development of mental processes. Locke's *Essay on the Human Understanding* may be regarded as the classic of psychologism in this sense. A more moderate form of psychologism only maintains that psychology should be made the basis of other studies, especially of logic.

PSYCHOLOGY is (1) the study of mind and of mental phenomena. That is the historical use of the term, a use that has been valid ever since the 17th century, when René Descartes, the dualist, drew the distinction between matter as extended substance and mind as unextended substance. (*See* PSYCHOLOGY, HISTORY OF.) This Cartesian view tends to turn psychology into the study of immediate experience, experience regarded in its own right as it comes directly to the conscious individual. Psychology thus finds itself describing experiences and formulating the laws under which experience is determined by its physical and physiological conditions.

(2) In the 20th century the scope of psychology was enlarged to include all the integrated action of the total individual, human or animal. Thus, modern psychology includes within itself the science of human behaviour, where behaviour is taken to mean the action or conduct of the whole person. Physiology deals with the action of separate organs or bodily systems and is thus closely related to psychology and not always to be distinguished from it.

In general, it may be said, human psychology studies the whole person—his thoughts, his conduct and also those properties of him which make him think and act as he does. For this reason, psychology is concerned with both consciousness and behaviour, each because it is important in its own right. Behaviour, however, gains additional importance since language, a special form of behaviour, is the sole means by which the consciousness of men can be revealed to the observing scientist.

SCHOOLS OF PSYCHOLOGY

Scientific psychology, partly because of its heritage from philosophy, of which it was for a number of centuries a part, has tended to become divided into schools, which differ from one another in respect of their beliefs about the primary purpose of this science. The most important schools that have played a prominent role in the history of 20th-century psychology are the following.

Physiological Psychology.—Wilhelm Wundt (1832–1920), who is regarded by some as the founder in the 1860s of the new experimental psychology, fixed the name physiological psychology upon this new science by the publication of his *Grundzüge der physiologischen Psychologie* in 1874. For 40 years the 6 editions of this systematic handbook both assessed the new psychology and fixed its scope. Thus, in the 19th century physiological psychology came to mean the experimental school as opposed to the nonexperimental methods of those philosophers who were writing about psychology, and, more narrowly, as opposed to the intentionalism of Franz Brentano (*see* below). In the 20th century physiological psychology is a field and not a school, the field of all psychologists who extend their investigations beneath the skins of the organisms studied. (*See* general section *Physiological Psychology,* below, p. 687.)

Introspectionism.—The psychology of immediate experience used the method of introspection for getting at the contents of consciousness. Wundt fixed this method upon the German psychology of the 19th century, and E. B. Titchener (1867–1927) upheld it in the United States. Until about 1915 it was regarded as the chief method for the study of human psychology.

Basically introspection consists merely in having the observing subject report and describe the contents of his consciousness—sensations, images, feelings, perceptions, intentions, ideas, thoughts and insights. There are, however, many cautions to be observed and many technical procedures to be followed in order to get complete descriptions. The school of introspectionism may be said to have died out with the deaths of Wundt in 1920 and of Titchener in 1927 and with the concomitant rise of behaviourism and other objective systems. On the other hand, report on the contents of consciousness still remained an important method of psychology, as, for instance, in psychoanalysis (*q.v.*). (*See* also CONSCIOUSNESS; INTROSPECTION.)

Intentionalism.—The act psychology, which Franz Brentano (1838–1917) got from the Scholastic philosophers and promoted in his *Psychologie vom empirischen Standpunkte* in 1874, constitutes an intentionalism because it represents mind as comprising mental acts which are by intention directed upon some object. *Seeing* is a mental act which must have some object, like *green.* The seeing is said to "intend" the green, which "inexists" within the seeing, being the "immanent object" of the seeing. Brentano's influence, great in Austria and Germany, also affected British psychology markedly. James Ward (1843–1925) followed Brentano's leadership, whereas G. F. Stout (1860–1944) followed Ward, and William McDougall (1871–1938) espoused a purposive psychology that was consistent with this tradition. No important U.S. psychology belonged within this school, except in certain respects the psychology of William James (1842–1910).

Functionalism.—The school of functional psychology flourished in the United States at The University of Chicago for a dozen years or more from 1896 on. Although it owed something to William James, it may be said to have been founded by John Dewey (1859–1952), supported by the Chicago philosophers G. H. Mead and A. W. Moore and headed by James R. Angell (1869–1949). Functional psychology was stimulated by the prevalent interest in Charles Darwin's views and the theory of evolution, for it holds that mind is to be understood in terms of the use it has for the individual in his struggle for survival. The chief function of mental phenomena is held to be "accommodatory"; *i.e.,* directed toward the successful adjustment of the organism to its environment.

This psychology of use, the psychology of the "is-for," is related to pragmatism (*q.v.*), the "functional philosophy" developed by C. S. Peirce, James and Dewey. Functional psychology considers both consciousness and behaviour, since both kinds of events can be understood as of use to the organism.

Functional psychology as a school disappeared in the furor over behaviourism (*q.v.*) sometime near 1915, but as a point of view it continued to be characteristic of U.S. psychology, as it had been since the start of the American "tradition" about 1890. The U.S. temperament has been practical and competitive.

The pioneers in the new continent struggled with nature, and their descendants continued a culture that is largely competitive. Democracy is the arena in which competition is free and unbiased. Such men need to assess their own capacities and their fellows', and psychology furnishes them with the means of assessment.

Thus the mental test, which measures differences in human capacities, thrived in the U.S. after having been invented in England by Francis Galton, Darwin's cousin. James McK. Cattell (1860–1944) supported a functional psychology of capacities at Columbia university, New York, N.Y., for 25 years, and indeed it is hard to find much U.S. psychology in the first half of the 20th century that was not concerned with the capacities, abilities or aptitudes of the individual, human or animal, to achieve some kind of success, whether the goal be the discrimination of colours, the finding of food in a maze with minimal errors and effort, or Albert Einstein's sudden insight into the significance of the relativity of movement. (*See* PSYCHOLOGY, HISTORY OF: *Functional Psychology.*)

Behaviourism.—Functionalism prepared the way for the school of behaviourism, which was founded by John B. Watson (1878–) about 1913. Watson complained that introspection had not advanced psychology, that its results were unreliable, and that psychology ought to ignore the existence of consciousness and deal only with behaviour. He had been working with animals, and with animals the functional capacities are fairly easily determined, whereas the inferences as to the nature of the animal's accompanying consciousness are uncertain and seemingly unimportant. Why not, he asked, take a suggestion from animal psychology, and limit human psychology also to the study of behaviour?

For a dozen years behaviourism dominated the U.S. scene in psychology, although there were many individual variations on the basic formula. When behaviourism encountered phenomena that are essentially introspective in nature, like perceptions and images, usually it simply substituted verbal report for introspection.

Since the data of consciousness have to be reported to be known, it is always possible to regard the behavioural report as the observed datum, thus reducing conscious phenomena to the behaviour of speech or writing. In this way behaviourism anticipated operationism (*see* below; *see* also BEHAVIOURISM).

Gestalt Psychology.—Contemporaneous with behaviourism was the German school of Gestalt psychology. Like behaviourism it represented a revolt of a younger scientific generation against the established conservatism of introspectionism. Its founder was Max Wertheimer (1880–1943), who was supported by Wolfgang Köhler (1887–) and Kurt Koffka (1886–1941). This movement, which dated from a paper of Wertheimer's in 1912, stressed the importance of considering parts only in relation to one another and the wholes which they form. It thus makes large use of what is called field theory; *i.e.*, theory formulated in terms of the simultaneous dynamic interdependence of all parts within a whole. It admits both consciousness and behaviour into psychology, but opposes their analysis into conventional units or elements. The leaders of Gestalt psychology all migrated to the United States after Adolf Hitler came to power in Germany, and there they had the effect of lessening the influence of introspectionism, which is based on the definite assumption of mental elements, and of behaviourism, which excludes consciousness from consideration.

Thus, the Gestalt psychologists tend to oppose the operationists who are the modern behaviourists. (*See* PSYCHOLOGY, HISTORY OF: *Gestalt Psychology.*)

Dynamic Psychology.—In the 20th century the growing concern of psychology with motivation and the springs of human action was traceable partly to Sigmund Freud (1856–1939) and psychoanalysis (*q.v.*) and partly to William McDougall's insistence on the importance of instincts in social behaviour. There was no clearly recognized, self-conscious school of dynamic psychology, but the importance of the field was fully appreciated. The psychology of motives, since it aims at predicting human action, is intensely practical because it furnishes explanations of human nature. Thus, dynamic psychology supports and is supported by the American interest in functionalism. It is consistent with Gestalt psychology, as is apparent in the work of Kurt Lewin. It is not inconsistent with behaviourism, as the contributions of E. B. Holt and E. C. Tolman have shown. It carries on, moreover, the protest against the static analyses of an introspectionism which never got around to treating the problem of motivation adequately. (*See* PERSONALITY; PSYCHOANALYSIS.)

Operationism.—In 1927 P. W. Bridgman, the U.S. physicist, pointed out that physical entities have no meaning except in terms of the operations by which they can be observed, and that a scientific hypothesis which cannot be tested by certain definite operations is meaningless, a pseudo problem. The psychologists were quick to seize upon this notion that entities can be defined by the operations for observing them, because such logic allowed them to define immediate experience in terms of the data of the report of the experience. It is possible in such manner to reduce all psychological phenomena to observable physical terms, substituting behavioural for conscious data. Some psychologists who favour these reductions to behavioural terms have called the practice operationism. The procedure turns out to be closely allied to the logical positivism of the Vienna philosophers such as Moritz Schlick, Rudolph Carnap and Herbert Feigl. It has also been called physicalism and behaviouristics. It is a much more sophisticated philosophic position than the original behaviourism which sought mostly to ignore consciousness instead of accounting for it in physicalistic terms. Operationism embraces consciousness and then reduces it to observable physical data, thus bringing psychology, by making it physical, within the unity of the sciences, an achievement which is one of the goals of the logical positivists.

Operationism is opposed to the Cartesian dualism of introspectionism and also to the more modern dualism implied in the theories of Gestalt psychology. Its insistence on the reduction of psychological entities to their observational bases is distasteful to Gestalt psychologists, who believe that such reduction violates the integrity of immediately observable phenomena. There is, however, no conflict between operationism, on the one hand, and functional and dynamic psychology, on the other. Operationism, moreover, *is* behaviourism made philosophically palatable. It follows that the modern dichotomy in systematic psychology lies between operationism, which includes behaviourism, and phenomenology, which includes Gestalt psychology and the other psychologies that deal with immediate experience without reducing it to the operations by which it is observed.

Experimental Psychology.—Originally experimental psychology was regarded as a school because it grew up in opposition to the nonexperimental psychology of the philosophical writers. Later, under Wundt's influence, experimental psychology came to mean human, adult, normal, generalized psychology—not animal, nor child, nor abnormal psychology, nor the psychology of individual differences. While that usage persisted, it was confusing because all fields of psychology claimed to use the experimental method. Properly speaking, experimental psychology is no longer a school but another name for scientific psychology, which appeals to experiment whenever possible.

(*See* EXPERIMENTAL PSYCHOLOGY; PSYCHOLOGY, HISTORY OF.)

GENERAL PSYCHOLOGY

The term "general psychology" is used to designate the generalized facts and principles of normal psychological phenomena and functions. Being general, general psychology excludes the psychology of individual or group differences; thus, it excludes child psychology, abnormal psychology and comparative psychology as well as differential psychology. At one time general psychology could be identified with the general principles of normal human adult psychology, but later, when it became plain that most of the principles of human learning can be investigated by the use of animal subjects, the restriction of general psychology to human subjects was ignored, and the analogy of general psychology to general physiology, which treats of functions

without regard to specific or individual differences, became exact.

The more usual main subdivisions of general psychology are (1) sensation and perception; (2) reaction and sensory-motor co-ordination; (3) learning, inheritance and thought; (4) feeling, emotion and motivation; and (5) personality, including intelligence and the specific abilities.

Sensation.—The study of the capacities of the organism for sensory discrimination was the chief topic of research by the experimental psychology of the 19th century. This early start for the researches on sensation, taken together with what proved to be the fruitfulness of the experimental method in the field, resulted in the accumulation of such a large body of information that any general psychological compendium of facts is bound to be weighted heavily with the facts and laws of sensation.

Usually this field is divided, according to Aristotle's classical distinctions, into five subdivisions: sight, hearing, smell, taste and, finally, the body sensations, which are sometimes grouped together under the general term of somaesthesis. Somaesthesis includes all sensory phenomena that arise from stimulation of the skin and the tissues underlying it, the muscles, tendons and joints, the viscera, and the vestibule and semicircular canals of the inner ear.

Sensory problems are also sometimes divided in accordance with the four principal attributes of sensation: quality, intensity, extensity and duration. The study of sensory *quality* resulted, for example, in the various laws of colour vision and in both the analysis of auditory experience into pitches and the working out of the laws of the interrelations of pitches. The chief result of the study of sensory *intensity* has been the establishment of the way in which sensitivity varies with the strength of stimulation, a relationship which was originally called Weber's law when it was thought to be simpler than it really is. The study of *extensity* led to the formulation of laws of shape, size, distance and the interrelationships of all three. The study of *duration* led to a knowledge of the capacities of the organism for the discrimination of intervals of time, from short durations of less than a second up to long durations. These distinctions among attributes cannot, however, be maintained with rigour, since many phenomena involve two or more of the four basic dimensions. Size and brightness are related in the visual perception of small objects. Space, time, brightness and even hue may come under consideration in working out the laws of visually perceived movement. (*See* AUDITION; FECHNER'S LAW; HEARING; ORGANIC SENSATIONS; PSYCHOPHYSICS; SKIN, SENSORY FUNCTIONS OF; SMELL AND TASTE; VISION OR SIGHT; WEBER'S LAW.)

Perception.—The study of perception became merged with the study of sensation, but originally perception was distinguished from sensation by its function of objective reference. The adequate account of sensation was held to be given by the description of immediately given experience that arises on stimulation of the sense organs, whereas perception, always conceived as based upon sensation, was regarded as giving information about the external world and the nature of the stimulating objects. To experience a visual pattern of black lines on a white ground is sensation; to recognize it as a drawing of a familiar face is perception.

Nineteenth-century psychology often devoted its chapters on sensation to the consideration of sensory quality and intensity, whereas it dealt with the patterning of sensation in respect of space and time in the chapters on perception—a distinction that is doubtless rooted in Immanuel Kant's conception of space and time as categories in respect of which other data are organized, but a distinction that did not in general prove useful to psychology.

Reaction.—The behaviouristic trend of modern psychology, as it appears successively in functionalism, behaviourism and operationism, tends to make reaction the central theme of psychology, displacing the sensory processes which were focal to introspectionism. A reaction is response to stimulation, and a response is usually muscular movement or glandular secretion, although in some animal species there are other end products of nervous action which may also be counted as responses.

The study of reaction times is as old as experimental psychology; the reaction experiment was first set up by astronomers (1858) in their attempt to determine fixed individual differences in the observation times of astronomical observers. Stimulus-response (S-R) psychology dated from John Dewey's inauguration of functional psychology in 1896.

Dewey made it clear then that psychologists cannot afford to limit their attention to stimulation or to response but must look primarily to the significant relationships between stimulus and response. After all a stimulus is not a stimulus unless it elicits some kind of response, and a response is not a response unless it is elicited by some kind of stimulation.

This S-R psychology was favoured by the growth of physiological psychology, by the study of reflexes and by the discovery of the conditioned reflex (*q.v.*).

Learning.—Under the topic of learning come all the ways in which the behaviour or thought of the individual, all the S-R relationships of the organism, are modified, except for those modifications that are predetermined at the time of conception by the basic biological inheritance of the individual. The growth and development of the individual are fundamentally dependent upon inheritance, although the precise ways in which they are manifested may be learned. An infant does not learn to be adolescent, nor a youth to be senile; each has to grow up to a later genetic stage. A child *learns* to walk, but *inherits* the capacity to walk—the legs, muscles and possibilities of nervous co-ordination. It is well recognized that there is no behaviour in which both inheritance and learning have not played essential roles.

The effort to separate the effects of heredity and environment, to separate "nature" from "nurture," in Francis Galton's phrase, is foredoomed to failure, except that the respective contributions of nature and nurture may be assessed in particular performances, often by studies upon the comparative resemblances of identical twins, fraternal twins, brothers and sisters who are not twins and persons with no special community of inheritance.

The experimental investigation of learning, which began with Hermann Ebbinghaus' famous experiments on memory, published in 1885, expanded to provide the principal laws of the memorizing and forgetting of materials consciously learned, of skills voluntarily acquired, or habits involuntarily fixed in conditioned responses, and of new knowledge acquired in the solution of problems. For all of this work both human and animal subjects have been used. The general principles applicable to human subjects have proved to be discoverable from work upon animals, which can be taught to acquire skills or to solve problems, or which can be "conditioned," as the phrase is. The conditioned response, discovered by I. P. Pavlov in 1903, consists in the establishment of an association between two stimuli, such that one stimulus gives rise to the response that was already the normal consequent of the other stimulus.

For instance, Pavlov, sounding a bell whenever he presented food to his dogs, found that the dogs, whose saliva normally ran at the sight of the food, learned to salivate at the sound of the bell before they saw the food. Some of these conditioned responses seem to be established without the learner's conscious appreciation of the process that is taking place and without his intention to learn, but later investigations showed that insight and motivation are prevalent in animal as in human learning and are perhaps in some degree essential to all learning.

The learning that takes place in the solving of problems requires *insight* and *thought*. Conversely, it is true that the outcome of successful thinking is usually remembered. For these reasons, thought has almost ceased to constitute a separate chapter in general psychology and has become a special problem of learning. The dependence of thought on motivation and intention has been recognized since the researches of the Würzburg school about 1905, and the use of insight in the quick formation of newly perceived relations has been understood since the rise of the Gestalt school about 1917.

Ebbinghaus established for half a century the current notion

of his day that associations are formed by the continued repetition of the conscious concurrence of the items associated. If you wish to learn a poem or a list of nonsense words, you merely say over and over again what you wish to learn until you have learned it. Similarly the rat learns its way to the food through a maze by repeatedly traversing the correct path. It is, however, no longer clear that mere repetition is a sufficient reason for learning. It seems rather that repetition only furnishes the opportunity for other factors to operate in cementing the new association, factors as yet imperfectly understood by psychologists but related to insight and motivation.

The question has also arisen as to whether *forgetting* depends merely upon the lapse of time after the establishment of learning. It seems more likely that learning decays, when not re-enforced by use, because new learning, which takes place in the elapsed time, interferes with the retention of the old. Certainly the inhibition of past learning appears to be least during sleep, and greatest whenever the opportunity for conflict with new learning is greatest.

(*See* ASSOCIATION, MENTAL; LEARNING; MEMORY.)

Feeling and Emotion.—*Feeling* has long been a prominent chapter in general psychology, a chapter which deals with the laws of hedonic tone, of the pleasantness and unpleasantness of stimulus objects and situations. It has tended to be resolved into the psychology of preferences and thus to become a topic in the general chapter on motivation. The fact that pleasantness and unpleasantness cannot be experienced at the same instant thus reduces to the fact that two objects cannot be preferred, each over the other, simultaneously.

Emotion, while defying precise definition in psychology, has been investigated in its physiological and motivational aspects. W. B. Cannon's emergency theory of emotion makes it clear that, in strong emotion, the body is put in readiness for efficient violent action, with facilitation of those muscular systems which would be used in attack or escape and with inhibition of the digestive and other vegetative functions.

The conditions of emotion are, however, simply special cases of motivation. A few, like fear in falling or anger in restraint, may be largely inherited. The rest depend, it would seem, on learning and conditioning. (*See* AFFECTION; EMOTION; FEELING, PSYCHOLOGY OF.)

Motivation.—It has long been recognized that the realization of particular stimulus-response relationships is dependent upon the *attitude* or *intention* of the subject at the time of stimulation. Ludwig Lange in 1888 found that the preparatory attitude may change reaction time in such an amount that the longest times are almost twice the shortest. In 1905 Narziss Ach showed that the whole pattern of the reaction consciousness depends on the intentional preparation—a *determining tendency,* he called it. Still later the importance of motivation as a condition of learning was recognized (*see* above). In dynamic psychology it is customary to specify the basic *needs* or *drives* which determine human or animal action, and often to measure their relative strengths under particular conditions, by observing the preference of the subject under conflicting motives. For instance, the strength of hunger in a rat after a known period of food deprivation can be measured by the strength of an electric shock from a grill, laid in the floor of a passageway, that will prevent the rat from crossing the grill in order to obtain food.

(*See* ATTENTION; HYPNOTISM; INSTINCT IN MAN; SUGGESTION.)

Personality.—For the most part the study of personality does not form a chapter of general psychology because it belongs to the special field of differential psychology. We find ourselves more interested in differences in personality from person to person than in those factors which are common to all. On the other hand, the fact that the individual is made up of a pattern of general and special abilities, that his behaviour is dependent upon his particular repertoire of attitudes and beliefs, that the development of his capacity for intelligent adjustment to novel situations increases rapidly in childhood to a maximum which is approached in early maturity—such facts are part of general psychology, and, with the statistical techniques of factor analysis, have assumed a position of primary importance among the fundamentals of psychological knowledge.

(*See* DIFFERENTIAL PSYCHOLOGY; INTELLIGENCE OR UNDERSTANDING; PERSONALITY.)

General psychology also includes the study of what are called the *psychological mechanisms*—the defense and escape mechanisms, rationalization, frustration and all the means by which the individual avoids neurosis and makes his adjustment to the requirements that his environment lays upon him.

(*See* DEFENSE MECHANISMS.)

SPECIAL FIELDS OF PSYCHOLOGY

The scope of modern psychology is indicated by the enumeration of those special fields which, in addition to general psychology, occupy the attention of particular investigators, teachers, writers and professional psychologists.

Physiological Psychology.—The physiological psychologists are those who carry on their researches by actual observation or manipulation beneath the skin of the organism whose reactions are being studied. For the most part they use animal subjects and operative techniques, as in those studies in which the functions of the brain are determined by removing or destroying a portion of the brain and noting the effects upon the behaviour of the animal whose brain has been altered. The rise of endocrinology led physiological psychologists to experiment on the effects of hormones on temperament and motivation, either by the injection of hormones into the blood stream or by the extirpation of the glands which secrete the hormone. So much is known of the physiological substrate of psychological phenomena that it is possible to write a fairly complete psychology in physiological terms.

(*See* section *Physiological Psychology* below for more detailed discussion; *see* also ENDOCRINOLOGY.)

Comparative Psychology.—For the most part comparative psychology consists of the comparative study of the behaviour and psychological capacities of different animal species, from the Protozoa up to the great apes and man. The topics of greatest interest have been instinctual behaviour as it is found in different species, the growth of intelligence throughout the evolutionary scale, and the social habits of certain insects and mammalian groups. Besides this animal psychology, comparative psychology sometimes also includes a comparison of the conduct and customs of human races, tribes and nations—a comparative social anthropology.

(*See* ANIMAL PSYCHOLOGY; INSTINCT IN MAN; PSYCHOLOGY, COMPARATIVE.)

Genetic Psychology.—Phylogenetic psychology is included within the comparative psychology that studies the development of the psychological functions in the evolutionary series. Ontogenetic psychology considers the development of the individual from conception to death. A great deal is known about the prenatal capacities of mammals for discriminative response, perception and movement. The psychology of childhood and adolescence began to receive attention about 1882 and was re-enforced in the 20th century by the importance which psychoanalysis attached to the early formative years of life. Child psychology is really now a special field of psychology, knowledge of which is recommended to all parents. The psychology of adult maturity is taken in charge, for the most part, by general psychology, but the psychology of later maturity and senescence is regarded as a special field, called gerontology. Geriatrics undertakes to assess the capacities which are derived from experience and which do not show marked decay in old age and to indicate the manner in which the aging can most successfully make their adaptations to the limitations which are forced upon them.

(*See* ATYPICAL CHILDREN; CHILD PSYCHOLOGY; PSYCHOANALYSIS.)

Social Psychology.—Social psychology, which is closely allied to sociology and social anthropology, considers the individual in the social structure. It began with the study of the formation of

crowds, groups and mobs, and of the principles that govern group action. It lays stress upon the intrapersonal motives of men, and the basic instincts, needs or drives that determine their action. In this way, social psychology became allied to dynamic psychology and the psychology of personality, and indirectly to abnormal psychology where the variations of personality are exhibited in extreme degrees.

Originally social psychology was forced to develop without much use of the experimental method, but after about 1930 there was an increasing use of "polling" techniques, in which public opinion or the opinions of special groups are sampled in many controlled interviews. The polling technique has also been used to obtain descriptive information about the actual conditions under which the members of a large group live or work. Many of these devices received especial impetus by their extensive use during World War II. For instance, propaganda, a social device for influencing the motivation of large groups, is seldom successful unless based upon a previous knowledge of the opinions and attitudes of the persons to whom it is directed.

(*See* ATTITUDES; PSYCHOLOGY, HISTORY OF: *Social Psychology*.)

Abnormal Psychology.—Originally abnormal psychology, dating from the work of J. M. Charcot in France which began about 1862, was focused upon the behaviour and motivation of insane and neurotic persons. It was the rise of psychoanalysis, more than anything else, that made abnormal psychology the field in which the nature of personality received the most attention, and that broke down the distinction between abnormal and normal psychology, merging them in what ultimately came to be called dynamic psychology (*see* above). The obsessions and compulsions of neurosis turn out to be only extreme and clear-cut forms of the prejudices and habit patterns of the normal person, and the line between the normal and the abnormal is apt to be placed simply at the point where institutional care becomes necessary for the individual who deviates persistently from the social average.

Modern abnormal psychology may be said to include clinical psychology (*see* section on *Clinical Psychology* below; *see* also ABNORMAL PSYCHOLOGY; DELUSION; HYPNOTISM; LIBIDO; PERSONALITY; PSYCHOANALYSIS).

Differential Psychology.—The study of individual mental differences, originally undertaken by Francis Galton about 1883 in his concern for inventorying the mental capacities of the British nation, developed in association with the mental tests which were devised to reveal individual differences among the members of large groups. Differential psychology may be said to complement general psychology, since the latter exhibits averages and generalities, whereas the former shows the variety and variation which occur about the averages. For the most part, differential psychology has been functional psychology, dealing with the capacities of persons to do well in the business of living, especially those capacities which can be quickly measured by psychological tests. Most of the discussion of the relative importance of nature and nurture (*see* above) in determining the character of the adult personality has taken place within the domain of differential psychology, which also provides the basis for the selective techniques of vocational and personnel psychology. The most effective tool for the determination of the dimensions of personality from the results of psychological tests is factor analysis, which reduces multiple test performances to the simplest analytical components. (*See* DIFFERENTIAL PSYCHOLOGY.)

Educational Psychology.—The oldest form of applied psychology is educational psychology. Psychology, the science that studies learning, contains the basic principles that pertain to education. Differential psychology, moreover, supplies knowledge of individual differences in aptitude and intelligence, differences that have to be taken into account if education is to be maximally effective. It was on these grounds that educational psychology got under way in the 1890s, partly under the aegis of G. S. Hall. Modern educational psychology involves the study of the principles and techniques of learning as applied to formal education or as worked out experimentally in the school situation, the study of abilities and aptitudes (especially the aptitude for learning which develops so markedly during childhood and adolescence, being related to intelligence or dependent on it) and the study of the techniques for arousing motivation. Since learning occurs only in so far as it is self-initiated by the learner, teaching consists almost entirely in stimulating motivation and in establishing conditions under which learning is most likely to occur. (*See* section on *Educational Psychology* below.)

Clinical Psychology.—Clinical psychology is the field of applied psychology that undertakes the assessment of personality and the counselling and guidance of persons who need help in their personal adjustments to living. The need for psychological guidance is great. There are child guidance centres, clinics for the behaviour disorders of children, school psychologists who aid in the adjustment of children to the requirements of schooling or of living in general, marriage clinics, psychological counsellors for adults. Thus defined, clinical psychology includes psychoanalysis and borders upon the medical counselling of psychiatrists.

(*See* section on *Clinical Psychology* below; *see* also PSYCHOANALYSIS.)

Vocational Psychology.—The study of the aptitudes, abilities and interests of both children and adults and of the means of assessing these variables by tests and interviews make up the major portion of vocational psychology, which is sometimes called personnel psychology when it is applied to the selection of employees for an industry or business or of men for special services in an army. The task of the vocational psychologist is to evaluate present aptitude and to predict success in the acquisition of skills for some new activity or work. The wide use of personnel selection in World War II increased the use of vocational psychology in the educational and industrial worlds.

Industrial Psychology.—Besides being of use in the selection of personnel for different jobs, psychology is employed in industry to determine the conditions for maximal efficiency in work. Industrial psychology studies the conditions which produce fatigue and monotony, and the most efficient ways to reduce fatigue by the introduction of rest periods, the effect of variety in work, the most efficient work habits, the ways to avoid having accidents.

Industrial psychology also considers the effects on work of temperature, climate, high altitude in aeroplanes, alcohol, tobacco, stimulants and sleep. It is concerned with the design of machines and other instruments for their most efficient use by human operators. A good machine must take into account both the perceptual and motor capacities of the man who uses it. Industry has also become interested in the training of operators, and certain U.S. results show that democratic leadership provided by a foreman produces, because of its motivational value, more rapid learning than an authoritarian attitude. Industrial psychology is also concerned with the problems of labour morale and the securing of efficient social relations between labour and management. (*See* FATIGUE; INDUSTRIAL PSYCHOLOGY.)

Professional Psychologies.—The growth of the applications of psychology after about 1920 was so great that it became necessary to distinguish between scientific psychology and professional psychology. The professional psychologist utilizes the findings of psychological research to render service of one kind or another. He may also engage in his own research, but the line between the investigation of general principles and the rendering of particular service is fairly clear. The foregoing paragraphs mention educational psychology, clinical psychology, psychoanalysis, vocational psychology, personnel psychology and industrial psychology as kinds of professional or applied psychology (*q.v.*). Closely related to clinical and industrial psychology are consulting psychology and business psychology. There is also legal psychology which deals with the many aspects of human nature affecting the operation of law, including the reliability of testimony and the detection of lying. The wide

application of psychology to military problems in World War II led to the recognition of a military psychology, in which all the psychological problems of training, of aptitude selection, of efficiency in work, of motivation and morale, of personal adjustment to normal living and to continued emotional strain are worked over in the military context and brought into the service of the army, navy and air forces.

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CLINICAL PSYCHOLOGY

Psychology is the science of human behaviour. Clinical psychology, an applied branch of that science, may be defined as the science, technique and art which deals with the application of psychological principles to the adjustment problems of human beings. Such a definition has several implications for clinical psychology in general, and for clinical methods in particular. It implies: (1) that clinical psychology is concerned with the individual case; (2) that the individual has some problem or difficulty which is disturbing either to himself or to others around him; (3) that both diagnostic and remedial measures are employed in dealing with these human problems; and (4) that clinical psychology is an art as well as a science and technology. It is these aspects which give clinical psychology its uniqueness.

The terms "clinic" and "clinical" are in some respects unfortunate and misleading. They were first used by Lightner Witmer, who in 1896 organized what he called a psychological clinic at the University of Pennsylvania. They are terms borrowed from medicine, where they are used correctly in accord with their Greek origin—meaning bedside—especially the bedside of the sick, or a class taught medicine or surgery by the treatment of patients in the presence of the students. The psychological usage, of course, has no reference either to a bed or the sick or to instruction. A psychological clinic is a place where children and adults go to get some help from a psychologist in the solution of some of their mental and behaviour problems.

The Clinical Problems.—Many attempts have been made to classify the behaviour problems which are seen in the clinic; none with great success. One common method of classification is to divide them into two categories—conduct problems and personality problems. Conduct problems are those which interfere with the rights and behaviour of other people, while personality problems are those which interfere with the personal adjustment of the individual. The former in their extreme manifestations may lead to delinquency and criminal activity, while the latter in an exaggerated form may lead to neuroses or psychopathy. While such classifications may be useful for descriptive or statistical purposes, it is clear that they have little practical or clinical value. Whether stealing, for example, is classified into one or the other depends upon the motivation of the act.

Some of the common problems for which children are referred for clinical diagnosis and treatment were tabulated by Luton Ackerson in a study of the records of 5,000 consecutive cases seen at the Illinois Institute for Juvenile Research. These are listed in the table. The per cent column indicates the number of cases in which a given problem was noted in the record by the psychiatrist, social worker or psychologist who studied the child.

It will be noted from the table that most of the problems seen in the clinic are those which might be described as conduct or personality disorders. There are, however, many other types of clinical problems which the psychologist is expected to handle either alone or in co-operation with a physician or psychiatrist. For example, special methods and techniques are required in dealing with the many difficult social and psychological problems of the blind or partially blind, the deaf and hard of hearing, the physically and mentally handicapped, the spastic, the epileptic, the postencephalitic, the bright child retarded in school, the child with severe reading difficulty, the person with speech difficulties and the person who has difficulty in making an adequate vocational adjustment. All of these require special, clinical methods and techniques which the psychologist is equipped to employ.

Common Problems for which Children Are Referred for Clinical Diagnosis *

Problems	Per Cent
Nervousness, restlessness, irritable temperament	41
Disobedience, incorrigibility, stubbornness, contrariness, defiant attitude	40
Retardation in school	37
Question of feeblemindedness or inadequate intelligence	31
Temper display, tantrums, irritable temperament	31
Dull, slow manner, listlessness, lack of initiative or ambition	30
Stealing	26
Immature childish manner or judgments, impaired judgment	25
Fighting, quarrelsomeness, violence and threatening violence	25
Enuresis or bedwetting beyond third birthday	25
Lying, marked untruthfulness	24
Advice replacement, commitment or institutionalization	24
Poor work in school	23
Crying spells, crying easily	22
Truancy from school	19
Masturbation	19
Truancy from home	18
Sensitiveness or worrisomeness, (general) sensitiveness or worry over some specific fact or episode	18
Bashfulness, shyness	17

*Based on records, 5,000 consecutive cases seen at the Illinois Institute for Juvenile Research.

The Nature and Motivation of Behaviour Reactions.—In order to gain a clear understanding of the methods and procedures used in dealing with the behaviour deviations which come to a psychological clinic, it is necessary to present, first, a brief statement concerning the development of normal behaviour, since the basic mechanisms involved in normal and abnormal behaviour are essentially the same.

One of the principles which has been fairly generally accepted by psychologists is that all behaviour is a form of adjustment whether it be socially acceptable, such as most of man's behaviour is, or socially unacceptable, as are most of the behaviour patterns mentioned in the table. Behaviour is what an organism does in response to some stimulus or complex of stimuli (often called a situation) which acts upon it. Lying, stealing, truancy, quarrelsomeness, disobedience, restlessness, stubbornness, violence, enuresis, masturbation, bashfulness and the many other so-called problems are simply names given to certain ways an organism meets and adjusts to a situation.

A second principle, closely associated with the first, is that most of the behaviour of human beings is learned; that is, it results from the repeated action and reaction between the individual and certain environmental forces. The physiological and psychological processes in this type of learning are the same as those involved in learning to swim or learning to read. The motivation and, of course, the external forces are different. This principle applies to socially unacceptable behaviour just as directly as it does to socially acceptable behaviour; *i.e.*, an individual learns to be honest just as he learns to be dishonest; he learns to lie and cheat and steal just as he learns to be upright and trustworthy; he learns to be unstable as well as he learns to be stable; he learns to be stubborn and disobedient just as he learns to be flexible and obedient.

A third postulate is that both acceptable and unacceptable types of behaviour can be learned only through practice; *i.e.*, by reacting to situations which call forth a certain response. (This is often called the reaction hypothesis.) In other words,

if an individual is to be honest, he must at some time in his experience (usually in early life) have had an opportunity to practice honesty. If an individual is stubborn and resistant, he must at some time or other have reacted to some situation which called forth a reaction called stubbornness, and so with any other behaviour pattern. This reaction hypothesis is one of the well-established hypotheses concerned with the development of human behaviour.

A fourth principle is that the practice or constant repetition of any behaviour reaction, or behaviour pattern, soon develops into what has been called habit; *i.e.*, a form of behaviour which tends to repeat itself when the appropriate stimulus or situation is presented. This principle is well recognized in the development of motor forms of behaviour, such as playing the piano, playing golf, running a machine, typewriting, etc. It is not so well recognized, but nevertheless just as important, in the development of the more complex ideational and emotional forms of behaviour. Such reactions as the development of an equation or the solution of an astronomical problem are, together with a certain native sagacity, largely the result of practice in previous forms of behaviour. So it is with emotional and attitudinal reactions, which develop as the result of practice or often because of the lack of it. An individual's concept of himself, his concept of his role in various forms of social behaviour, the feelings and attitudes he has toward himself and others result from the constant repetition of these same ways of thinking, feeling and acting at an earlier stage in life, usually in childhood or early adolescence. Through this constant repetition these forms of behaviour become habits; *i.e.*, they become fixed or preferred ways of acting and thus dominate, control and direct later activity. They constitute what is often described as the personality structure.

There are two or three corollaries to this fourth principle which must be mentioned. One of the most important of these may be stated as follows: Habits which are necessary and normal at one stage of life if persisted in become quite abnormal at a later stage. For example, it is normal and natural for a child to form habits of love and affection toward his mother. If, however, these same childhood habits of love and attachment persist without some modification into young manhood and adulthood, they become abnormal and bring the individual into conflict with the mores of his society.

A second corollary is that the lack of practice may be just as significant in the development of nonadaptive or abnormal behaviour as the actual practice of a behaviour pattern. For example, if a growing individual has never had an opportunity to react to situations which call forth honesty, kindness to his associates, a friendly manner, a tolerant attitude, a flexible nature, confidence and trust in people, a happy cheerful disposition and all the other behaviour patterns, which in our culture constitute what is described as a normal well-adjusted person, to that extent he will exhibit deviate or abnormal behaviour.

A third corollary of this fourth principle of adjustment, which must be briefly mentioned in order to understand the development of abnormal reactions, is that much of man's so-called unconscious behaviour (*i.e.*, behaviour of which he is unaware) is also subject to conditioning or habit formation. This was well demonstrated by the classical experimental work of Roderick Menzies. This experimenter was able to show that such delicate forms of response as the dilation and constriction of the blood vessels could be conditioned. By presenting first the original stimulus and associating with it some other stimulus such as a light, a bell, a spoken word or some physical contact, he was able to develop a substitute response in much the same manner as Pavlov, the Russian physiologist, was able to condition the flow of saliva in the dog.

The significance of this experiment for the understanding of the development of abnormal behaviour, such as is frequently seen in clinical cases, is quite obvious. The experiment suggests that in many abnormal subjects (*e.g.*, cases of hysteria and neurasthenia) the appearance of such symptoms as nausea, nervous indigestion and fainting spells may be attributed to conditioning; *i.e.*, the formation of habitual forms of response to new stimuli. In more technical language it means that the smooth or nonvoluntary muscles of the body can be conditioned in the same way as the striped or voluntary muscles.

It is necessary to present briefly a fifth principle in order to understand the motivation of either normal or deviate behaviour. This principle, first developed by R. S. Woodworth, and later enlarged upon by Gordon W. Allport, has been called the principle of functional autonomy. It may be stated simply as follows: by the continued repetition of an act certain neural mechanisms often called bonds or habits are established within the organism, which in turn become themselves motivating forces, or what Woodworth called drives. Thus, the organism becomes self-propulsive or autonomous and the postulation of such questionable concepts as instincts becomes unnecessary.

According to the theory of behaviour presented here, the following stages in the development of behaviour may be recognized:

1. The arousal of some physiological need or desire, such as hunger, thirst, etc., within the organism.
2. Resulting tension or conflict from the physiological activity.
3. Trial-and-error activity to resolve the tension.
4. Satisfactory socially accepted resolution of the tension.
5. The establishment of habits of response resulting from the successful and satisfying solution of the conflict.
6. These habits become drives or motivating forces and tend to repeat themselves.

Certain types of abnormal or deviate behaviour may develop at either stage 4 or 5. If, because of any one of a large number of possibilities which may arise in one's experience, no successful or satisfying solution results from the trial-and-error activity (*i.e.*, if conflict and frustration persist), the resulting behaviour will be "abnormal." Or it is possible that the behaviour growing out of the activity may be accepted in one social group or gang and not accepted by the dominant social group of which he is a part, in which case the behaviour likewise becomes abnormal or deviate.

Clinical Procedures.—We have dwelt at some length on the motivation and nature of behaviour reactions for two reasons: First, it gives an understanding of how many of the problems which come to the clinic develop and, second, it has a direct bearing on the methods of diagnosis and treatment. It is clear from the previous discussion that no adequate understanding of any behaviour pattern can be achieved without an investigation of at least four determinants of human experience: (1) The physical organism itself must be carefully examined; (2) the environmental forces which have acted upon the organism, and to which it has either consciously or unconsciously reacted must be thoroughly investigated (in other words, a detailed case history must be secured); (3) the individual's own feelings and attitudes toward the alleged problem, as well as his sense of values, must be studied; and (4) his abilities and aptitudes for growth and change must be appraised.

Finally, the results of these examinations, investigations and appraisals must be integrated and woven into a single picture of a growing, dynamic, living human being so that methods of treatment can be instituted. These various aspects of clinical procedure will be discussed in order.

The Physical Examination.—Every individual coming to a psychological clinic or being treated by the psychologist has, or should have had, a careful physical examination by a competent physician. The experienced psychologist holds to this rule rather rigidly even though 70% or 80% of the cases thus examined come back with physical findings negative or at most with minor physical defects. It is important in dealing with any clinical problem that the psychologist make sure either that he is not working with a behaviour disorder which is the result of some physical defect, or that if he is working with such a case, he do so in close co-operation with a medically trained person. A close working relationship with a physician is necessary for two reasons: It satisfies parents and clients who often are convinced that physical illness is responsible for the disorder, and it protects the psychologist from being accused of neglecting the physical factors.

The Case History.—In general the most important single instrument in the clinical examination is the case history. It is only through a case history that the psychologist can gain an understanding of the sequence of events which has produced the behaviour for which the individual comes or is referred to a clinic. It is only through a knowledge of the environmental forces, in their chronological sequence, which have acted upon the individual and to which he has reacted, that the psychologist can gain insight into the behaviour and consequently make a reliable diagnosis. These environmental field forces include not only those which constitute the cultural and community pattern, but also the subtle interactions in the immediate family group to which the individual has been exposed. Especially important are the forces to which the individual has reacted in the early years of his life, since these reactions form the habits of thinking, acting and feeling which become selective and contribute heavily to the determination of his later behaviour. In many clinical cases a detailed history alone is all that is needed to establish an adequate diagnosis and suggest methods of treatment.

The historical data required for the understanding of any given case will depend, to some extent at least, upon the problem involved. For example, it is of little value to secure a detailed report of the mental and physical welfare of the paternal and maternal grandparents or the aunts and uncles of a young child referred for nail-biting, thumb-sucking or enuresis. On the other hand, such information may be very necessary and pertinent if the child were referred because of mental retardation or some kind of seizure.

A number of detailed outlines for taking or recording the case history have been published. A useful one is contained in L. F. Shaffer's book, *The Psychology of Adjustment* ([under the editorship of Leonard Carmichael] Houghton Mifflin; N.Y., 1936). The following broad categories with a few of the details indicate some of the important lines of inquiry usually followed in these outlines:

Skeleton for Case History

I. Identifying data—name, age, sex, nationality, religion, etc.
II. Statement of problem
III. Congenital and physical factors determining behaviour
IV. Environmental forces or situations
  A. In the home:
    1. Father
    2. Mother
    3. Siblings
    4. Physical conditions in the home
    5. Method of control and supervision
  B. Community and cultural factors
  C. Educational and school experience
  D. Occupational experiences
  E. Recreational experiences
V. Reactions to the congenital, physiological and environmental forces
  A. Reactions in early childhood
  B. Reaction in later childhood and adolescence
VI. Sources of Information

Interview with the Client.—The interview is one of the clinician's most important instruments. It is on the interview that he must rely for much of the information necessary for a reliable diagnosis and it is through the interview that he must carry on much of his treatment. The art of interviewing is, therefore, carefully cultivated and refined by the experienced clinician.

There are so many circumstances which might alter the technique used in the interview that it is hazardous to attempt any generalization; nevertheless, there are a few rules which may be held inviolate. In clinical practice, most of these become so much a part of the clinician's technique and manner that he uses them unconsciously.

(1) The skilful clinician has a genuine interest in the welfare of his client. He has a warmth of feeling and understanding which is at once recognized as real and sincere and which induces an acceptance and confidence on the part of the subject.

(2) He is a good listener and is willing to permit the client full and free expression without injecting his own ideas, opinions or theories. This does not mean that he is a passive robot. The good listener is one who by his apparent passive manner still convinces the subject that he is genuinely interested in his problem.

(3) He is a keen observer of behaviour and is skilled in the art of interpreting expressive movements, verbal responses and changes of expression. He is able to recognize these as cues to the subject's ways of thinking, feeling and acting. While he is keen he is at the same time cautious. He recognizes that in the absence of objective data it is easy to make serious errors of interpretation.

(4) He has insight into the motivation of his own behaviour. He is aware of his limitations as well as his strengths and is able to compensate for them in some socially acceptable way.

Appraisal of Aptitudes and Abilities.—The appraisal of aptitudes and abilities by the use of psychological tests is such an important aspect of clinical methods that it was formerly frequently regarded as the only technique a clinical psychologist should use. Clinical psychologists later came to rely more and more on other techniques, such as those already described—the case history and the interview; nevertheless, psychological testing remained an important aspect of clinical methods.

Psychologists and other scientists through their constant and persistent research over a period of years have made available a large number of instruments for the appraisal of human behaviour. There are many manuals and textbooks describing these instruments, their use and interpretation. The reader is referred particularly to those by Edward B. Greene, Oscar K. Buros, R. Pintner, L. M. Terman and Maud A. Merrill, and David Wechsler.

Psychological tests are available for the study and analysis of a wide range of human problems, covering the age span from infancy to adulthood. In fact, these instruments had become so numerous by mid-20th century that mastery of the technique of administration and interpretation of all of them had become quite impossible. Usually the clinician has specialized either in the analysis of some particular type of problem, such as delinquency, marriage counselling, educational and vocational guidance, or in the problems of some particular age group, such as the preschool child, the adolescent or the problems of the aged.

In general, the psychological tests and inventories available for the appraisal of human behaviour can be classified into the following categories:

I. Tests of general intelligence (often described as tests of scholastic aptitude)
  A. Individual tests (those which can be given only to a single individual at one time)
    1. Verbal; *e.g.*, revised Binet tests
    2. Nonverbal, sometimes called performance tests
  B. Group tests (can be given to a group of individuals at the same time)
    1. For the primary grades
    2. For the intermediate grades
    3. For high school grades
    4. For college
II. Tests of school or academic achievement, sometimes called subject-matter tests. Tests are available for all subjects at all levels from the kindergarten to college
III. Vocational achievement tests and tests of special aptitudes. Tests are available for the appraisal of mechanical aptitude, clerical skill, speed of typing, motor agility, space perception, musical aptitude and appreciation, skill in the fundamentals of visual art, etc.
IV. Vocational interest inventories. These are used to determine the relative strength of an individual's interest in a profession, trade or occupation
V. Character and personality tests. These tests attempt to give a quantitative statement of the degree to which an individual deviates from the normal or average in some of the fundamental personality characteristics, such as neurotic tendencies, introversion-extroversion, sociability, ascendancy-submission, personal and social adjustment and other similar traits
VI. Rating and attitude scales. These are techniques for determining how a person feels about some controversial issue, such as communism, religion, birth control, etc., or are designed to get an appraisal of how a person rates among his friends and acquaintances on some particular trait, such as honesty or friendliness
VII. Tests of special disabilities, used to determine the degree of brain damage, degree of deterioration resulting from some disease, or some motor or sensory defect

The tests in some of these categories are much more reliable

and valid than those in the others. In general, the educational tests have the highest degree of predictability for the function for which they were constructed. Then follow the intelligence tests and the tests of special aptitudes and abilities. Character and personality tests have not proved to be so accurate in predicting the real situation.

Although in the clinical examination the most important purpose of the psychological test is the quantitative evaluation of some aspect of behaviour, nevertheless the psychologist also makes and records observations and impressions of the client during the testing session. Often these observations contribute more to the understanding of his behaviour than does the quantitative rating. In one sense, the testing situation may be regarded as a controlled situation in which the individual's behaviour is being observed.

Methods of Treatment.—*Some Theoretical Considerations.*—The term "treatment" as it is used in clinical psychology is in many respects an unfortunate one because it fails to reveal to the reader the nature of the procedure involved. In fact the term actually conceals the essential characteristics of the process in that it tends to imply that the treatment is something which can be imposed from without. "Therapy" has similar objections. These terms, like "clinical," were borrowed from medicine and have, unfortunately, brought with them some of the same meaning they had in that discipline.

The term "re-education," or even "education," might more nearly describe the nature of the process than either "treatment" or "psychotherapy." The essential nature of psychological treatment is the same as that involved in any other educative process. The chief difference between the education by the clinic, on one hand, and the education of the home, the community or the school, on the other, is that in the former it is necessary to devise techniques and schemes to break down old habits as well as to establish new ones, while in the latter the teacher, parent or guardian is concerned for the most part in building up new ones only. Even this distinction does not always hold. Often the good parent or the good teacher is a good clinician, employing with skill and accuracy all the essential methods of treatment employed by the psychologist. Frequently, it is the chief task of a parent or teacher to re-educate as well as educate.

Treatment involves a change in behaviour. The task of the clinician is so to arrange events and situations as to bring about this change. If the child has been brought to the clinic because he has been truanting from home and school, then the task of the clinician is to change this behaviour pattern. If a client comes because he has a number of unexplained fears and anxieties, the task of the clinician is to help him get rid of them. Treatment of any problem involves either the acquisition of a new behaviour pattern, or discarding an old one, or both.

The method of developing new patterns of behaviour is a problem to which psychologists have given a great deal of attention. On one point there seems to be general agreement; namely, that behaviour can be developed only through some kind of a reaction to a situation or a stimulus. This has already been referred to as the reaction hypothesis. It is stated by Arthur I. Gates in *Psychology for Students of Education* (Macmillan) as follows: "All forms of human behavior, whether muscular activities, such as those of grasping, striking, or speaking; glandular activities such as the secretion of tears, saliva or gastric juice; or mental activities, such as perceiving, imaging, remembering, thinking or reasoning are reactions to definite stimulation."

The hypothesis has two implications for so-called treatment: (1) If a behaviour pattern is to be changed, some stimulus or situation must be constructed to motivate the change; and (2) the subject must be given some opportunity to practise or exercise the behaviour in the making. These are essential elements in the acquisition of any behaviour pattern. If this hypothesis is accepted, then no treatment can be effective without having inherent in it these two factors.

Many techniques and methods have been used by psychiatrists, psychologists, teachers, ministers and priests in their attempts to change behaviour patterns, and practically all methods from Coué̇ism to psychoanalysis have some claim to success, in terms of the individual case. The lame have walked and the blind have seen. Little carefully controlled experimental work on the relative value of different methods of therapy, however, has been reported. Thoroughgoing and systematic accounts of various treatment techniques have been reported by Carl R. Rogers, Leo Kanner and J. McV. Hunt.

In general, these treatment processes may be classified into two large categories: those involving actual change of the environmental situation, and those involving change of attitude toward the environment on the part of the client. The difference between these two is more apparent than real. As far as the psychological process which goes on within the individual, they amount to the same thing; *i.e.*, they modify the stimuli which play upon the individual and thus modify his behaviour. These two methods will be discussed in order.

Modifying the Environmental Forces.—Psychologists have used many techniques to modify the environmental forces which play upon the individual: (1) If the situation demands it the client may be physically removed from one situation and placed in another; *e.g.*, moved from his home and placed in a foster home or institution. Thus, he is forced to react to a completely new set of environmental situations with the expectation that by so doing the desired changes in behaviour will result. (2) The field forces which act upon the individual and to which he reacts may be changed by changing the attitude of the parents, siblings, teachers and others toward him, and thus a change in behaviour may result. (3) A change in the environmental forces may be brought about by providing more adequate recreation facilities and play activity. The client may be provided with membership in some club or given a library card, or sent to a camp, or, if the individual is older, he may be advised to take a vacation.

The methods of modifying the field forces can be almost indefinitely multiplied, depending upon the results of the diagnostic procedures. The three methods mentioned are those commonly used in clinical practice. The value of this type of treatment will depend upon the skill and ingenuity of the therapist in providing situations which the client accepts, for it is only as he accepts them that they will have any re-educational value.

Modifying the Client's Attitude.—In many instances the treatment cannot be carried out through the modification of the environmental forces alone. Often it is necessary to effect a change in the individual's attitudes toward himself, toward his associates and, perhaps, toward society in general. Frequently, a complete reorientation of his concept of himself or his concept of the relationship between himself and his associates or the relationship between himself and his immediate family is necessary. During the process of his development, he has accumulated a number of faulty habits of thinking and feeling and acting, and a complete modification of his philosophy of life is the only method by which his behaviour can be altered.

This modification of behaviour is always difficult and prolonged and often it is impossible. If the client has developed fixed ways of feeling and acting, then he is likely to assume that same role toward the therapist and resent any intrusion into his private affairs. Or he may attempt to prove to the therapist that his way of thinking and feeling is the only correct one and everyone else should accept it.

Many techniques have been devised and developed in the attempt to modify the individual's ways of thinking, feeling and acting. One of the best known is psychoanalysis (*q.v.*). This is an elaborate theoretical psychological system, a discussion of which does not belong here. As a technique of therapy, it involves a detailed report to the analyst (and under his direction) of the past experiences of the individual and especially the experiences of early childhood. He is expected to report his relation to the mother, the father, the siblings, his associates and the influence of these upon his own development. This report, which may take several months, is interpreted to the client in accordance with psychoanalytic theory.

The assumption in this method of therapy is that once an individual has an intellectual understanding of all the forces that

make him act the way he does he will change his behaviour to more socially acceptable patterns.

Another technique for modifying human behaviour is that developed by Carl Rogers. This has been called the nondirective or client-centred method of counselling and psychotherapy. The chief difference between this and the older psychoanalytic approaches from which it is partially derived is that the focus of attention in the therapeutic relationship is on the development and integration of the individual into a more consistent personality during the counselling process and not on an analysis of his problems through a probing into his past history. It is assumed in this procedure that the client is capable of effecting this integration if he is given an opportunity to relate and consider his experience as well as his own thinking and feelings.

Clinical Methods in Industry.—*The Selection of Personnel.*—The clinical approach to understanding of human motivation and personality structure has been increasingly used in the selection of personnel in industry, especially in the selection of top management. At the supervisory level the older approach (namely, that of making selections on the basis of a battery of tests) proved relatively sterile. It was assumed that the more elaborate and more time-consuming method of the clinical approach would prove more successful. This assumption had not, however, been experimentally demonstrated by the mid-20th century.

The methods used in the clinical approach in industry are essentially the same as those in use in counselling centres, guidance laboratories and clinics already described. In industry, however, the orientation and the problems to be solved are quite different. The clinician is not, as a rule, so much concerned with the problems of the individual as such as he is with predicting probable success in a given position. The methods are usually used in the selection of men for supervisory positions. Some of the questions the clinician must be prepared to answer are such as these:

Does the man think accurately and comprehensively?
Is he able to look ahead and make long-range plans?
Is he able to take orders without offense and give them with composure?
Can he lead others to accept his ideas without force or regimentation?
Can he give criticism frankly, honestly and objectively?

In selecting a man for a supervisory position, it is necessary to be able to answer these and many other questions dealing with the intellectual, emotional and social characteristics of the client before making any prediction about the man's success in a given position.

The information which enables the clinician to attempt answers to these questions and make a final recommendation to management is not secured from objective measurements alone. The amount of error in prediction is considerably reduced by following the usual clinical procedure of integrating the test findings with information gathered from a personal history and an interview with the candidate.

The Developmental Interview and Upgrading.—The therapeutic procedure, or developmental interview as it is called in some organizations, follows the same line as that used in the usual clinical situation, except that as a rule the ultimate purpose of the interview is to increase the man's efficiency in a given position and prepare him for upgrading rather than the development of his personality as an individual, although the two possible objectives are by no means incompatible. Frequently, greater efficiency on the job is best achieved and preparation for upgrading is best accomplished by conducting the developmental interview with the purpose of helping the client meet and solve some of his own personal problems.

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EDUCATIONAL PSYCHOLOGY

Educational psychology is that branch of psychology which deals with applications of the subject to the work of the schools or other educational agencies. In large part it utilizes material in related branches such as child development and mental measurement, but includes much distinctive matter of its own, as on the psychology of reading and arithmetic, and the social psychology of classroom relationships.

Co-ordination of Development and Education.—Educational psychology may be thought of as concerned, first of all, with proper co-ordination of educational programs with processes of psychological development. At what age should a child start to school? There is much evidence that many children can profitably begin nursery school as young as two or three. There they learn to get along with other children, have more resources for healthy play than most homes afford and are under the supervision of young women especially trained in understanding of young children and their problems. When should the usual more formal schooling begin? The average child of four is quite evidently too immature to begin a subject such as reading; continuing close inspection of the printed page is a strain on childish eyes (which tend to be farsighted), vocabulary is too limited and capacity to learn visual symbols is as yet inadequate. There is much to suggest that the usual age of six is the best age to begin reading; but there is also evidence that the less able children may well delay reading, meanwhile developing more simple skills and direct learning through field trips and activities in the school. Is 16 too young to enter college, or 20 older than desirable? When should young men and women finish their full-time schooling and begin their life careers? Do adults present special problems as regards interests, ways of learning or personality of which adult education should take account? All these are important questions which became better understood as a result of research in the total field of educational psychology.

Investigations of child development bear not only on desirable ages for beginning or concluding various segments of the educational program, but also on desirable features in the program at different ages. Thus, boys' reading interests are different at 12 and 17—centred on adventure and mechanics at the first age, but beginning to show romantic leanings at the latter. This romantic interest is reached earlier by girls, as would be expected because of their earlier physical maturing. A type of poetry which is not understood at one age and strongly disliked at another may be a delight at yet a third stage of development. Only if the reading matter which a school (or library or home) offers young people at each age is suitable to their stages of development will they profit from that material or enjoy it.

Since the modern school is concerned not simply with the learning of formal school subjects but more broadly with total development, evidence regarding the social psychology of childhood and adolescence is also relevant for educational planning. Numerous investigations of childhood companionships have shown stages of growth from the superficial associations of young children to gang groups all of the same sex in later childhood, and the "crowd" of both sexes in adolescence. School activities appropriate to each age can do much to foster healthy social growth.

Application of Research on Learning to Education.—Gradually, the numerous investigations of the learning process made clearer the problems of teaching and helping children to progress more readily. In fact, evidence accumulated to show that (contrary to common belief) children in good modern schools were progressing more rapidly and learning more effectively than pupils of 50 or 100 years before. Thus, it became known that reading is a process of recognizing whole words or phrases much as one recognizes a face, rather than knowing a word as composed of certain letters. Children in modern schools often start to read by learning words rather than the alphabet. Likewise,

children learn most adequately when the learning is related to projects or undertakings which are part of their everyday out-of-school life and closely related to childhood concerns. Thus, one investigation showed that when a class read about what could be done to deal with a local epidemic that caused the illness of some of its members, made measurements and figured costs for screening to prevent fly-borne transmission of the disease and wrote reports about the epidemic which they proudly presented in neighbourhood meetings, they not only learned more about health problems but also read more widely, became more accurate in arithmetic calculations and wrote more carefully than pupils in other classes who had simply had the conventional work in hygiene, reading, arithmetic and composition.

Clever but simple experiments have indicated that praise is more effective than criticism in stimulating learning, that effort falters when no progress seems to be made, that goals which are vague or so difficult as to seem unlikely of accomplishment make the learner fumble and seek other interests. Other experiments have shown that much if not most of the more miscellaneous information learned in school (facts of history or vocabulary of a foreign language) are soon forgotten, but that information and skills which are used, and larger understandings, appreciations and attitudes, are retained much longer.

Experimentation on "transfer of training," or the extent to which a pupil's study of one subject carries over to affect his work on another subject or in another field, has important bearings on both teaching and the curriculum. Thus, study of Latin appears not to "train the mind" in the sense that from long wrestling with Latin syntax one develops stronger "mental muscles" and in consequence can deal more effectively with history or bookkeeping or business problems. Rather, training is relatively specific. A pupil who has studied Latin may, a little more readily than one who has not, infer the meaning of unfamiliar English words of Latin derivation; but he may not do better with English terms derived from Arabic or German. However, it is possible to "train for transfer." Thus, by pointing out Latin words having English derivatives, and developing skill in analyzing English words for their roots and in use of the dictionary, a Latin teacher may increase the help his subject gives in English word study. And there is evidence that by emphasis on methods of wide applicability, a skilful teacher of almost any subject can make it of wider usefulness. Journalism or bookkeeping, as well as Latin or geometry, may thus increase English vocabulary or habits of accuracy.

Educational psychology is also concerned with tests and measurements. Numerous tests of general ability are available to aid in determining whether a given child is bright or dull for his age. Tests in the school subjects show how he stands in reading or arithmetic or algebra or foreign language, and diagnostic tests analyze a pupil's difficulties. Other tests deal also with his attitudes and beliefs, his tendency to form hasty judgments or react excessively to what is seen or heard, his honesty or cooperativeness. "Sociometric" tests show his social status in a group. These various measurements guide teachers in their work. They may also help pupils by showing what they are to do, where they stand, what their difficulties are and how they are progressing.

Individual Differences; the Individual.—Educational psychology also concerns itself with individual differences in rate and nature of development and in rate and method of learning. Differences in physical development are great, and may present psychological problems. Thus, in a given group of 15-year-old boys, one may weigh 150 lb. but another only 80 lb. One may still be a prepubertal boy but another may have reached puberty three years before and show both the maturity of physique and the interest in the other sex natural to a high school senior. These differences present problems in planning sports so that some boys will not be grossly outclassed physically by others. They should be also taken into account in planning social activities; a boy who has not yet reached puberty will be out of place in a group of youngsters for whom companionship with girls is the new-found consuming social interest.

Differences in mental traits are also great. In a given school a few 10-year-old children may be no brighter than the average 6-year-old, whereas an occasional superior child may be as bright as average youngsters of 14. Some fifth-grade children may read four times as fast as others; some complete a lesson in one-fourth the time others need. How best to advance pupils, group them or make work in each class adjustable to take account of such differences is a major education problem.

Educational psychology is concerned not only with such differences in various traits, but also with their correlations—the extent, for instance, to which pupils who learn quickly remember well. In general, these correlations are positive; thus, the common belief that the rapid learner forgets more quickly is not true. In general, bright children also tend to develop more rapidly and at a given age to be larger and socially more mature than less intelligent youngsters; popular concepts of the intellectually superior child as physically puny and socially maladjusted are incorrect. It is therefore feasible for many bright children to progress through school at a faster than average pace.

The individual is not simply a collection of traits, however. Modern research has emphasized the fact that he is an integrated, dynamic personality. His failure in algebra may be because of mediocre intelligence. But it may be, instead, a result of poor grade school teaching of arithmetic, and remediable upon adequate diagnosis. It may be a by-product of acute emotional distress caused by lack of status with schoolmates, or conflict in the home. Educational psychology seeks especially to penetrate through the more general facts about human development and learning, and reach the major underlying influences which make each individual what he is. Understanding of these is most important if any educational program is to attain maximal effectiveness.

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LEGAL PSYCHOLOGY

Psychology deals with the prediction and control of behaviour, and the law is concerned with the regulation of conduct. These two objectives obviously have much in common, and the field of legal psychology explores this common ground with a view to reducing errors in testimony and preventing crime through better understanding of its causation.

Psychological Sources of Error in Testimony.—Even a straightforward witness may make mistakes. Some of these may be a result of failure to perceive the original event correctly. Typical instances would be: nearsightedness or colour blindness; adaptation of the eye, as when going into a dimly lighted room from the sunlight outside and consequently failing to observe an individual or an obstacle; judgment of the length of a time interval as influenced by what else the witness was doing in that interval. Certain types of stimuli such as loud sounds, unusual events or large or moving objects secure a higher degree of attention and hence will be reported more accurately.

Memory.—Further error may be the result of lapses of memory in the period between the event and the testimony. Something observed only once would be less readily recalled than something noted repeatedly. Emotions are disrupting experiences and persons involved emotionally in an accident or a fight would be more apt to forget details than would a dispassionate bystander. Memory is adversely affected by disturbances after the observation. A person who is knocked unconscious could not be expected to give a good account of events right up to the moment when he was hit. Recognition is a special phase of memory and mistakes are common when the new object contains some elements like those of the earlier one and those common elements suffice to give an impression of familiarity. In identifying suspects, false recognition may be minimized by having the witness select the

suspect from several possibilities rather than responding categorically to a single suspect.

Suggestion.—When securing testimony by questioning a witness, there is a danger of obtaining incorrect answers through the medium of suggestion; that is, planting an idea which the witness accepts. The examiner may give suggestions unintentionally in accordance with his own theory of what happened. The form of the question also has some bearing on its suggestiveness. Leading questions may be ruled out in the trial, but nevertheless, if they are asked at all, the suggestion may influence the witness and also the jury.

Some of the foregoing sources of error in testimony have been recognized by the courts and precedents have been established. Others are obvious to the psychologist but have not appeared as yet in actual court procedure.

Psychological Techniques for Crime Detection.—The term "lie detector" is unfortunate, because it implies a certainty which is unwarranted. There is no more a lie detector than there is an appendicitis detector or a tuberculosis detector. A physician notes symptoms such as body temperature, pulse, breathing rate and blood count and on the basis of these symptoms makes a diagnosis. By the same token the psychologist notes certain aspects of breathing, blood pressure and electrical resistance of the skin while a suspect is being questioned, and, from various subtle symptoms in the graphic record, diagnoses guilt and falsehood. Several techniques are employed simultaneously, but in the following discussion they will be treated separately.

Blood Pressure.—Probably the most successful indicator of deception is the systolic blood pressure. A continuous record which is a function of the systolic pressure may be obtained by a pneumatic step-down device connecting a rubber cuff placed around the upper arm with a metal bellows and recording pen writing on a moving paper tape. The graphic record shows a little wave for each pulse beat, and if the blood pressure increases, the crests of these waves reach a different level. The record is taken continuously during oral examination of the suspect. This examination must include control questions on which the suspect will undoubtedly tell the truth. It is also well to phrase the questions so as to elicit "yes" or "no" answers because the muscular work of talking introduces irregularities into the record which complicate the interpretation. After each question there is usually a slight rise in blood pressure for a few seconds. If there is an emotional disturbance from telling a lie, this rise in blood pressure is apt to be a little greater and a little longer. Diagnosis is based on comparison of these changes on crucial questions with those on control questions.

Breathing.—A graphic record of breathing may be obtained by placing about the chest a device which operates pneumatically and causes a pen to trace on the moving paper tape a wavy line corresponding to the inspiration and expiration. The expert generally interprets this record qualitatively in terms of changes in rate or depth. A more detailed analysis may be made by computing the ratio between inspiration and expiration time for each breath. If the ratio after the suspect's answer is greater than the ratio before his answer, there is some presumption that the answer is false and vice versa.

Electrodermal Response.—Changes in the electrical resistance of the skin are caused by emotional conditions. This electrodermal response is recorded by placing two electrodes on the skin and applying a few volts. Changes in potential between the electrodes can be amplified sufficiently to operate a galvanometer which in turn may record on the moving tape. The extent of the deflection and its rate of change may be diagnostic. The electrodermal response is not so successful as the blood pressure in actual detection work. It appears to be more specific for the type of emotion originating in some sensory disturbance like a startle, whereas the blood pressure responds more to emotions resulting from ideas, such as those involved in deception.

Association Reaction Technique.—In the oldest of the psychological techniques for crime detection, the examiner presents stimulus words one at a time, the suspect responds with the first word which occurs to him and the reaction time required for this response is recorded by an electrical timing device. Some of the stimulus words are crucial, in the sense that they would remind the actual offender of the crime but would have no such significance for the innocent suspect. The other words are normal or control words. The guilty suspect may betray himself by responding to the crucial stimulus words in such a way as to reveal familiarity with the crime or if he is able to suppress such incriminating responses, the reaction times may be longer. A supplementary technique involves a pneumatic reaction key which the suspect presses at the same time he gives his oral response. Actually the apparatus records the position of his finger continuously on a moving tape and a premature or unusual manual response will be noted.

Difficulties with Crime Detection Techniques.—It is sometimes asserted that techniques like the foregoing would convict the innocent. An excitable person would undoubtedly show considerable disturbance under examination even though innocent. The point is, however, that the individual is always used as his own control. The innocent, excitable suspect might show disturbances on the control questions but would show little more on the crucial questions. An unexcitable, guilty suspect on the other hand would show rather slight disturbances on the control questions but appreciably more on the crucial because of the additional increment of emotion resulting from deception.

Usefulness of the Technique.—From the early 1920s techniques of this sort were employed in examining criminal suspects. Their greatest usefulness lies in preliminary examination with a view to getting further clues, eliminating innocent suspects and, in general, narrowing down the problem for the police. The scientist does not use the device to frighten the suspect into a confession which may be untrue and actually the result of suggestion. Neither does he compel anyone to undergo this type of examination. However, most suspects voluntarily submit, because refusal would appear suspicious.

Legal Status.—Techniques of this sort up to the mid-20th century had not been admitted to any extent as legal evidence. There had been a few cases, however, in which defense and prosecution agreed in advance to have an examination conducted by these methods and to waive any question of admissibility of the evidence. In the hands of properly trained persons these psychological techniques can be of considerable help in the field of criminal interrogation. In the wrong hands they can be grossly and unscientifically misused.

Psychological Factors in Causation of Crime.—Some criminal behaviour can be traced directly to mental disorder or disease in the offender. A patient with a delusion that someone is trying to kill him may take matters into his own hands and attack someone whom he "recognizes" as the persecutor. Delusions of grandeur may lead a person to write checks on an imaginary bank account. General instability may result in violence or wanton destruction of property. One type of epileptic may commit murder during a seizure and have complete amnesia for the act. Sadism, a sex perversion centring around cruelty, may involve the most gruesome type of murder. Borderline disorders as contrasted with major insanities also contribute to delinquency. When a person becomes frustrated by some combination of circumstances, he may not meet his problem in normal fashion but get emotional release through some questionable behaviour. Shoplifting sometimes is an outlet for frustration and the desire to assert oneself.

Mentally Defective Delinquent.—The mentally defective or feeble-minded person has characteristics which, in a way, predispose him to crime: he is unable to compete satisfactorily in a vocational situation, with resulting financial difficulty; he lacks foresight and will, for instance, commit a murder with no consideration of an alibi; he tends to act on impulse and is unduly suggestible. Numerous studies have been made of groups of delinquents to determine what proportion are feeble-minded. The results depend greatly on how the sample is selected, but in general reveal a sufficiently large proportion of defectives among the delinquents to constitute a real social problem. The proportion is usually higher with juvenile delinquents than with adults,

and is likewise considerably higher with repeaters than with first offenders.

The casual criminal has nothing in his history and no observable psychological characteristics which would indicate that he is going to commit a crime. He simply gets into a situation that is too much for him. The main problem here is to forestall a second offense.

Suggestion as a Cause of Crime.—A frequent source of suggestion, that is, getting the idea of criminal behaviour, is found in a youngster's associates. If his group is indulging in petty delinquencies, it is natural for him to do likewise and go from bad to worse. Another source of unfortunate suggestion may be the home, especially if it involves undue laxity of behaviour. Newspaper publicity is another source; crime news is featured extensively and in detail, so that the reader may find just how the jewellery store window was cracked. He may get the impression that almost everyone does this sort of thing. There is often insufficient emphasis on conviction and punishment. The same principles may operate to a lesser degree in books and periodicals which feature crime. Motion pictures contribute information as to criminal *modus operandi*. They may be alleged to teach that crime does not pay but, all too frequently, the audience spends several hours observing a criminal who is clever, well-dressed and glamorous and has a good time while it lasts, and the retribution that finally overtakes him occupies only a few seconds and fails to leave a lasting impression. Television operates similarly.

Drugs.—The drug addict has a profound motivation to get more of the drug and will stop short of nothing. This may lead to violation of the drug law or actual violence for the purpose of obtaining money to buy more narcotics. Alcohol contributes somewhat to crime. Contrary to popular belief, it is a depressant rather than a stimulant as far as actual mental and motor performance is concerned. The feeling of superiority is somewhat illusory but there is a general lowering of inhibitions.

Psychological Factors in Crime Prevention.—*Predelinquency.*—The crime usually is not the first symptom of mental disorder, but the individual manifests delusions or withdrawal tendencies long before he gets into trouble. Relatives or school personnel should be aware of the significance of these symptoms and get expert help in diagnosis. Police have sometimes located these predelinquents by investigating more carefully the chronic complainant who may actually be thus manifesting his instability. It is much the same story with the early detection of mental defectives who may later develop delinquent tendencies. Intelligence tests administered in the school system may help on this point.

Eugenics.—Mental defect and mental disorder have a distinct hereditary element. There are numerous instances of families with a high incidence of feeble-mindedness in successive generations. With mental disorder the situation is complicated by the fact that both predisposing and exciting causes are involved. One may have the hereditary predisposition, but does not become insane unless he gets into a situation which touches it off. Nevertheless, numerous studies reveal an unduly high proportion of mental disorder among relatives of disordered persons.

If mental defect and mental disorder account for a fair amount of delinquency and these characteristics are to quite an extent hereditary, an obvious crime prevention procedure would be to stop breeding feeble-minded and insane.

Control of Sources of Suggestion.—Another contribution to crime prevention would be the control of sources of suggestion mentioned in the preceding section. Suggestion from associates could be minimized by giving the youngsters more salutary things to do in their spare time through provision of recreational facilities. Some toning down of crime news might be feasible with more emphasis on retribution. The motion picture scenario might eliminate some of the criminal detail and the glamour and put more emphasis on the penalty.

Drugs.—Enforcement of laws regarding narcotics is difficult because of the small size of the material. An appreciable amount can be transmitted under a postage stamp. A long sentence for addicts sometimes makes it possible for them to become weaned in the process. Education as to the danger may help forestall youngsters from trying a drug out of curiosity and thus getting the habit.

Punishment.—One function of punishment is to deter people from committing crime. If the deterrent effect is analyzed psychologically, it appears to have two aspects—the severity of the penalty and the certainty of its enforcement. Some people are deterred primarily by one aspect, and some by the other. If punishment is to be an effective deterrent for everyone it is necessary to stiffen up both aspects—severe penalties and rigorous enforcement.

Another function of punishment is reformation of the criminal. While he is incarcerated, it may be possible to correct his underlying philosophy, to teach him a vocation that he can follow when he gets out, and to help him plan his life so that he can keep out of trouble and find interesting and profitable things to do. A little counselling at this point supplemented by some follow-up after his exit by a sympathetic worker may go a long way in keeping him straight. Many of the casual criminals mentioned above need not be permanently delinquent.

Education.—The educational system has contributions to make to crime prevention. For one thing it keeps the youngsters out of mischief while they are in school. Vocational education is another aspect. There is much controversy as to the comparative importance of vocational and cultural education, but at any rate vocational adjustment does have an obvious relation to getting along satisfactorily from an economic standpoint and perhaps keeping out of trouble. Vocational guidance, which often is part of the school program, can contribute in similar fashion. If the individual is directed into a field in which he has a good chance of vocational success, then his whole life adjustment will be better and the probability of his getting into questionable activities will be thereby reduced.

Trade-Marks and Trade Names.—Trade-marks and trade names are designed to protect the manufacturer who has invested capital in the promotion of his product and to protect the consumer who wishes to purchase more of a product which he has found satisfactory. Sometimes, however, a trade name or mark that is similar to the original deceives some purchasers. The manufacturer of the original product may take legal action against the alleged infringement. A basic consideration in such a case is the actual extent of confusion between the two names or marks; *i.e.*, the probability that the consumer will actually purchase the wrong brand. This is essentially a psychological problem in the field of recognition.

It is possible to determine experimentally the degree of confusion between two similar trade-marks or names. A list of trade names is presented to a considerable number of persons at a standard rate and these observers merely attempt to remember the names. Then a second list is presented more slowly and they are required to indicate which of the words in the second list were actually in the first. Some of the names in the second list are identical with those in the first, and some are entirely new. The name used by the plaintiff is included in the first list and the name used by the defendant in the second. It is possible to determine what proportion of the observers erroneously state that the name of the defendant actually was in the first list. This per cent of confusion must be evaluated relative to the amount of confusion on the words that are duplicates or actually new, as this latter indicates the general difficulty of the experimental conditions. Investigations along these lines have served as the basis of expert testimony by psychologists. (H. E. Bu.)

PHYSIOLOGICAL PSYCHOLOGY

Physiological psychology is the science which deals with the relations of behaviour and of mental processes to the physiological activities of the various organs of the body. Development of the science has been complicated by the apparent distinctness of the two problems implied in this definition. Behaviour, even speech and other modes of transmitting ideas, is made up of muscular movements and so can be dealt with as a part of the

activity of the body. The relation of mental states to bodily activity, on the other hand, has seemed to many students to constitute a problem of an entirely different order. The mind-body problem has been a major topic of metaphysical speculation and has influenced the direction of much of the research in psychology.

Some of the effects of injuries to the brain were known to the physicians of antiquity. Galen taught that the brain is the seat of the intellect, as had members of the Alexandrian school before him, but the belief that vital processes are maintained by circulation of body fluids, or humours, led to the ascription of mental functions to the ventricles of the brain and to other organs, especially the heart, liver and spleen—a belief still recalled by such terms as sanguine, melancholy and phlegmatic, descriptive of temperamental traits. Progress in understanding behaviour was impossible until the rapid development of anatomy during the 15th and 16th centuries laid a foundation for physiological studies.

The first attempt to formulate a systematic physiological account of behaviour was that of René Descartes (1649), who ascribed the movements of animals to the mechanical action of the nerves but reserved to man an immaterial, rational soul, intervening in the actions of the brain. The next two centuries witnessed controversies between those who, like Giovanni Borelli (1680) and J. O. de Lamettrie (1745), sought a mechanical explanation of vital phenomena and the advocates of mystical, vitalistic theories such as that of Georg Ernst Stahl (1707). The observations of Jan Swammerdam (1674) on muscular contraction and of Thomas Willis (1681) on the effects of destruction of different parts of the brain initiated the experimental study of the functions of the nervous system. Understanding of reflex action and of special functions of the different parts of the brain was extended by Johann Unzer (1771) and George Prochaska (1784), who compiled and interpreted the knowledge of their times. The distinction by Charles Bell (1811) between sensory and motor nerves and the extensive experiments by Pierre Flourens (1824) mark the beginning of the modern period of research on the nervous system.

Evidence for dissociation of mental functions by brain injuries, derived from the demonstration of speech defects following damage to the frontal region by Paul Broca (1861), and of paralysis of voluntary movements following destruction of the motor cortex by G. Fritsch and E. Hitzig (1870), went far to destroy the conception of the unitary character of mind and to establish the theory of the dependence of behaviour upon nervous activity. Following these investigations, the study of the nervous system expanded with amazing rapidity. In the next 50 years more than 3,000 articles dealing with behavioural disturbances following brain injuries in man alone were published. In 1874 Wilhelm Wundt published the first book dealing specifically with physiological psychology, and established a laboratory devoted to the subject, but the important contributions continued to come chiefly from the physiological laboratories and the clinics. Charles S. Sherrington demonstrated the intricate relations of reinforcement and inhibition among reflexes, and the Russian physiologists, Ivan Pavlov and W. von Bechterev, extended the conception of the reflex to include learned actions and cerebral functions. Finally, the invention of methods of electrical amplification made it possible to trace nerve impulses within the central nervous system and to demonstrate beyond question the uninterrupted physical continuity of nervous activity from the stimulation of sense organ to the production of muscular movement.

The conception of the relation of mental processes to the body changed steadily under the influence of the physiological studies. Belief in the interaction of mind and body as distinct modes of being, expressed by Descartes, was weakened by the attacks of the 18th-century materialists, by evidence for the physical continuity of reflex action and for the similarity of nervous structure and function in animals and man. Even in 1870, Fritsch and Hitzig described the motor cortex as the point of entry of "single psychic functions into material," and L. Hermann could deny the validity of their observations and the possibility of separate localization of functions in the cerebral cortex because the mind is one and indivisible. The rapid acceptance of the physiological determination of behaviour, however, soon left mind without apparent function, an epiphenomenon, as Thomas Huxley termed it. For a time the theory of psychophysical parallelism, first formulated by Gottfried Leibnitz (1795), was widely held. This assumed that mind and body represent two independent causal sequences, timed to run concurrently, but without any mutual influence.

Psychological analysis was, however, rapidly doing away with the supposedly unique character of mind. Wilhelm Wundt and his followers reduced experience to sequences of sensation and feeling, and Oswald Külpe demonstrated that the effective activities of thought, the organizing of ideas or acts, is entirely unconscious and can only be inferred as a nonmental activity. The new realists attempted to analyze further the distinguishing characters of mental processes and were able to define them only as relations between terms having in themselves no attributes of mind. The outcome of these psychological studies was the conclusion that mental states and activity are characterized solely by their organization, and that this organization may be identical with that of the physiological activities of the brain. This identity hypothesis in one form or another had become dominant in psychology by the mid-20th century. It was still only a working hypothesis but it was being continually supported as knowledge of neurophysiology revealed the basis of relationships which have been thought to be uniquely mental. The transfer of problems to physiology from the realm of psychics is illustrated by the history of psychophysics, which began as a study of the relation between intensity of stimulus and intensity of sensation. These studies revealed a constant ratio, expressed roughly by the statement that the intensity of sensation varies with the logarithm of the intensity of the stimulus. Gustav Fechner, who developed the measurements, believed that this law expressed a quantitative relation between neural activity and mind, and was thus a truly psychophysical measure. The law, however, did not hold for very weak or very strong stimuli. Work in neurophysiology showed that the measurements actually describe the relation between the intensity of stimulation of a sense organ and the number of nerve impulses which it discharges, and that the discrepancies at low and high frequencies are caused by the limited number and refractory periods of the nerve fibres involved. Many such instances justify the expectation that the organization which seems characteristic of mental processes will be found to be that of nervous activity.

Physiological psychology came to deal primarily with the physiology of the nervous system. There were, however, many instances of the influence of physiological processes upon behaviour which could not at mid-20th century be described in terms of nervous activity. Among these were the effects on behaviour of oxygen deficiency, of fatigue, of the concentration of internal secretions, of vitamin deficiencies, of toxic drugs, to cite only a few examples. Their effects on mental activity and behaviour may be studied and the results may find practical application before their mode of action through the nervous system is known. Physiological psychology had come to be largely concerned with the action of such agents, whose effects were known but by no means completely understood. It is a compilation of material from many sources—biochemistry, anatomy, physiology, clinical neurology, psychology and psychiatry—selecting relevant facts from each and orienting them in reference to the problems of behaviour. There is space here only to enumerate topics which have been most intensively investigated and to indicate the nature of the results.

Neurophysiology.—The action of sense organs, the transmission of nerve impulses to the central nervous system, their integration there and the final excitation of muscles are described in articles on the special senses and on the nervous system. These facts are basic for physiological psychology but need not be reviewed here.

Heredity of Mental Traits.—The difficulty of measuring individual differences and the readiness with which they are

modified by environment has limited the study of their inheritance to the more extreme and stable variations. In experiments with animals, both temperamental traits and learning ability have been shown to be inherited. In man, emotional traits, certain types of mental deficiency and the tendency to some nervous and mental diseases are clearly hereditary. Studies of identical twins indicate that the level of intelligence may also be genetically determined. With few exceptions, such as amaurotic family idiocy and sex-linked colour blindness, such traits show blending inheritance and multiple gene determination.

Physical Types and Personality.—The possibility of association of mental traits with external characters of the body has claimed interest from ancient times and many systems of character reading from the shape of the face, head or body have been advocated. The most widely known of these is Franz Joseph Gall's phrenology, which attempted to deduce the functions of the brain from the shape of the skull. Ernst Kretschmer's claims for behavioural differences between pyknic, asthenic and athletic body types (the fat, the lean and the muscular) acquired the largest scientific following. Careful investigations of the claims of these various systems failed to reveal any consistent relation between somatic characters and temperament or capacity. Only in certain pathological conditions, such as microcephalic idiocy and the glandular dysfunctions of cretinism and exophthalmic goitre, are such relations clearly established. There are marked individual differences in the microscopic structure of the brain which may be expected to correlate with differences in behaviour and personality traits but their significance has not been determined.

The Basis of Sleep and Activity.—Rhythmic periods of rest or sleep and of activity are characteristic of all higher animals. The destruction of certain basal portions of the brain results in somnolence from which the subject may be aroused with difficulty. This suggests that normal waking activity may be sustained by reinforcement from these lower centres. If the suggestion is correct, the cessation of reinforcement during normal sleep still requires explanation. The accumulation of fatigue products has been proposed as the cause of sleep but their effectiveness has not been demonstrated. Reduction of sensory stimulation and the establishment of habitual rhythms of activity have been shown to be important factors in production of sleep.

Individual differences and diurnal variations in total activity have been extensively investigated. Genetic factors and a number of physiological variables such as the level of activity of different endocrine glands have been found to modify activity. Their mode of action is by altering the metabolic activity of the nerve cells, but details of this are not well understood.

Physiology of Emotion and Motivation.—Emotional states are usually accompanied by observable bodily changes. Rates of heart beat and respiration may alter, the skin flush, blood pressure rise or fall, the muscles tense. William James suggested that emotion consists of the sensations aroused by these bodily changes and a large number of studies seeking to relate specific emotions to such changes have been carried out. They have revealed great individual variation in the expression of any given emotion. Even laughter and weeping, perhaps the most definite forms of emotional expression, may occur inappropriately as in "weeping with joy," and there is no consistent relation between patterns of muscular activity and specific emotions. Facial expressions by which emotions are judged seem to be largely an acquired gesture language, likely to appear only in social situations and lacking in the congenitally blind. The accumulated evidence indicates that emotion is an altered level of general activity of the nervous system, an increase together with an impulsion to some activity, such as aggression or flight, or a decrease resulting in apathy and blocking of action. With increased activity there is excitation of the sympathetic nervous system resulting in a number of bodily changes which tend to increase the efficiency of skeletal muscle. From these facts Walter B. Cannon developed the theory that the bodily changes observed in strong emotions constitute a mobilization of energy in preparation for strenuous effort. The role of the hypothalamus and other nervous structures is described under that heading.

Emotional attitudes are important in motivating behaviour, and the study of emotions is one approach to the problems of the nature of interests and of incentives to activity. These problems have not been reduced to a physiological level, and physiological studies have been limited to investigations of hunger, thirst, the sex drive and similar primitive incentives. Such studies have revealed the susceptibility of the nervous system to specific chemical influences, the direct activation of sex activity or maternal behaviour by hormones in lower animals, increase or decrease of aggressiveness in primates under the influence of androgens or estrogens, activation of food seeking by sugar deficiency in the blood, and the like. Methods for direct study of their chemical action on the nerve cells had not been devised at mid-20th century.

Learning and Memory.—The problem of what changes take place in the nervous system during learning and the nature of the traces by which memories are preserved has given rise to innumerable speculations, ranging from the theory that learning involves a growth of new connections between nerve cells to the theory that nerve cells may secrete chemicals to which other cells become sensitized, by analogy with the development of specific allergies. No direct evidence in support of any of these theories had been obtained up to mid-century. Physiological studies had been limited to determination of the effects of various agents upon the rate of learning or in producing amnesia. The influences of age, sex, strength of motivation, of dietary and endocrine deficiencies, of fatigue, drugs, traumatic shock and various injuries to the nervous system are among the topics which have been intensively investigated. The results are complex, and no brief generalization of them is possible beyond the statement that any agent which retards the development or depresses the normal chemical activities of the brain tends to retard learning and impair memory.

Intelligent Behaviour.—Physiological studies have been confined to description of disorders of thought and behaviour which result from subnormal or pathological conditions of the brain. Agents which retard the growth of the brain, such as exposure to X-rays at certain stages of foetal development or thyroid deficiency in childhood, result in mental retardation. Toxic drugs may produce specific mental symptoms such as the vivid visual hallucinations of mescal poisoning or the euphoria of alcoholic intoxication, or they may produce a general slowing and confusion of thought. Injuries to the brain produce a variety of intellectual defects, which may be rather specific, such as the difficulty in finding words in mild aphasis, or may be a more general deterioration of comprehension and judgment. Small and sharply limited injuries are more likely to produce specific defects, large or diffuse lesions to result in more general deterioration.

Such facts are well established but their interpretation is still largely speculative. Intelligent, adaptive and creative behaviour is exceedingly complex and psychological analysis has made little progress in defining the various functions or capacities which contribute to it. An adequate adjustment to the situations of life requires that judgments be based upon consideration of a large number of relevant situations or memories. This capacity to deal simultaneously with a number of items is an important element in intellectual ability, and agents which disturb cerebral functions reduce the number of activities which can be carried out concurrently and integrated in final action. Thus, in perception, a patient with brain injury may be able to note one by one the various items in a picture but be unable to relate them to one another and so to comprehend the significance of the picture as a whole. Defects of judgment may result from a similar limitation of associative connections. In formal tests, the patient may be restricted in ability to classify objects, arranging them according to use but not by material or colour; he may be facetious or obscene where social custom forbids such behaviour. Limitations in capacity of this nature may be understood in terms of reduced number of associative connections or heightened thresholds of excitability, but there are many other processes which contribute to adequate adjustment and none of

them had, at mid-20th century, been adequately analyzed either in psychological or physiological terms. A physiological account of intelligent action was still an aim, not an achievement of science.

Applications.—Although physiological psychology was still far from an understanding of its fundamental problems, its discoveries had found many useful applications. Interest in the nature of retinal fusion and of seen movement led eventually to the invention of the motion picture. Other studies of sensory physiology had found almost equally spectacular application in the fields of illumination and communications engineering. School hygiene and safety engineering in industry and on the highway employ the results of many studies of sensory physiology, fatigue and reaction time. The science has contributed largely to the development of instruments facilitating night vision, flight at high altitudes, efficiency in desert and arctic conditions, etc. In medicine it was just beginning at mid-century to find applications in the treatment of nervous and mental disease.

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PSYCHOLOGY, COMPARATIVE concerns the study of similarities and differences in adjustive capacities and personality among the important types of living beings, from plants and unicellular organisms to the primates including man. It is currently interpreted as the science of lower-animal nature in comparison with that of man. A wide view of the subject held earlier by W. Wundt and others would include human comparisons now generally studied under the special titles of *Genetic* or *Child Psychology* (*q.v.*), *Abnormal Psychology* (*q.v.*), and *Ethnology* or *Folk Psychology*. The present article will be concerned with an examination of the psychological makeup and capacities of lower animals and man in comparison with one another.

Comparative psychology is studied not only because learning about the capacities of given animal forms is in itself interesting, and because of practical applications in fields such as medicine and animal training, but also because of its relation to human psychology. With the rise of an experimental comparative psychology and its rapid growth during the 20th century, the scientific study of lower animals has thrown much light upon questions in human psychology such as the early development of individual behaviour, fundamental impulses such as those involved in motivation, the nature of learning and methods of learning, and many others. Frequently human psychologists employ lower animals as subjects in their experiments, not only because these are easier to obtain in numbers and can be much better known as to background and better controlled under experimental conditions than human subjects, but also because of certain similarities in behaviour which can be identified dependably. It is possible to learn much about man by studying lower animals; moreover, the discovery of differences illuminates the similarities.

In primitive times man was forced to learn about animals because of his constant struggle with them for existence. There developed intimate relations with animals as domesticated members of the household, and in some cultures a mystical fear and worship of animals as enigmatic beings. The common-sense tendency to regard the actions and capacities of lower animals as similar to those considered prevalent in fellow human beings always has been strong in human society. People often talk to animals, appealing for action or for sympathy, and interpret their conduct as though dealing with other human individuals. One rather extreme development of this tendency has been the doctrine of transmigration of souls or metempsychosis, which holds that in other generations the human soul may reside in the body of some lower animal.

Through recorded history two different views have developed concerning man's relation to the lower animals, and on what basis he should compare himself with them. One, which may be termed for convenience the *man-brute view,* tends to stress differences often to the point of denying essential similarities altogether; the other, which may be termed the *evolutionary view,* calls attention to similarities as well as to differences. Aristotle formalized the man-brute view by attributing a rational faculty to man alone, and lesser faculties to the animals. Through Thomas Aquinas this provided a basis for the view of Catholic theologians that man possesses an immortal soul which sets him forever distinctly above and apart from other beings, which lack such an immortal soul. On the other hand, the rise of Darwinism in the 19th century led scientists to look for relationships between man, considered to be a highly evolved animal, and the other animals. This has come to be the modern view in science, and it is in this sense, and only for convenience, that the terms "man" and "animal" (*i.e.,* lower animals) will be used in this article. For scientific evidence indicates that continuity in the evolution of the organism has provided a basis for continuity of essential relationships in the evolution of psychological functions which exist, together with obvious differences, between lower and higher stages in the animal series.

Anthropomorphism.—There is an irresistible human tendency of long standing to ascribe human attributes, emotions and capacities, to other beings. Attributing human experience to lower animals is a form of anthropomorphism which became popular as an outgrowth of Darwinian evolutionism although it is far older in human history. It is an ancient human habit to think that, (1) "since I am of course well acquainted with my own thoughts and reasons for acting, because I am conscious," (2) "when I see other men and animals presumably behaving as I do, it follows that psychological causes equivalent to my emotions, impulses, and ideas, must be basically responsible." Thus it is said that moths and other insects fly to the light out of curiosity; the hen is proud of her chicks and wishes to teach them what she can; the rattlesnake sounds off in order to warn of his presence; pets and domestic animals are noble or sly and deceitful according to conditions, and so on. Jean de La Fontaine wrote his fables from the standpoint of anthropomorphism as opposed to the "animal-machine" theory of René Descartes, to prove that man is not the sole possessor of humanlike faculties. This view is recognizable today as one frequently held among writers of animal stories. Its validity is doubtful.

Although much interesting literature has developed through anthropomorphic crusades to prove that animal doings are based upon human traits, unfortunately such stories are always coloured to an unknown extent by the writer's prejudices toward humanizing his animal subject. The anthropomorphic attitude draws popular interest to animal doings, yet this practice involves two fundamental flaws which make it an undependable means of gathering evidence. In the first place it is typically grounded upon the usually unquestioned assumption that any individual is well acquainted with his own thoughts and psychological functions and even understands their causes. Upon this belief modern clinical psychology casts serious doubt, advising an attitude of caution on the part of would-be interpreters of psychological occurrences, particularly when untrained for observation or interpretation. Another difficulty is that a scientifically untrained individual, however well-intentioned, may be content to use a single outstanding occurrence in the life of an animal as a basis for his interpretation, especially one which has dramatic features making the telling and retelling of it a fascinating exhibitionistic act. But a single observation is low in reliability, especially when one's perception is influenced by his prejudices and preconceived notions. Furthermore, it is a well-known fact that with each retelling new features are unwittingly introduced and old ones changed so that the original observation becomes even less reliable than before. When it assumes the form of a consistent practice of interpreting the behaviour of animals on the basis of selected instances or stories believed typical, this tendency is called *anecdotalism.* Thus Plutarch in ancient Rome, La Fontaine in 17th century France, and countless other writers from early times to the present, have

busied themselves in reporting eloquent stories designed to disclose astounding mental capacities in lower animals.

Although the evolutionary position has been substantiated in its main contentions concerning mental relationships among animals, its real substantiation has come from experimental evidence and not from hearsay reports. The methods of anecdotalism, however amusing as literary exercises, lack the careful and critical examination of evidence which is demanded by the complexity of the problems. No statement concerning a psychological function may be held as sound if it grows out of an unchallenged and questionable report. Fact-gathering whether by observation or by experiment necessitates more than an interest in animals, it requires a special training in the scientific methods of investigation for which personal feelings alone are not a substitute. Even when an animal story is reported by a reputable person of veracity, there is no necessary assurance as to its soundness. Whether a given report comes from laboratory experiments or from observations of animals in their native habitats, it must be examined for dependability and subjected to certain questions, especially these: under what conditions and with what precautions against error in gathering and setting down facts,—were these findings recorded?

In comparative psychology as in science one generally uses the soundest method of study at hand. An observer of nesting behaviour in birds constructs a hideout or "blind" in order to minimize disturbances through his presence, and thereby gains *control* through excluding an undesirable distorting factor. By introducing a camera, binoculars and perhaps automatic recorders of the bird's movements, he further decreases the difference between his field investigation and laboratory experiments. A great proportion of the investigations in comparative psychology have been performed indoors in the laboratory, in order to obtain the maximal amount of control over conditions. There it is possible to regulate general conditions such as age and physiological condition of the animal subjects, to exclude disturbances, to vary environmental conditions such as temperature and illumination or keep them constant according to the experimental plan, and to introduce the special apparatus which is appropriate for ensuring accuracy both in the test itself and in recording results. Thus animal psychology has employed the maze method as one means of testing learning, special problem boxes to test intelligent behaviour, and a variety of other test situations all of which are designed to increase the reliability of the evidence which the experimenter eventually reports.

Interpreting Evidence.—The soundness of any interpretation obviously is limited by the validity of the evidence on which it is based. To illustrate how important it is to check evidence at the source before admitting any interpretation, let us consider one of the many cases in which special humanlike abilities have been claimed for performing animals. A horse named Hans, owned by Herr von Osten of Berlin, after long training, began to amaze audiences with his apparent ability to solve mathematical problems by tapping out the answers with one forefoot. Then, when a problem was written on the blackboard before him, the horse appeared to arrive at correct answers with such success that it seemed the owner's insistent claims for mental calculation on his behalf must be correct. Even problems in calculus could be "solved." Although the explanation of mathematical calculation was widely accepted by the public, inevitably there were expressions of skepticism, particularly among scientists. Many people suspected some trick; others thought that if the owner was honest the claims for calculation must be valid. However, scientific investigation carried out by Dr. Otto Pfungst of Berlin reached a different interpretation. In the first place, the horse was tested with Herr von Osten absent, with the result that he performed as usual; hence the owner's presence was not necessary and there appeared to be no trick depending upon him. In further tests it was soon discovered that Hans could not perform unless someone present knew the answer, showing that the operation somehow depended upon the direct influence of human individuals. Any assumption of telepathy was excluded by new controls. When Hans was blindfolded he could not give the answers, therefore a visual influence of some kind from persons present must be involved. The source of the cues was discovered when Pfungst and his assistants carefully watched the behaviour of individuals present who knew the answers. It was noticed that when a problem was presented such individuals would involuntarily bend forward very slightly, whereupon the horse would begin tapping. Hans would continue tapping while the person remained tense in this position, but when the proper number of taps had been made the questioner would jerk his head slightly upward, whereupon the horse would stop tapping. Slight movements of this kind are known to psychologists as the imperceptible changes in attitude which occur almost invariably when a person attending to an act of questioning recognizes that the correct answer is approaching. Although the observed minimal movements were exceedingly small, Pfungst concluded that these accounted for the presumed calculating ability of the horse merely by controlling the starting and stopping of his tapping. The facts justify the interpretation that, unbeknownst to his owner, Hans during his training had acquired the habit of tapping in response to visual cues. That such a habit and not calculation was involved was suggested by other circumstances, among them the fact that under the best conditions the horse could "do" the simplest problems no more readily than the most difficult. In agreement with this interpretation, "answers" to simple and complex problems alike often were incorrect by one or two digits, indicating that Hans had received his cue to stop tapping now somewhat too early and now too late. Still other indications in his behaviour favoured this interpretation, such as the fact that Hans usually would start to tap mechanically as soon as the problem was presented, without even looking at the figures written on the board before him.

This illustration brings out some of the principal characteristics prerequisite to an interpretation in comparative psychology. The interpreter does not insist upon his first hunch, but recognizes the need for a thoroughgoing investigation of the phenomenon under varied conditions, with control of every factor of possible influence. Thus in Pfungst's study of Hans the importance of vision, the presence of persons who knew or did not know the answer, and the behaviour of persons present, all were appropriately tested. When all possible evidence has been gathered through investigation, the experimenter then sifts and organizes it logically, perhaps with the aid of mathematical techniques, to find the explanation which best fits the facts. Whether the investigation is simple or complicated, and whatever its nature, the described safeguards are needed.

Adaptive Behaviour or Purpose.—Difficulties frequently arise in interpretation because of one's general point of view. Under natural conditions, for example, the behaviour of animals generally conforms rather strikingly to what would be called "appropriate" or "best" in the given situation by the human observer. Thus the hinged leaf of the Venus's fly-trap closes when a fly alights upon it, but not when stirred by a gust of wind; the scallop closes the valves of its shell tightly when the approaching starfish, its common enemy, is still at a distance; the octopus frequently remains secluded until its common prey, the crab, approaches closely; the chimpanzee, confronted with food out of reach, may be able to attain the food by means of a stack of boxes which he arranges. Acts which *seem* well adapted to the given animal's survival or welfare under particular conditions are often described as being "purposive." For those seriously interested in obtaining an adequate explanation, this generalization of purposiveness in behaviour raises certain difficulties.

The above cases are typical—what can be said about them? First, these are acts which occur substantially as described; the reports are reliable. We can also say that the acts have in common one characteristic: that each of them tends to further the life processes of the animal and to fit it to its surroundings by removing some difficulty. In this respect they are like the behaviour of a tailor fitting a suit, they are all *adaptive*. As thus defined, adaptive acts may and do vary widely in nature, from lower to higher levels in the animal series; for much of typical animal behaviour is adaptive. Although many theorists really

mean nothing more than this when they use the term "purposive" for behaviour, others do mean much more; hence it is necessary to continue the examination of these varied activities in the light of a distinction between what is "adaptive" and what is "purposive" in behaviour.

The names of Hans Driesch and W. McDougall are associated with the development of a view in the nature of *teleology* (Gr. *teleos,* an end, and Gr. *logia,* speech), through which directive forces comparable with human purposiveness or volition are regarded as present in all animal behaviour of the type termed above "adaptive." When a man behaves purposively, with the assistance of thought processes he bends his efforts toward attaining an end which he can anticipate or predict. If all animals actually performed their adaptive behaviour on the basis of such a volitional process in order to attain given anticipated ends, the problem of interpretation and explanation in comparative psychology would be relatively simple, since the same type of solution would apply to all cases. The difficulty is the ever-present danger that the teleological type of explanation may arise from the theorist's prejudices and preconceived notions rather than from a careful and systematic study of the evidence.

Morgan's Canon as a Guide in Interpreting Behaviour.—A useful rule in scientific interpretation is the *principle of parsimony,* which may be stated as follows: Of alternative explanations for a given phenomenon choose the simplest, that is the one which involves the fewest assumptions, provided it is no less adequate than the others to meet the facts. This principle was applied to comparative psychology by C. Lloyd Morgan, in the following terms: "In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale." (From C. Lloyd Morgan, *Introduction to Comparative Psychology,* Scribners.)

The purposive, anthropomorphic type of explanation for the above examples would be that the Venus's fly-trap *needs* food, hence closes in response to insects but not to inedible objects which touch it; the scallop *recognizes* an enemy in the starfish and closes its valves to avoid destruction; the octopus hides *so that* its own enemies will not see it and its own prey will pass close by; the chimpanzee stacks the boxes *for the purpose of* obtaining the suspended food. At first sight all of these purported explanations may appear simple; however it would be unsound to adopt any one of them until it had been examined in the light of Morgan's canon, and until possible alternatives had been considered. Actually, these explanations are all complex, because each is loaded with untested assumptions. Each of them assumes that the organism understands the nature of the situation as might a man (*e.g.,* the octopus somehow *knows* that it is out of sight when behind stones); furthermore there is the assumption that the animal foresees what will happen as the result of one action or its alternative (*e.g.,* the scallop anticipates being killed if it does not close its valves), and that these organisms are capable of weighing the possibilities and choosing the correct act as might a reasoning man. In each case the presence of humanlike capacities such as understanding meanings, anticipating results and choosing between alternatives is actually implied by the purposive type of explanation.

Morgan's canon would call for discarding the purposive explanation in any case of adaptive behaviour which the results of investigation reveal is based upon simpler processes. From this standpoint, the experimental evidence favours a purposive explanation in *only one* of the described instances. This is the case of the box-stacking chimpanzee, for which the investigations of W. Köhler and others show that the animal can anticipate failure when jumping from the ground to suspended food, can understand the significance of a box as a means of nearing the food, and is able to develop a solution for such problems through a process qualitatively resembling human reasoning. To account for the fly-trap's reaction, however, it is necessary only to assume a simple reflexlike reaction to a simple stimulus, for the halves of a leaf close together when the delicate central leaf filaments are touched by some foreign object. As for the scallop, experiments show that the valves are closed in response to a chemical effect of sufficient strength, since the scallop does not close its valves if the starfish appears behind glass (visual control) but does so when concentrated starfish broth is released in the water nearby. The assumption of an intent to hide in the case of the octopus is vitiated by an experiment of Bierens de Haan, who found that the animal would slip between plates of glass where it was fully in sight as readily as between pieces of slate. A simpler explanation in line with the facts is that the octopus comes to rest most readily when its body is well in contact with surfaces, hence frequently nestles in crevices—not because of an understanding of hiding.

The above cases illustrate simply the value of investigation in comparative psychology as a means of testing assumptions and reaching the most adequate explanation for each case. Too frequently a purposive account proves to be a mere naming of the results of given activities (*i.e.,* the animal is protected, or obtains food) without really explaining them. A name alone is not acceptable as an explanation, and in fact may suggest an incorrect line of interpretation. Rather, the explanation or theory which is advanced for a given phenomenon, from the closing response of the scallop to box-stacking in the chimpanzee, must grow out of evidence derived from actual investigation and not out of assumptions based simply upon analogies between the behaviour of lower animals and man. For experimentation has shown repeatedly that activities which appear to be very similar in that they lead to similar adaptive results (*e.g.,* both the leaf-closing of the fly-trap and the box-stacking of the chimpanzee may be termed "food-getting behaviour") may be very different in their psychological makeup. The uncritical assumption of abilities akin to human reasoning in all instances of adaptive behaviour must be judged no more helpful to scientific explanation and no sounder logically than is the dogmatic denial of reasoning or comparable abilities in all animals below man.

THE CRITERIA OF PSYCHOLOGICAL STANDING

Some Schemes of Psychological Levels.—On what basis may the psychological status of a given animal be judged? A belief of long standing in the philosophical background of psychology is that a fairly definite series of levels exists among human psychological processes which is paralleled by corresponding psychological stages in the animal series. The earliest elaborate development was the scheme of Aristotle with its four general levels: a nutritive faculty alone, possessed by plants; the addition of sensory faculties in the lowest animals; the addition of an appetitive faculty in the higher animals; the addition of a rational faculty in man. As another contribution to the speculative period, the ideas of Descartes embodied a simpler scheme: a lower level of animals viewed as automata, and man as the sole rational being on a higher level. In 1905 R. M. Yerkes offered a differentiation of levels based upon functional criteria: (1) discrimination, or a general form of reaction, characterized by the sea anemone; (2) docility, or modifiable reactions, characterized by the rodent; and (3) initiative or variability in reaction, characterized by primates. This scheme was one of the first to be offered on the basis of actual experimental tests of animal capacities.

The first criticism generally offered of such systems is that they are merely speculative and pre-experimental, or antiexperimental in that they tend to restrict the view of the experimenter. The objection is that such schemes tend to oversimplify animal nature, which is fairly complex even in the lowest forms of animal life, and encourage artificial interpretations of animal capacities. The sharp distinction of psychological levels is considered unnatural in other ways, for example in the implication that a given capacity is present in a qualitatively homogeneous form through all animals on a given level. For example, Jacques Loeb differentiated higher animals possessing associative memory (*i.e.,* governed by the energy properties of stimulation) from simpler forms; yet experimentation has disclosed not only a considerable overlapping of these divisions, but also much variation in the qualitative nature of learning and memory in different animal forms. Investigative experience has come to favour the view that schemes of "psychological levels" are a useful means of representing the transition

from lower to higher stages of psychological abilities, and are a desirable means of summarizing our knowledge concerning animal relationships so long as they do not imply an unnatural discontinuity from level to level.

Consciousness a Doubtful Criterion.—Attributing consciousness to any lower animal and speculating how it must feel to be that animal is an irresistible everyday tendency which has its formalized side in speculative philosophy. The general position is that when we see in another individual a behaviour more or less similar to our own, we are justified in attributing to the other individual, man or lower animal, a conscious experience similar to our own. Thus Michel de Montaigne thought that brutes must possess the power of imagination, because of occurrences like the startling and barking of dogs in their sleep. The origin of psychology in philosophy, and the domination of introspective methods in early experimental psychology, accounted for a prevalent tendency toward analogized consciousness at the time experimental comparative psychology began to develop late in the 19th century. For several reasons this tendency later changed considerably, partly because of opposition from physiologists engaged in behaviour work, but mainly through countertendencies in interpretation which developed from attempts to use consciousness as a criterion of animal mentality. The chief objections were two. First, the methods of introspection were judged uncertain in validity for human psychology, and worthless in studying lower animals which can not speak; also it was recognized that the method of analogy, which must necessarily be employed, is subject to basic deductive weaknesses. For if inferences concerning the qualitative aspects of even the simplest mental states in man are held doubtful, what can justify applying the method of anthropomorphic analogy to lower animals? In the words of M. F. Washburn (from *The Animal Mind,* 1926 ed., Macmillan company)

> We speak, for example, of an "angry" wasp. Anger, in our own experience, is largely composed of sensations of quickened heart beat, of altered breathing, of muscular tension, of increased blood pressure in the head and face. The circulation of a wasp is fundamentally different from that of any vertebrate. The wasp does not breathe through lungs, it wears its skeleton on the outside, and it has the muscles attached to the inside of the skeleton. What is anger like in the wasp's consciousness? We can form no adequate idea of it.

The attitude of behaviourists like J. B. Watson is to deny the validity of analogizing consciousness and to favour replacing the concept of consciousness with more objective terms in psychology.

The Objective Attitude in Comparative Psychology.—The development of behaviourism in general psychology was strongly influenced by events in comparative psychology. Particularly in the United States, the view gained ground early in the 20th century that the objective methods of natural science afford the only dependable means of studying and comparing animal behaviour. Careful study of an animal under controlled conditions should furnish evidence leading to a valid psychological description of the animal's capacities, without having to use analogies from the human level. Perhaps the chief contribution of this movement to the growth of comparative psychology was its emphasis upon developing objective techniques rather than relying upon traditional subjective procedures, for evaluating and comparing the psychological resources of different animals.

To appraise a given animal activity, the psychologist must consider not only the general nature of the activity under study and its adaptive value, but also the individual's background. He must take into account what factors in the characteristic organic makeup of the species have contributed to the act, as well as its relation to individual experience. For neither the stability nor the adaptive efficiency of a given animal's behaviour pattern are as crucial in determining the animal's psychological status as are the possibilities that appropriate changes in the pattern may occur under new conditions for which the individual is unprepared.

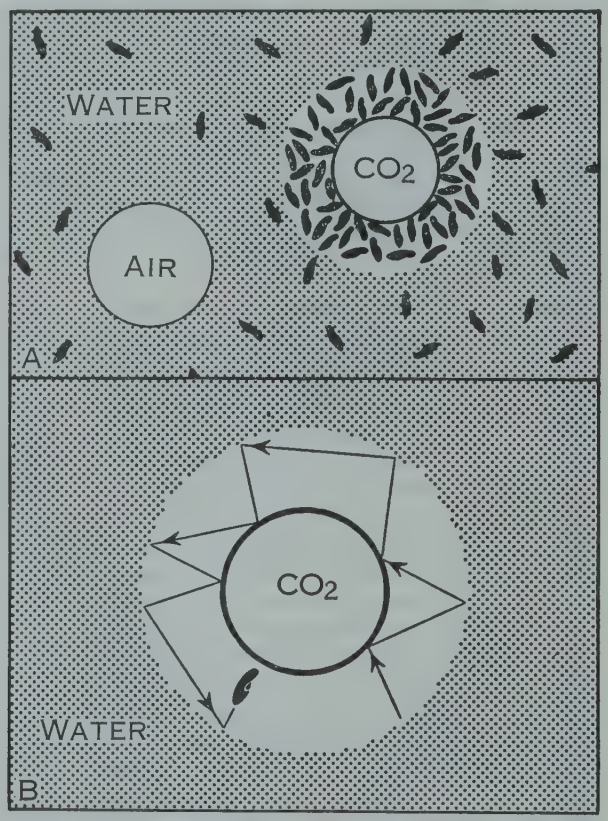
Ideally, the first necessity for comparative study is to understand as far as possible the characteristic behaviour capacities and resources of each animal type. Then it is not sufficient merely to assign positions in a series, describing some animals as inferior and others as superior; the basis of the presumed inferiority or superiority must be clarified through appropriate comparisons. The principal weakness of a topical study, which deals in cross-sectional fashion with subjects such as "emotion" or "learning," is that it risks the defects of faculty psychology by assuming, for example, that a "faculty" such as "memory" exists apart and distinct from other capacities, and that it takes the same form wherever found. The fact is that a given capacity, such as learning, overlaps other abilities and may be very different according to the animal type involved. Higher animals do not necessarily repeat the makeup of lower animals with the mere addition of certain new abilities. On the contrary, instead of a recapitulation in which the characteristics of lower animals are repeated in the higher, closer study may disclose similar factors in development (based on a common ancestry) which when merged with new factors assume *new* psychological significance. These matters may be illustrated by passing in review some outstanding differences observed among various types of animals.

CRITICAL POINTS OF CHANGE IN THE ANIMAL SERIES

Protozoa and the Concept of "Simplicity."—The Protozoa frequently are termed the simplest animals. This can not mean that their activities are necessarily few in number, for H. S. Jennings and F. Alverdes have shown that the movements of the ciliate *Paramecium,* for example, are highly diversified and variable according to conditions. This organism is propelled forward, rotating about its longitudinal axis, by the beating of minute hair-like cilia covering its slipper-shaped body. When a stimulus change is encountered the organism may pause momentarily, rotating narrowly or widely in place before continuing in a new direction, or may reverse its direction by backing through a shorter or longer distance at an angle varying from acute to obtuse. The behaviour itself is not simple, for the organic (protoplasmic) changes underlying the many variations of ciliary stroke in these different reactions are involved and little known; however, it *is* simple in the sense that each behaviour change can be understood as a direct reaction to a somewhat different stimulus. The specific properties of the stimulus appear to be critical, in particular its intensity; for example, a gentle contact typically elicits slight interruptions of forward movement perhaps without any backing, whereas strong contact elicits a pronounced backing reaction. A variety of evidence indicates that the physico-chemical properties of the given stimulus directly govern the extent and the duration of modification in forward swimming. This behaviour is not simple in the sense that there are few items in the animal's repertoire, but rather in the sense that it may be understood in terms of relatively few concepts. For the direct dictation of response by the properties of stimulation is the lowest order of psychological concepts.

Nevertheless, protozoan behaviour frequently appears surprisingly involved. When Jennings dropped carmine particles upon the disc of an attached trumpet-shaped ciliate *Stentor,* as the stream of particles continued to fall there occurred a series of reactions passing from an initial slight contraction of the oral disc (the region first affected) to more and more complete contractions of the entire animal which finally broke it free from the substratum. These successive reactions occurring under conditions of repeated stimulation have been viewed by some as a series of "trials," as Jennings described them. Others more objectively view the reactions as the consequence of a spread of protoplasmic change through the animal, with each repetition of the external effect producing a different reaction more widespread through the organism. At first only the funnel end reacts; then as the internal excitation spreads the stalk becomes involved, contracting farther and farther toward its attached base. Apparently complex as to its protoplasmic basis, the behaviour may be understood simply in terms of an accumulation of physiological changes capable of producing new results as it builds up and reaches more remote localities. The notion of "trials" emphasizes the adaptive possibilities of these changes, but at the same time misrepresents the psychological nature of the acts, which are forced by stimulation rather than being "trials" in the sense of *attempts* at given results.

The above case illustrates how, in the simple psychological system of the protozoan, variability in reaction widens the adaptability of an animal to surrounding conditions. Jennings demonstrated that paramecia collect around a drop of acid in their medium; not through direct approaches to the acid but because they first swim without interruption into the area, then recoil from the



FROM JENNINGS' "BEHAVIOR OF THE LOWER ORGANISMS," COPYRIGHT 1906, 1933 BY COLUMBIA UNIVERSITY PRESS

FIG. 1.—(A) JENNINGS' OBSERVATION OF PARAMECIA COLLECTING IN CIRCULAR ZONE OF WEAK ACID AROUND A BUBBLE OF CARBON DIOXIDE. (B) PATH OF AN INDIVIDUAL PARAMECIUM AFTER ENTERING SUCH A RING AS SHOWN ABOVE

acid-deficient border area upon each chance entry. Since in the ciliates, altered stimulation typically interrupts forward swimming differently according to its intensity and other physicochemical properties, the organisms thereby are enabled to avoid many injurious agents in their environment. The adaptability of such reactions in unicellular organisms, together with the fact that they make possible retaining optimal (*i.e.*, most suitable) environmental conditions, stems from the fact that variable swimming persists until conditions recur favouring normal locomotion.

The status of behaviour changes in Protozoa has been much discussed. As examples of special changes which have been demonstrated, ciliates like *Paramecium* ingest less carmine after having taken in carmine particles for a time, and the effect extends for a time to each of the daughter individuals after the division of a satiated organism; *Amoeba* puts forth successively fewer pseudopodia before each further reversal of direction, when repeatedly exposed to bright light; *Paramecium* reverses more and more promptly when introduced successively into a narrow capillary tube from which it can escape only by doubling around. Some experimenters consider such changes equivalent to the "learning" of higher organisms, pointing to the similarity between graphic records of time- or movement-reduction in these cases and in the learning of higher animals. However, others stress the limited time during which such changes persist in Protozoa, also the fact that many of these behaviour changes have been duplicated without putting the protozoan through "trials," merely by chemical treatment, for instance. Perhaps the most relevant point favouring the latter and simpler interpretation is that the described changes soon disappear without leaving any trace of a lasting alteration of the typical species behaviour pattern.

Behaviour Organized on a Reflex Basis.—For an evaluation of internal organization underlying behaviour in the (organically) simpler multicellular invertebrates, the starfish and its relatives such as the sea urchin have been useful subjects. Experimentation has shown that the component activities of co-ordinated feeding, locomotion, and other common activities in these lower invertebrates may be regarded as true *simple reflexes*. In a simple *reflex arc* (*i.e.*, reflex circuit) there is an afferent neurone or specialized receptive cell (*see* NERVOUS SYSTEM) which when stimulated transmits energy impulses to a specialized motor cell which in turn arouses muscle tissue to contract. Thus, when we touch one of the mobile spines which cover the ball-shaped body of the sea urchin, nervous impulses pass from excited receptor cells at the base of the spine to motor cells and through them to muscles which move the spine. A weak stimulus arouses impulses which cause one set of muscles to bend the spine *toward* the side touched; if the stimulus is strong another set of muscles is aroused which bends the spine *away*. Other reflexes characteristic of the echinoderms include the responses of the pedicellariae, little jawlike structures which rise and snap shut when adequately aroused, and the *tube feet*, small fingerlike muscular structures capable of bending and adhering to the substratum by their terminal sucking discs. In all but the simplest types of reflex arc the receptive cell does not connect directly with the motor cell, but transmits impulses to it through the specialized internuncial or association cells of a centralized nervous system. Throughout the animal series the normal functioning of internal organs (*e.g.*, the heartbeat) or systems of organs (*e.g.*, digestion) is controlled by reflex arcs in a more or less automatic manner. In man, reflex processes occasionally intervene in general behaviour, as when one sneezes irresistibly in response to dust in the air. However, in higher organisms such reflexes have a very different significance from that in lower invertebrates.

In the echinoderms the prominent features of ordinary behaviour are activities such as those described for pedicellariae, tube feet, and spines. Actually, the effective operation of each of these types of equipment depends upon the local makeup of the given structure and not upon a more general control. When any one of these structures is cut free from the animal and appropriately mounted, it is still capable of responding to stimulation in its characteristic manner. Thus, independent spines bend toward the side on which weak stimulation is offered, and away from the side of strong stimulation; the long snap-pedicellaria closes to light touch and the single biting pedicellaria rises when stronger stimulation is presented, essentially as when these structures are present in the intact organism. The fact that local activities of this kind are coupled together to make up the body of normal behaviour in echinoderms led J. von Uexküll, who performed these experiments, to call the animal a "community of reflexes." The same term may be applied to the medusa or jellyfish form of the coelenterates, whose severed mouth-tube bends and takes food as in the complete organism when mounted and appropriately stimulated, and in fact to the local activities of lower multicellular invertebrates generally. Their behaviour pattern exemplifies the concept of "chain reflexes," of local and essentially independent activities which combine into series when appropriately aroused in the intact organism.

However, these local functions alone do not account for the unity and co-ordination observed in normal activities such as the locomotion or feeding of the starfish. The tube feet of this animal come into play in feeding, after the pedicellariae have held the prey for a time, because nervous impulses have reached them from the pedicellariae. These different structures are unified by a generalized web of conduction tissue called the *nerve net*, which is widely present in the body-wall and which links the action structures functionally together. The nature and arrangement of the nerve net are such that it conducts more or less equally in all directions, differences depending mainly upon the nature of ex-

ternal stimulation. Thus when one spine of the sea urchin is strongly stimulated at its base, the surrounding spines on all sides bend away from the locality, the reaction spreading until the spines of a considerable area have bent outward. However, if a circular cut is first made through the tissue around a given spine, the surrounding spines do not react when this one is stimulated. The nerve net exemplifies the function of primitive generalized conduction systems, which unify the local functions of the organism without determining the pattern of behaviour. In human behaviour such functions are very subordinate; for example, nerve-net tissue in the intestine permits the co-ordination of sections of the tube in normal digestion. However, in the adult sponge, one of the simplest multicellular animals, even such a generalized unified nervous structure is lacking, hence the contractile chimneys through which sea water enters the organism open and close independently through the action of external stimulation upon them separately.

Echinoderms such as the starfish possess a further degree of organization in behaviour. For example, when overturned upon their backs, the starfish and some of its relatives are capable of returning to the normal position. One pattern of righting typically predominates when previous stimulation and the handling of the organism in overturning it are regularized. This involves the twisting of the two or three rays of one side so that their tube-foot surfaces first touch the ground, then attach progressively farther toward the central disc. Their leverage raises and swings the body of the starfish until it falls overbalanced upon its ventral surface and is righted. For this to occur as described, it is necessary that the rays of one side do not twist and attach their tube feet. A. R. Moore has shown that if a cut is made through the nerve ring of the central disc, through which the radial nerves of all five arms are normally connected, when the animal is overturned all rays are caused to attach in an unco-ordinated manner so that righting occurs very slowly and abnormally if at all. This shows that normally co-ordinated righting depends upon the possibility that nervous impulses from the rays first to attach may reach the opposite side through the central nervous system and somehow inhibit (*i.e.*, interfere with or displace) the twisting and attaching of these rays. Thus through nervous function the normal unitary behaviour of such an organism rests upon the temporary subordination of certain local reflex activities to others which are themselves reflexes.

Such an interplay among the local functions of a community of reflexes illustrates one of the simplest ways in which an organization may be achieved in individual behaviour. Organizations attaining advanced degrees of elaboration and plasticity become possible when reflexes are dominated by wider patterns not themselves reflex, as when scratching a flea bite is inhibited in a dog when food comes in sight. Not only do reflexes themselves become more elaborate and diversified in higher organisms, as in the variety of reflex-cleaning activities of which insects are capable, but they also become related to other activities in new and more varied ways. Hence the concept of the reflex as such must be revised according to the given case.

Notwithstanding the known shortcomings of echinoderms in functioning as unitary individuals, Jennings reported experimental results which led him to endow the starfish with a capacity to learn. The starfish was overturned so that it must right itself, and in each repetition one particular pair of arms was prevented from leading the righting reaction by using a glass rod to separate the tube feet forcibly from the substratum. The results after 180 trials showed that the arms thus restrained took hold less readily than originally, an outcome which Jennings interpreted as "habit formation." However, A. R. Moore attributed the results to an injury of the restrained arms through use of the glass rod, so that they became less sensitive and more sluggish in the course of the experiment. He produced similar results without putting starfish through righting tests, merely by rubbing the tube foot surfaces of given arms with a glass rod or treating them with weak acid. In higher organisms, temporary behaviour changes forced by simple desensitization or fatigue of local structures are not ordinarily regarded as cases of habit formation or learning. It seems necessary to think of instances such as this as more simply constituted than the term "learning" would imply.

CONTRIBUTIONS OF A CENTRALIZED NERVOUS CONTROL

Cephalization and a Simple Brain.—The limitations of lower invertebrates are definitely improved upon in groups such as worms, molluscs and particularly insects. Basic types of advance appear in the behaviour of the earthworm. This organism is equipped with a specialized anterior end which is not only the most sensitive and highly mobile of all localities, but also the dominant locality by virtue of possessing a brain (superior nerve-ganglionic centre). This *cephalization,* or head dominance, permits reacting to a wide range of stimuli in fairly well-directed ways. In an experiment by W. Hess, for example, earthworms turned rather directly away from the source of strong light or toward the source of weak light. Thus a different basis of organization permits a much wider range of environment and action than is possible through the more limited organization of Protozoa and other lower invertebrates. The significance of a specialized leading part for more efficient locomotion and reaction is indicated by the fact that a marine worm deprived operatively of its superior ganglion crawls about irregularly, does not turn readily upon contact with a corner, and burrows less readily than does a normal worm. Such a specimen is incapable of extending directly from its burrow and precisely seizing a shrimp or other passing organism (a chemically-controlled reaction) as does the normal individual. The fact that the removal of the worm's superior ganglion does not completely remove such normal reactions, although it reduces considerably their directness and precision, indicates that at this stage the brain has a limited dominance as a more efficient transmitter of nervous impulses from the most sensitive regions of the organism, and not that its own makeup gives it a unique control over behaviour organization which is absent from other centres in the nerve cord. In the insects, on the other hand, the role of the brain has advanced from that of a *superior transmitter* to that of an *indispensable organizing centre.* Although a wasp or ant may walk about in a somewhat co-ordinated manner for a time after the head has been removed, before dying, only scattered reflex components of normal behaviour such as stinging may occur, and most of the complex normal behaviour repertoire (*e.g.*, the solitary wasp's ability to dig a burrow and parasitize prey) will be absent.

Organization of Precise Orientation.—The regulation of locomotion in relation to external stimulation undergoes a marked improvement in worms, molluscs and arthropods as contrasted with lower invertebrates. The tropism theory of Jacques Loeb emphasized the significant fact that, first of all, it is the evolution of a true bilateral symmetry and the specialization of a permanent anterior end which provides the basis for an increased scope and precision of orientation in space. In contrast to an echinoderm like the starfish or a coelenterate like the sea anemone, in which directionalized movement in response to light and other stimuli is typically deficient in precision, the higher invertebrates exhibit marked improvement. The improvement is seen first of all in behaviour such as total movements of the organism with reference to external stimulus sources, as when a snail turns toward the side on which a lettuce leaf has lightly touched a tentacle. At this stage it is not the nature of the object, but the crude energic properties of stimulation which are effective. For example, worms approach the source of a variety of chemicals, if weak solutions are used, but move away from the source if the same chemicals are intense; with intermediate concentrations of these chemicals the reactions are variable. The directive influence of differences in the intensity of stimulation acting upon receptors of the opposite sides of the body is indicated by experiments such as that of S. J. Holmes and K. W. McGraw, in which a cricket with covered left eye turned persistently toward the left when placed in strong diffuse light. Similarly, a normal animal turns to the left when a strong light is placed at its right.

Further improvements in the precision and variation of orientation become possible with the evolution of greater specialization in receptors and in nervous equipment (*see* ANIMAL BEHAVIOUR). The octopus, with some capacity for visual accommodation, moves

forward only when an object (*e.g.*, a crab) appears within a given range of distance; among insects which have compound faceted eyes some, like the honeybee, under appropriate conditions are capable of moving toward a single point of light stimulating one eye alone. Although the role of improved receptors appears very prominently in specialized orientation, advancements in nervous and muscular structure, particularly the first of these, are also essential. For example, cutting the nerve-fibre tracts which connect the two sides of a worm's simple brain, or much more so an insect's complex brain, greatly reduces the precision of normal movement with reference to stimuli. However, neither the accuracy of orienting movements toward or away from a source of stimulation, nor the nature of the receptor involved (*i.e.*, its complexity, or similarity to mammalian receptors) alone justifies conclusions as to the psychological status of the act. Numerous experiments indicate that on this level it is the specific quantitative characteristics of stimulation (*e.g.*, intensity, size, amount of change, rate of movement) which control the timing and precision of approach and withdrawal, rather than the qualitative nature of the object. Simple factors such as these appear to control the responses of the octopus, and the fact that it has a well-developed lens eye approaching that of many mammals in complexity does not mean that it "recognizes" its food as do higher mammals. Bierens de Haan found that when an octopus was presented with a crab in full view within a glass jar, the crab was seized only when a tentacle chanced over the rim of the jar into contact with it, without any directive aid through vision.

Simple Learned Modifications.—The improvement of behaviour organization through learning first occurs in the flatworms, in which conditioned-response changes have been demonstrated. Light ordinarily causes the marine flatworm *Leptoplana* to move about, whereas local contact stops locomotion; however, after 25 five-minute periods in which light was coupled with a tactual stimulus, the worm remained quietly in the light without movement. Similarly, M. Copeland trained the marine worm *Nereis* to appear from a glass tube when it was lighted, or when it was darkened, depending upon which of these visual changes had been combined with meat juice during the training period. In the earthworm a specific movement in space may be acquired through learning, as in the experiment described below.

The subject was introduced into a glass-covered T-shaped alley system in which a turn to the left at the junction brought the worm into contact with an electrode delivering an electric shock, whereas a turn to the right brought the subject into a dark box. Within 160 trials the problem had been mastered by many of the worms, which then turned consistently to the right upon leaving the entrance alley. That the habit was not dependent upon a simple localized sensory or muscular change was indicated by results when the positions of electrodes and dark box were reversed after original learning. Worms which had learned to turn to the right side now reversed their trained turn to the left within 75 trials, a distinct saving which indicated a central nervous basis for the learning.

The organization of behaviour would appear to be considerably enhanced by the capacity for learned modifications. The capacity for simple conditioned responses and for the simple changes in directed locomotion of which worms are capable, must alter some of the normal activities of these animals, although not to the extent that learning influences higher invertebrates. Illustrated by the conditioned response, which may be regarded as its simplest form, the essence of learning is that through experience under given conditions a particular reaction is given to stimuli previously incapable of eliciting such behaviour. In Copeland's experiment with the marine worm, light (the new or *conditioned* stimulus) initially was not effective in causing the worm to appear from its tube. Meat juice, however (the original or *unconditioned* stimulus), was effective; and the application together of these two stimuli produced a changed organization whereby light possessed a new type of control over reactions. In the T-maze behaviour, although somewhat more complex, there is a similar occurrence in which certain stimuli encountered near the junction acquire control over the right-turning reaction so that actual contact with the electrodes is no longer necessary. In such learned acts a new sensory-motor organization is involved, more lasting than the limited changes of which lower invertebrates are capable because it is not restricted to local sensory or motor changes alone.

FIG. 2.—CONDITIONING THE MARINE WORM NEREIS. AT FIRST LIGHT (NEW STIMULUS) AND CHEMICAL (ORIGINAL STIMULUS) MUST BE COMBINED ON EACH TRIAL; FINALLY LIGHT ALONE BRINGS THE WORM FORTH

An adequate organic basis for such accomplishments is afforded particularly by a central nervous system with sufficiently evolved ganglionic centres and interconnections to permit new sensory-motor reorganizations to arise under appropriate environmental conditions. The mere possession of a centralized nervous system with ganglion cells is not sufficient, for the starfish with its simple conduction system has not been demonstrated capable of true learning. Work on higher organisms has demonstrated that the further evolution of centralized conduction patterns gives rise to new possibilities in the complexity and qualitative nature of learning.

Instinctive Behaviour at Its Maximum.—The arthropods and especially the insects greatly exceed lower vertebrates in the complexity and diversified specialization of their activities. It is in this group that the problem of *instinct* (Lat. *instinctus*, impulse) comes prominently to attention. Of course, the mere application of the word "instinct" does not explain any act, and a variety of viewpoints is found in the literature, from the attempt to explain instincts as chain reflexes to the idea that the animal possesses an inherited awareness of a given plan of action. It is difficult to find adequate criteria for what is essential of so-called instinctive activities. Commonness to all members of a species requires the proviso "under given conditions," as well as the exclusion of common activities ordinarily *learned* by most members of the species. Most adequate is the criterion that "instinct" concerns activities which depend predominantly or wholly upon the nature of the animal's inherited organic equipment as played upon by given environmental conditions, with learning absent or in a minor role.

In this sense the activities of invertebrate animals in general are "instinctive," in that the action of certain typical environmental stimuli upon an inherited organic equipment of given nature results in a predictable kind of behaviour. These behaviour patterns and their component activities (*e.g.*, the starfish's righting response; the spinning of webs by spiders) are typically very adaptive, as noticed earlier in this article. However, such adaptiveness can not be attributed to psychological factors of purposive character in the given individual; for example, the fact that one species of solitary wasp stings spiders, another species caterpillars, can not be interpreted as a "seeking out" of the respective victims as a man singles out an object qualitatively. T. W. Ziegler has pointed out that the "purpose" concept generally depends upon a misunderstanding of the actual nature of the act. Thus the dragonfly lays its eggs upon water, not because the individual anticipates the development of the young in water, but because when gravid it is caused to react in this way to a shimmering surface. This explains why the eggs are frequently laid non-adaptively, for instance on a freshly tarred roof which gleams in the sunlight. The typical adaptiveness of "instinctive" acts can only be understood as a result of the long evolutionary process which has produced in the given species an equipment of sense organs, nervous system and muscles capable of such and such reactions when aroused in particular ways in a given environment.

To understand the nature of particular acts, it is essential to discern the particular organic circumstances under which they occur, and the environmental factors implicated. For example, the larva of the moth *Myelois* develops from an egg which is laid in the head cluster of an herb. The larva feeds upon the plant until mature, then leaves the herb and enters the stem of a

nearby plant such as a thistle within which it develops into an adult. A critical phase of the act concerns failure to remain within the herb. É. Rabaud varied temperature, humidity and other environmental conditions in an attempt to discover the cause; however, regardless of such changes the larva would remain in almost any place but the herb once it had ceased to feed and had matured. The evident basis of the act was an avoidance response to the essential chemical of the herb, apparently introduced by organic changes occurring at maturity. On a similar basis the larvae of many plant-feeding Lepidoptera become positive to gravity and negative to light upon reaching maturity, whereupon these larvae descend from the food plant and enter the ground where they enter pupation.

Such behaviour may be regarded as automatic in the sense that it occurs in dependence upon the arousal of particular organic equipment such as sense organs, and often upon the attainment of a particular physiological condition. To illustrate the latter, J. H. Fabre in his argument for the "inflexibility of instinct," reported that mature mason bees can perform only once the action of biting their way out of the paper cells in which they pass their pupation period. However, L. Verlaine found that within the first day after their original escape the young individuals could repeat the act, unless the material closing the cell was too hard or tough for the strength of their biting reflexes. Fabre was mistaken in his conclusion because he tested misrepresentative conditions. That an apparent "inflexibility" really depends upon the existence of a given organic condition may be illustrated by the fact that spiders can repair torn webs, or not, depending upon the condition of their different spin-glands; and dispossessed caterpillars can construct new cocoons unless they have reached an advanced stage at which their supply of silk is nearly exhausted. The performance of different functions according to age in certain social insects has been attributed by G. Rösch and others to given structural changes depending upon growth. For a time after first emerging from pupation, the young worker honeybee specializes in feeding larvae; however, brood-feeding ceases when the salivary glands atrophy at the 15th day, whereupon the young worker busies herself mainly in comb-construction and other activities within the hive. This specialization persists through the period when the wax glands are in their most active secretory condition, then at about the 25th day the bee begins her activity as a forager outside the hive.

That it is the organic factors (such as given visual organs, etc.) and not the "behaviour pattern" itself which the insect inherits is indicated by experiments such as those of W. H. Thorpe. Normally the ichneumon fly *Nemeritis* lays its eggs upon the larvae of the flour moth, upon which the ichneumon larvae feed as they develop. However, when ichneumon larvae were raised experimentally upon larvae of the bee-wax moth, later as adults they laid their eggs parasitically upon these insects instead of the normal prey, the flour moth. Such findings suggest that the selective stinging or ovipositing responses of adult females in parasitic insects such as solitary wasps (*e.g.*, one species to bees; another to spiders, etc.) are based not only upon the evolution of factors such as chemical receptors of given sensitive properties, but also upon a *learned* habituation to a particular chemical as a characteristic part of its early environment. That a similar learned adjustment is involved in the "nestmate recognition" of social insects is indicated by experiments upon artificial mixed colonies of ants. Individuals of four or five different species which have lived together in a common nest from the time they are artificially removed as new or callow workers from their cocoons, attack members of the colonies from which they were originally removed, but not their accustomed nestmates. Evidently they have become habituated to a composite of the different chemicals established in the unusual nest situation, so that the nest chemicals of their respective species are disturbing to them.

Many other results show that the inherited organic factors which underlie so-called instinctive activities require given environmental effects and frequently require the influence of learning in some form if the characteristic behaviour patterns are to appear. Certain findings for social insects such as ants indicate that the learned modification of given early reflexlike responses (*e.g.*, automatic regurgitation of food upon tactual stimulation of mouth-parts) provides a basis for the development of more complete behaviour such as approaching and feeding other individuals of the colony. It is quite possible that the following of odour-trails as in many ants comes into being as an extension of the individual's earlier habituation to a given chemical within the nest. Thus an alternative to the rather mystical view of insect social behaviour as a set of "instincts" is that while certain specific inherited organic factors are essential, the pattern depends for its nature upon a characteristic environmental situation and individual habituation.

In evaluating the status of insect activities, certain other ways in which learning appears in their lives must be considered. Honeybees and other social insects have been shown capable of learning simple discriminations between wave lengths of light (colour vision), as well as between figures of different outlines. Honeybees and ants have been trained to visit a food-place at one or in other cases two particular times of day, by presenting food only at such times during the training. Other tests show that this ability, called "temporal memory," depends upon stimuli from internal processes which arouse the insect after training. Ants of certain species have learned maze patterns of some complexity. All of these instances involve a marked elaboration of the capacity for orientation over that found in lower vertebrates, in which a tropistic orientation directly forced by stimulation is predominant. Nevertheless, the manner in which insects learn and the complexity of some of their habits does not prove to be more than a secondary factor in their behaviour. Their behaviour, like that of invertebrates in general, is species-stereotyped and dominated by factors arising through organic inheritance. (*See* Social Insects.)

THE FUNDAMENTAL VERTEBRATE BEHAVIOUR PATTERN

The possibilities of vertebrate organization, in particular of the tubular type of nervous system with its anterior brain (*see* Brain), are not very fully realized in cold-blooded vertebrates and birds. The control of locomotion and equilibrium is substantially as well developed in the lowest vertebrates as in mammals, illustrated by the versatile three-dimensional movement of fishes in their aquatic medium; however, the mammals are greatly superior in their capacity for individually new behaviour in response to environmental difficulties.

Contributions of Growth or Maturation.—Through the work of G. E. Coghill in particular, the appearance of basic vertebrate activities such as locomotion and the feeding lunge has been traced to the growth of different components of reflexive sensory-motor arcs in the nerve tube. Coghill's method in studying the appearance of fundamental activities in the salamander, a tailed aquatic amphibian, was to observe closely all new changes in behaviour and for corresponding ages to make parallel studies of the growth of nervous tissue in detail. For example, there was found an early nonmotile stage during which the animal does not move at all unless the muscles are stimulated directly; at this stage no nerve cells have developed connecting sensory surfaces with muscles. Then at about 30 hours of age there gradually enters a bending of the head away from the side stimulated, a response based upon the growth of cells in the nerve tube conducting impulses from the stimulated part of the skin to efferent (motor) neurones which arouse muscles on the opposite side of the neck. Coghill traced the appearance of the complex S-movement of swimming in this amphibian to later and more complex growth changes in the nerve tube. The work shows that in the development of swimming in this organism, the appearance of successive modifications in behaviour depends upon the growth of new types of connection in the nervous system. The organism may be drugged to prevent movement through the early period of development in which swimming normally appears, yet upon recovery swimming appears as in normal animals, by virtue of previous organic growth in the motionless specimens. Although these mechanisms are much more complex than those described for lower invertebrates such as the starfish, they are substantially on the same level of reflex-integrated behaviour.

Broadly speaking, the innate reflexive and structurally-dependent components are dominant over behaviour in the lower vertebrates from fishes to birds. Characteristically, activities such as those involved in feeding and mating are governed by the discrete (*i.e.*, separate) and partial characteristics of a situation, such as the visual-movement effect of an object, rather than upon its nature as a whole. Fishes, amphibians and reptiles tend to give their respective forms of the characteristic vertebrate forward lunge irresistibly in response to the movement of objects in the visual field. In one experiment frogs struck repeatedly at a fly surrounded by a ring of sharp points; in another, all attempts to train toads to snap at motionless mealworms turned out negatively.

Factors Limiting Modification.—To be sure, modifications are possible within limits through conditioning. Fishermen find that artificial bait is most effective when the given fly or plug resembles the prey upon which the fish are feeding at the time. Minnows have been trained to inhibit their initial snapping responses to chalk falling through the water, while continuing to respond to pieces of bread as before. The learned habits of lower vertebrates, like their unlearned responses, are dominated by the effect of discrete stimulative properties. However, it frequently happens that given discriminations can not be learned, because of interference from unlearned factors. In an experiment with the lizard *Lacerta,* H. Ehrenhardt found distinct limits to the possibility of training, where it opposed unlearned responses. Initially the animals were tested in their responses to simple geometrical figures which were moved before them against a black ground. Their spontaneous lunges were elicited most readily by the movement of figures with even outlines, such as circles; least readily by figures with broken outlines, such as triangles and crosses. In an attempt to change this state of affairs, a training series was conducted in which the preferred circle was always presented with a quinine-treated mealworm mounted before it, the less-preferred cross with an untreated mealworm. Yet within 850 trials no effective modifications of the original responses appeared.

In submammalian vertebrates it is not the nature of the object, but the discrete properties of the stimulus (*e.g.*, movement, size, brightness) which are adequate to elicit responses. K. Lorenz uses the term "releasers" for stimuli which characteristically arouse given types of response; however, this concept has been criticized as too simple and not emphasizing the actual nature of effective stimuli. The problem is far from easy. For example, the characteristic mouth-opening response (gaping) of young birds in many passerine species is elicited at first only by mechanical stimulation, vibration or movement of the nest; later it is given to the visual stimulation presented by any object (*e.g.*, a black disc) which is larger than one-eighth inch, moving and above the horizontal visual plane of the nestling. Then the young bird tends to gape toward the highest part of the stimulus object, especially at any small protuberance in that part of the figures. The facts suggest that at first the young bird reacts on an unlearned basis to very general stimulus properties, but gradually becomes conditioned to respond to special features of the external situation which have accompanied feeding (*e.g.*, protuberances resembling the head of the parent bird above its body at the edge of the nest).

In submammalian vertebrates the behaviour repertoire appears mainly through arousal of inherited structures in a given environment, with learning subordinate. This is true in the birds, which have a particularly rich equipment of natively-determined activities. In many of these, like migration, it is difficult to discern any essential contribution of learning in the principal acts. Migration in the spring, as it occurs in birds like the junco, evidently is set off through the attainment of internal changes (in pituitary glands, sex glands, fatty tissues) caused by the progressive springtime increase in daily illumination. Birds migrate in the wintertime, if this environmental change (*i.e.*, increasing illumination) has been duplicated experimentally. The direction and the main course of migration, when better known, may also prove to be based upon unlearned factors (*e.g.*, temperature gradients, food supply). The case is different for activities such as homing and pecking, for which experience seems indispensable. Thus, for a pigeon to return dependably from unknown territory, the bird must receive a systematic early training in which successive returns to the cote are made over increasing distances in a given direction. Other activity patterns, such as pecking in the domestic fowl, seem to depend upon a post-hatching process involving learning, in which certain early reflexlike activities are modified and integrated. Shortly after hatching the component activities (head lunge, bill opening and closing, and swallowing) are essentially independent; however, through a gradual process of improvement a fairly well-organized and accurate pecking response appears within four days. Chicks which are fed artificially and kept in the dark for a few days must go through the same process of gradual improvement, although in their case it occurs more rapidly, in part because of organic advantages such as greater muscular strength. Chicks which are artificially delayed longer than two weeks can be trained to peck at food only with great difficulty, since they have learned to feed in other ways than by pecking. Thus it can not be said that maturation or growth dependent upon hereditary factors contributes the *pattern* or organization of pecking in the chick; rather, it contributes the individual components (swallowing, etc.) which must be organized together according to experience. Other evidence indicates that although the chick pecks at small bright objects without benefit of learning, it can discriminate between edible and inedible objects only on the basis of early experience in pecking.

In reptiles and birds, although learning is still subordinate to unlearned factors in the development of behaviour, it contributes more in general than in fishes and amphibians. In the lower vertebrates generally, psychological organization is limited not only by a domination of unlearned factors, but also by a characteristic lack of plasticity and scope in learning. The habits, simple or complex, tend to be controlled by limited features of a situation rather than by broader aspects to which mammals can learn to react. For example, in an experiment by J. Porter, sparrows learned to open a puzzle box containing food by pressing either one of two parallel trip strings which operated the door. Then the strings were moved farther apart; this prevented the birds from opening the box, since the subject's response was to alight where a string had been, instead of responding to either string in its new position. Rather than learning how to open the door, the bird had merely acquired the stereotyped response of alighting in a particular spot, which scarcely prepared it for adjustments to changes in the situation.

The Brain and Behaviour.—To understand the basis of the characteristic deficiencies of submammalian animals, as contrasted with mammals, it is necessary to consider the function of the nervous system in the organization of behaviour. Behaviour organization is restricted to a low level in invertebrates like the starfish, in which adequate nervous interconnections are few and the dominance of available centres is greatly limited. In the worms there is an advance in the sense that a principal centre has appeared, yet it dominates largely as a superior transmitting centre rather than an organizing centre. The insect brain is superior in function, yet its organizing influence is rudimentary, as is shown by the fact that the activities which appear are always coloured by the characteristic reflexive properties of lower centres or of local functions.

A similar condition prevails in the lower vertebrates. As comparative neurologists, and in particular C. J. Herrick and C. Ariëns Kappers, have shown, the brain of the inframammalian vertebrate exercises only an incomplete control over the lower reflexive systems. Below mammals the brain is not yet capable of discharging unitary patterns of impulses to lower centres under the influence of many sensory aspects of a situation. Instead, the olfactory system centred in the forebrain, and the visual system in the upper midbrain, are interrelated poorly for activities beyond reflexive types. This accounts for handicaps such as the described inability of lizards to learn the inhibition of a strongly visually-dominated response. An improved correlation of the principal receptive centres of the vertebrate brain becomes possible through the appearance of a specialized type of tissue known

as neopallium (new brain) or *cerebral cortex* (*see* BRAIN). True cortex is present as a small laminated area in the upper forebrain of some reptiles and less clearly in birds, but in mammals covers the entire surface of the forebrain. When the principal centres of the central nervous system are interconnected directly and indirectly through cerebral cortex, its presence permits the overriding of reflexive types of behaviour by patterns organized in dependence upon the wider aspects of an experience. It is the evolution of cortex in particular which is responsible for the greatly broadened capacities of mammals for new behaviour.

PSYCHOLOGICAL SUPERIORITY OF THE MAMMAL

In the mammals from marsupials to man, the psychological limitations of lower animals are overcome to an increasing extent. In keeping with more versatile capacities, the world of the individual animal becomes increasingly wider and varied. The range of these capacities is broad, evidencing itself particularly in the resources of individuals for acquiring appropriate ways of behaving in new situations.

Development of Behaviour in Mammals.—Correlated with the longer infancy and childhood which characterizes mammals in general, conditions favour the accumulation of a far greater fund of new behaviour patterns than in inframammalian animals. This is particularly true in higher mammals such as primates. In general, the higher we go in the mammalian series, the longer the time required for the processes of organic development (especially growth of sense organs, nervous system and muscles) called *maturation.* Accordingly, behaviour processes which are closest to reflexes and require the least learning appear earlier in most lower mammals than in higher. For example, the young opossum at birth is able to crawl from the cloaca over the mother's abdomen to her pouch, by virtue of the fact that at this early time (just 12–15 days after development began) its forelegs are capable of pulling it along as the abdominal hair of the mother is grasped reflexly. At this stage the hind legs are virtually useless. Once in the pouch it becomes attached to a nipple and remains for several weeks, but after 60 days occasional excursions are made to the outside, and the animal has become capable of running and climbing well. In contrast, although at birth the human infant has a hand-grasp reflex sufficiently strong to support its weight for a minute or two, crawling typically does not take place until after 8 months of age and independent walking until after 15 months.

Even with their more rapid maturation, lower mammals typically are poorly equipped for coping with the external environment at the time of birth. Newborn kittens and puppies are essentially embryos, although capable of activities such as the sucking reflex and a crude righting response. Adequate external adjustments of the adult type appear slowly. Although it is recognized that growth contributes heavily to basic activities such as walking, the roles of environmental conditions and learning are not to be excluded in any case.

Influence of Environment and Learning.—Traditionally, activities appearing at or shortly after birth, or activities appearing widely through a species, have been considered inborn and "instinctive." Yet it has been objected that in the typically gradual appearance of activities in the developing mammal prior to birth, simple conditioned-reflex learning is possible, and furthermore, under much the same postnatal conditions all members of a species may be influenced by learning in similar ways. For example, Z. Y. Kuo has shown that the appearance of the characteristic mouse-hunting response of kittens depends to a large extent upon the kind of environment in which certain structural equipment is called into action. The first appearance of the act of pouncing upon a mouse is not "hunting," but is merely due to the fact that seen-movement excites the kitten to dart forward. This response is somewhat similar to the more stereotyped forward-lunge of lower vertebrates. In the kitten, what act becomes established depends upon prevalent conditions. In the characteristic environment, pouncing leads sooner or later to the taste of blood, since the kitten inherits sharp claws capable of puncturing the mouse's skin. The taste of blood stimulates feeding, and after a few repetitions the mouse-killing act is established. Under other conditions different results arise. By shocking kittens from the first in the presence of mice, the pouncing response was displaced by a fear reaction. By having kittens live continually in the presence of mice their responses to mice became those of social companions. The results indicate that while the inherited construction of the kitten is such that it readily makes given responses, organized patterns of behaviour such as mouse-hunting must be built up through experience.

Effect of Heredity Typically General.—It can be said that the specific influence of hereditary factors is much greater in the lower mammals than in the higher. For example, sexual activities appear less stereotyped in chimpanzees than in rats, and their organization evidently is much more influenced by experiences such as those in play. But for mammals in general, hereditary physiological influences limit and bear upon behaviour in broad and indirect ways, instead of determining the composition of particular complicated acts as in lower animals. It has been shown for example that the basis of the characteristic docility of the albino rat as contrasted with the savageness of the gray Norway rat is physiological and hereditary. Wildness is dominant in the progeny, which shows wildness-tameness in Mendelian proportions when further crosses are made (*see* GENETICS). The increasing difficulty, as puberty approaches, of controlling the previously tame domesticated young of ordinarily savage forest animals, such as the cats, suggests that glandular secretions play a part in species differences of this type. Similarly, when under the influence of the glandular changes incident to bearing young, mammalian mothers of various species are likely to show an increase in irritability and aggressiveness. Such factors tend to oppose or distort the capacities of an animal for intelligent behaviour, and their presence to variable extents in mammals high and low in the group adds difficulty to judgments of relative intelligence.

Of all animals, it is man himself whose adult behaviour pattern is the slowest to appear and the least dominated in final makeup by maturation. In a study in which a human infant and a chimpanzee infant were raised from birth in the same household, with a similar treatment, the benefits of more rapid organic maturation at first were all in the young chimpanzee's favour. At the age of five months it had reached a performance level exceeding that of the human infant at one year, exhibiting activities such as climbing, manipulating objects, and responding to individuals around him. The superiority of the chimpanzee in the co-ordination of progression and other general activities continued; however, the human infant presently began to excel in other respects. After he had reached the age of one year, with the appearance of the first true word-sounds, it became clear that in accomplishments such as mastering new meanings of objects and responding to adults, his accomplishments lay well beyond the chimpanzee's limitations. It is evident that the psychological superiority of the human individual over other mammals rests not merely upon his longer preparatory period of infancy and childhood, but his capacity for acquiring new and increasingly plastic adjustments to things and individuals around him during this period.

Drive and Motivation in Mammals.—Certain classes of behaviour once spoken of as "instincts" have become understood more clearly in modern experimental psychology as products of organic "drives." Drive is a term for a particular physiological source of nervous energy promoting activity in the individual. Examples of major drives are thirst, sex, hunger and, under special conditions, parental drive. Each type of drive-energy is known to arise from a rather distinctive type of physiological condition: for instance, the hunger drive emanates chiefly as nervous impulses from the rhythmic contractions of a fairly empty stomach; the sex drive from complex conditions centring around the secretions of the sex glands. The individual drives tend to have identifiable rhythms, each increasing and decreasing in a characteristic periodic way. The dependence of rhythmic changes in general behaviour upon internal drive fluctuations has been established in many experiments, for different animal forms and for man. An interesting study by G. H. Wang demonstrated

a relationship between the oestrous (egg-maturation) cycle and the daily amount of activity in the female rat. Each animal was kept in a small cage, from which it could enter an adjoining revolving wheel when prompted to exercise. A cyclometer attached to the wheel recorded the total amount of activity for each day, and parallel examinations were made of the rat's reproductive tract for signs of oestrus. It was found that the oestrous or heat periods came regularly at 4–5 day intervals, and at corresponding times there always occurred marked increases of activity in the females. This activity rhythm did not appear in the immature female, and it disappeared in the mature female after spaying, during pregnancy, or after menopause.

Drive signs such as stomach contractions have been demonstrated in animals from molluscs to man, and their influence upon behaviour has been identified in a variety of instances. Some broad distinctions may be made in the types of responses given by different animals to drives. Invertebrates and lower vertebrate animals tend to respond to specific stimuli in characteristic tropistic or reflexive ways when these stimuli are encountered by a drive-aroused individual. For example, a female burrowing-wasp of given species, fertilized and laden with mature eggs, stirs about and is especially excited to sting a spider when one is encountered; the egg-laden female jewel fish is particularly attracted by the movements of an individual of brilliant coloration and adequate size. The effective stimuli are essentially unlearned. The potency of movement to excite the feeding responses of lower vertebrates has been mentioned. In contrast, the object or incentive which attracts a hungry mammal tends to be discriminated from others on the basis of stimulus properties governed largely by individual past experience. The peculiar individual food habits of many pet dogs and cats illustrate the point. The increasingly broadened and specialized responses of mammals to drives depend upon a superior capacity for learning differences among environmental conditions. There is also an important difference between lower and higher mammals, which comes to a head in primates and especially man: the acquisition of the ability to have a drive-tension satisfied or lessened by objects or conditions only indirectly related to the original incentives. A pat on the head stimulates a trained dog to further efforts, but a rat can acquire such special learned control only slightly if at all. Chimpanzees may be trained to work for poker chips which later may be inserted into a food-delivery slot; thus the inedible object itself acquires a measure of drive-satisfying effectiveness for the animal. This is a capacity for symbolic satisfactions which reaches its greatest development in the highly indirect power of words over human motivation.

Sensitivity and Perception.—There have been many attempts to describe the world of the lower animal, on the basis of what is known about its sensitivity. Thus one might speculate that for the honeybee a flower patch is a pattern of colour and even conveys to the insect peculiar glimmers of ultra-violet here and there; to the bird skimming low the patch is vari-coloured without ultra-violet effects, whereas for the house-cat stalking the bird, the scene has a washed-out and colourless tinge. Such descriptions have the vagueness of all inferences concerning animal consciousness.

To be sure, the first step in understanding an animal's effective environment is to explore its sensitivity. A basic type of investigation in animal psychology concerns these three problems: what types of stimulation the animal is equipped to sense; what are the upper and lower limits (thresholds) of sensitivity in each of the sensory fields; and what is the acuity (*i.e.*, the degree of sharpness) in each field? In the general sensory equipment of animals countless striking differences are found. There are animals living altogether in darkness, such as cave-fishes, or below the surface of the ground as does the mole, which are very deficient visually or completely blind while possessing a well-developed olfactory sensitivity. Others, like most birds, have well-developed visual sensitivity but are poor in olfaction. Many insects, such as the housefly and the honeybee, although lacking visual sensitivity to the long wave lengths of light (seen by man as "red") are visually sensitive to the rays shorter than those seen by man and most other animals (the ultra-violet band). Some animals such as the cat and dog are insensitive to differences in the wave lengths of light which affect man as colours or hues, whereas others such as the honeybee, many fishes, most birds and monkeys possess a distinctive sensitivity to wave length differences more or less similar to that of man. While we can not prove that these animals can see hues as does man, the objective facts are similar, since in critical tests they can distinguish given wave lengths of light (*e.g.*, 575 mμ, "yellow" for man) from grays of corresponding brightnesses.

There are many important differences in the range of sensitivity. For example, some insects (*e.g.*, the cricket) possess special receptors called chordotonal organs which are specially sensitive to high frequencies of "sound." Many lower animals are sensitive to frequencies above the effective limits of human hearing. The hunter's dog can learn to respond to the exceedingly high-pitched tone of a special whistle, near 30,000 cycles per second, although the hunter himself can not hear it since his upper limit is near 20,000 cycles.

Insect-feeding bats offer another example. It was long thought that their astonishing ability to avoid small objects when flying in the dark was attributable to fine tactual sensitivity; however, it has been shown that the bat's remarkable aptitude for dark-flying depends upon a keen hearing of the reflections of its own supersonic (*i.e.*, above the human limit) vocal utterances from surrounding objects. When bats were released in the dark they were able to fly skilfully among numerous fine wires strung closely together; however, when the bat's ears were plugged, thus eliminating hearing, or when its mouth was fastened shut, thus stopping the high-pitched vocal sounds at their source, the skill disappeared.

In connection with acuity, or keenness of sensitivity, one striking difference in the vertebrate series is that in the most primitive vertebrates, such as sharks, olfactory sensitivity or smell tends to be a highly developed and dominant sensory field, whereas in the higher vertebrates and especially the primates, the dominant field is vision.

Data concerning sensitivity are especially useful for understanding an animal's way of life under natural conditions. For example, a mammal with keen olfactory sensitivity can track prey and tends to become a night forager, especially when vision is acute in dim light, as in the cats. In contrast, one with superior bright-light vision and less acute smell, as the diurnal monkey, ordinarily settles into a routine of daytime activity and sleep at night. Also, the facts of sensitivity are of especial use in accounting for responses in lower animals more or less limited to the tropistic type of behaviour, in which the properties of stimulation are dominant.

Sensing *v.* Perceiving.—Sensory data alone have their limitations for understanding psychological differences among animals. For example, many birds have a well-developed lens eye and a visual acuity which approaches that of man himself and exceeds that of many lower mammals such as cattle and most dogs. Yet psychologically, when the critical matter concerns using sensitivity in mastering object meanings and object relationships, birds are inferior. The status of an animal's sensory equipment is not necessarily a trustworthy guide to its psychological standing.

The resources of the organism for *perception* (*i.e.*, sensing objects in terms of meanings) is better judged in terms of how it deals with objects under varying conditions. For the reflexlike responses which feature the food-getting activities of cold-blooded vertebrates, an interpretation on the level of tropistic behaviour is justified whereas the inference of any true "food" meaning is questionable. For lower vertebrates in general, feeding is essentially a matter of what stimuli are adequate to release the unlearned lunge response; the object-organism relationship depends upon inherited sensory and nervous properties of the animal, rather than upon a special learned meaning of the object. In the full sense of the expression, this is essentially *seeing* and not *perceiving*.

Simplest Perceptual Relationships.—However, the organic

basis for meaningful-sensitivity or perceiving appears to be initiated to some extent even in lower vertebrates, as a capacity to respond to sensory change. For example, after minnows had been trained to respond by snapping at the actual movement of a small bar of light accompanied by food, the snapping response could be elicited merely by exposing the bar twice in rapid succession in closely adjacent positions. Under comparable conditions a human subject would report seeing a "movement," and that evidently was the essential effect upon the fish. The effect of "apparent movement" thus seems to be present throughout the vertebrate series. Many psychologists, and especially those adhering to a Gestalt or Configuration theory, consider such phenomena indications of an ability to "establish relationships."

What is the nature of such capacities? G. Révész trained chickens to peck grains only from the smaller of two figures, by using successively pairs of circles, triangles and arcs clearly different in size, and giving grain only with the smaller member of each pair. Then in a test two arc-figures were presented, identical in size, and both bearing free grains. The typical response of a trained hen was to peck grain from the upper figure but not the lower one. The results suggest that fowl are subject to an illusion of size similar to that of a human subject, who would see the top arc as the smaller, although objectively the two arcs are identical in size. A similar experiment with different materials was performed by W. Köhler. Chickens were first trained to peck grain only from the darker member of a pair of gray cards, then after several hundred trials of original training, new pairs of different grays were presented as tests. In nearly three-fourths of the tests the chickens pecked from the darker gray of each new pair, regardless of its absolute position in the brightness series. Correspondingly, chickens originally trained to peck from the brighter gray of a pair chose the brighter member of new test pairs. Similar results were obtained in comparable tests of a chimpanzee and a child.

These results show that throughout the vertebrate series there is present a capacity for reacting to a visual situation as a unity, in that the visual elements of the situation act reciprocally. If such an organization is termed a "relationship," it should be remembered that its unity is attributable to processes on the physiological level, rather than to more complex processes requiring intelligence.

Contrasts in Perceptual Capacity.—The perceptual limitations of lower vertebrates are suggested by results concerning the basis on which they deal with others of their own species. In the Siamese fighting fish, for example, the male responds similarly to the female and to artificial objects such as clay plugs within a given size range. If the size exceeds certain upper limits and movement is too rapid, the artifact is attacked as are other males. These findings indicate that the male's response depends upon certain discrete visual characteristics which are unlearned. H. E. Howard found that in birds such as the bunting, a mother which feeds her young regularly when they are on the nest will neglect them to the point of starvation when they are removed a short distance from the nest. Evidently the meaning of these objects for the mother bird is far from the level of what "my youngsters" conveys to a human mother. On the other hand, an experienced mother monkey can feed and protect her young in a variety of situations away from the accustomed nest.

With experience an important factor, treatment of the object becomes more versatile in dependence upon changing conditions. The first step is *sensory discrimination*—learning to distinguish and respond appropriately to simple sensory differences. Mammals, less tied to unlearned responses and better learners than lower vertebrates, excel in this capacity. Dogs learn innumerable fine odour discriminations; monkeys learn many delicate visual discriminations. In tests of weight discrimination in monkeys, the animals soon learned to pull in by its string the heavier of two visually identical boxes. The learning involved is relatively simple for a mammal; the critical matter is whether the animal can distinguish two new stimuli on the basis of a given characteristic such as auditory pitch, or visual brightness.

The next stage involves the mastery of a *schema*, or pattern of sensory cues, to the extent that giving a response may depend upon special conditions such as the presence or absence of certain parts of the pattern. At first a young hunting dog may turn to follow almost any animal scent; later, if properly trained, he will track only partridge and only if the scent is fresh. This type of accomplishment, which has been called *conditional discrimination*, places far greater demands upon learning ability than does simple discrimination, and unless very simple lies beyond the capacities of lower mammals.

Appropriate response to the perceptual schema becomes more difficult when it is encountered in a variety of situations, accompanied by variations which initially disturb the animal. For example, not all pet dogs can learn that a walk is forthcoming only when the master wears his hat, rather than when he merely stands near the door holding the leash. A control over the essential significance of the schema despite the presence of various confusing meanings under different conditions, marks the mastery of a more complex set of relationships frequently termed an *abstraction*. As an elementary instance, white rats after hundreds of trials become able to jump to a three-cornered figure ("triangle") in any position into which it is tilted, and avoid a circle; whereas the chick is lost, after learning to discriminate these two figures, if the specific learned position of the "triangle" is changed.

Discerning a given pattern in varying circumstances, amid confusing differences and partially similar features, is an accomplishment in learning relationships of which only the higher mammals are clearly capable. The limit of the lower mammal for "abstraction" is soon reached. In contrast (as N. Kohts has shown with her matching-from-sample technique) the chimpanzee is far more versatile, and can single out the given schema (*e.g.*, "triangle") although it is presented in different sizes and colours and among other figures similar to it in colour and size.

Very different attitudes have been taken toward the subject of perception in comparative psychology. To those who find in lower animals a mind analogous to human consciousness it seems desirable to attempt an inference from behaviour of the animal's consciousness of its environment. On the other hand, modern experimentation has strengthened the tendency to describe the perceptual capacities of different animals in terms of how they can deal with objects under different conditions. Analogies from human consciousness are often criticized as vague because they are not readily checked against fact, and because they are strongly influenced by the simplest aspects of sensitivity. The key matter for perception is not the presence or absence of given features of sensitivity (such as colour vision), but rather, the given animal's ability to organize sensory data in dealing appropriately with new situations. This is critically dependent upon its resources for learning new adjustments.

THE LEARNING CAPACITY

If lower animals are superior in their fund of activities influenced by hereditary equipment, this is more than balanced by the capacity of mammals for acquiring new behaviour through learning. E. Hering and others have viewed memory as a general property of all protoplasm, in that the action of a stimulus upon organic matter always leaves some physiological changes which may influence further responses to stimulation. In this sense "memory" would include even the simplest types of trace effect and behaviour changes such as those in plants and Protozoa. Such changes are comparable with those termed *hysteresis* in physical objects—for example, a temporary change in electrical conductivity through the action of a single charge upon a metal bar. However, in the comparative psychology of learning, the fact of primary importance is not the mere presence in the organism of some trace-effect of stimulation, but what class of trace is involved as indicated by its contribution to the organization of individual behaviour. The problem then becomes one of studying the change in organization in relation to the animal's environmental adjustments. Learning to turn right may be termed a *habit*, whether it appears in earthworm or in man, in the sense that in both cases a learned activity is involved; yet the manner of learning and the significance of the act for further behaviour is certain

to differ radically in the two cases. To understand the nature of learning it is necessary to study such differences among various animals.

The Varieties of Learning.—*Adaptation and Fatigue Phenomena.*—The simplest type of "trace" phenomenon is one based upon processes akin to sensory adaptation or muscular fatigue. If a child has become dark-adapted by staying in dim light for a time, as long as given chemical changes persist in the rod-cells of its eye it will see poorly in bright light and collide with objects. A dog which has just run a long distance scratches himself weakly, because of fatigue changes (*e.g.*, lactic acid in muscles) which temporarily impair muscular contraction. Similar instances based upon adaptation or fatigue are identifiable throughout the animal series from Protozoa to man. They are not generally classed as instances of learning, for these reasons in particular: they are really only local in their scope, survive only for limited times, and do not affect the typical behaviour of the individual in any extensive or relatively lasting way.

It is otherwise with many instances of negative adaptation, in which given stimuli in the course of time cease to have their initial effect. A snail in an aquarium continues to feed and does not contract as at first when it is jostled by a passing fish; a trained draft horse becomes accustomed to wearing his harness without disturbance; a clerk becomes able to work in a noisy office. Such cases involve more thoroughgoing and lasting changes in behaviour than is possible through simple local trace effects such as those underlying fatigue and sensory adaptation. Very probably they are closely related to simple conditioned-response learning.

Conditioned Responses.—Conditioned-response learning is found at the lowest point in the animal series where learning has been dependably demonstrated—in the flatworms. It has been described as the simplest form of learning, in that the essential result of the conditioning process is a new stimulus-response connection, and the nature of what is learned depends upon what given stimuli play repeatedly upon the animal. That is, the experimenter or animal trainer, by his selection of a given pair of stimuli, determines what new behaviour is to be acquired. The procedure is simple: on each trial an original or "unconditioned" stimulus, selected because it elicits the critical reflex or other response at the outset, is presented with a new or "conditioned" stimulus which does not at first produce this response. By pairing these stimuli repeatedly, the new stimulus finally is made a controlling (*i.e.*, fully conditioned) stimulus, in that it now elicits the critical response in the absence of the original stimulus. In the classical experiment of I. P. Pavlov with dogs, meat-powder-in-mouth was the unconditioned stimulus, secretion of saliva the critical response aroused by it, and a bell-sound the conditioned or new stimulus which finally came to elicit salivation through repeated combination with the meat powder. (Fig. 2.)

It is probable that almost any given response, reflex or learned, may be conditioned if the necessary stimuli are appropriately paired. Although at first a dog scratches only in response to local irritation of the skin (*e.g.*, from a flea bite, or a mild electrical shock) the appropriate pairing of this original stimulus with the snapping of fingers, the sight of a whip, or the smell of perfume, will condition the critical scratching reflex to the given new stimulus. In higher animals, and especially in the mammals, additional features of the situation beside the focalized new stimulus typically gain some importance for conditioning. In Pavlov's experiment, for instance, both the general appearance of the customary room and the tactual effect of the experimental harness were of importance as secondary conditioned stimuli, as was shown both by occasional responses to such stimuli alone, and by the reduction of salivary response to a given conditioned stimulus (*e.g.*, a buzzer-sound) when the animal was tested in a new room without his harness. In this way features of the situation which are regarded as incidental or are overlooked by the experimenter may become critically important, as in the case of the "counting horse," which had somehow become conditioned to start and to stop tapping according to slight movements of persons nearby.

Conditioned responses are not the same wherever found in the animal series, but vary in their degree of complexity and their relation to other behaviour. For this the learning capacity of the given animal is critical. In the invertebrates capable of conditioned learning and in lower vertebrates, conditioning is held largely to combining reflex or forced responses with elementary (*i.e.*, uncomplicated) stimuli. In mammals, there appear wider possibilities of conditioning learned responses to more complex stimuli, and we may speak of systems of conditioned responses. The importance and prevalence of such learning is illustrated by many routine (but learned) acts in food-getting, evading customary disturbances, and other everyday practices of domesticated and pet animals. The milkman's horse with its ability to start or stop according to given special footstep-and-bottle sounds may be offered as an example.

In mammals there appears more and more prominently an ability to modify conditioned responses according to prevailing conditions. For example, in conditioning a dog to bell-sound (new) coupled with a shock to one leg which elicits reflex flexion (pulling back) of that leg, not only does the bell-sound alone presently cause the given leg to pull back without the electrical shock, but other changes appear. It is noticed especially that, as training continues, the leg gradually flexes less and less, until finally it lifts just enough to clear the paw from the shock. The learned modification of conditioned responses according to their consequences (*i.e.*, food, or removal of an irritating stimulus) actually represents the merging of *conditioned*-learning with *selective* learning, to be discussed below. Such elaborations of conditioning become possible in higher mammals, particularly in dependence upon their superior nervous equipment, as experimentation has shown. For example, the above experiment leads to skilful paw-withdrawal only in normal dogs. When the cerebral cortex of the brain was removed by operation in certain dogs, later, even after hundreds of trials, no conditioned learning was possible beyond general excitement and random leg flexion when the bell sounded. In contrast to the skilful response of one paw in normal dogs, the shortcomings of conditioning in mammals without brain cortex resemble the limitations of lower vertebrates and invertebrates.

Trial-and-Error or Selective Learning.—This form of learning, which reaches its peak in the highest mammals, has not been clearly demonstrated below the arthropods. It may be illustrated by the behaviour of a hungry dog outside a food-box which can be opened only by pulling a cord which hangs on one side of the box. If such problems are quite new to the dog, his first responses are highly variable. He does nearly everything which is possible for him to do under the conditions. He paws at the bars and squeezes his nose between them, paws and scratches at the ground near the box, at intervals runs around the box, then presently sits and howls. At length the cord is pulled by chance, in the course of random biting or pawing at objects, and the dog enters the open door when he sees it, to the food. The first trial typically is very long; however, as E. L. Thorndike first reported from experiments with cats and other mammals, further trials involve decreasing amounts of random activity and hence less time is required to pull the cord. Because of these characteristics the name "trial and error" is frequently applied to such learning. The first change to appear is that more and more time is spent working in the general vicinity of the cord; gradually superfluous activities drop out until finally the dog pulls the cord as soon as he is introduced into the situation, and directly enters to the food. The animal has mastered a habit which, through what is called *selective learning*, an organization of appropriate responses remains from his initial random behaviour.

Many kinds of problem-box situations have been used in studying selective learning, from types in which the animal's escape or his entrance to food depends upon pressing a pedal, unfastening a latch, or working a lever, to elaborate combinations of these and other difficulties. Higher mammals such as the monkey master problems (*e.g.*, a combination of latches) which are insoluble for the lower forms, not merely because of superior manipulative ability, but especially because of a superior capacity for organization in learning. Birds, in contrast to mammals, not only seem

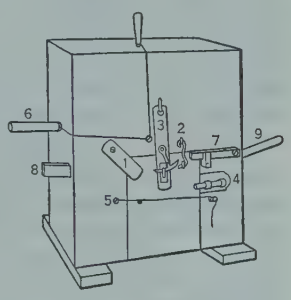
FROM (1) KÖHLER, "MENTALITY OF APES" (HARCOURT, BRACE; KEGAN PAUL, TRENCH, TRUBNER); (2, 3) KOHTS, "INFANT APE AND HUMAN CHILD," REPRODUCED FROM YERKES, "CHIMPANZEES" (YALE UNIVERSITY PRESS)

PRIMATE BEHAVIOUR STUDIES WITH CHIMPANZEES

1. Köhler's chimpanzee Sultan making a single stick-tool of two sticks, each too short to reach distant food through a wire fence
2. Not humour, but a temper tantrum
3. Mrs. Kohts pretends distress; the chimpanzee appears to be sympathizing

to learn more slowly, but also acquire an inferior mastery of the problem. For example, they may be taught to press a horizontal string to open the door of a box; but if this string is moved to another place on the box after the habit is learned, birds tend to work in the place where the string hung at first instead of shifting their efforts to the string in its new position, as most dogs would. Inferiority of the lower vertebrates in selective learning appears especially as an inability to master relationship between the critical act (string-pulling), the object acted upon (the string) and the end result (getting food).

An instrument much employed in the study of selective learning is the maze or labyrinth, in which the presence of blind alleys affords a special means of studying the elimination of errors. A variety of animals has been tested, from the crab to the chimpanzee and man, in maze patterns of many types and degrees of difficulty. Some of the differences are striking. For instance, to learn a simple maze with only one blind alley the crayfish *Cambarus* required at least 60 trials; whereas ants of the *Formica* (mound-building) species have learned mazes containing six blind alleys within 35 trials, and white rats required 12 trials or less to master the same pattern (enlarged to scale).



FROM KINNAMAN IN "AMERICAN JOURNAL OF PSYCHOLOGY," VOL. 13, P. 112 (1902)

FIG. 3.—KINNAMAN'S COMBINATION PUZZLE BOX FOR TESTING MONKEYS. NUMBERS INDICATE THE REQUIRED SEQUENCE OF MANIPULATING ITEMS FOR SOLUTION OF PROBLEM

More significant than the number of trials required is the fact that inframammalian animals learn in a different and inferior way as compared with mammals. In the maze-learning of ants and birds, for example, not only do particular errors tend to persist much longer than in the rat, but avoidance of individual blind alleys progresses much as though these were independent problems. For the rat, learning to avoid different blind alleys is interdependent. The rat's organization of the maze habit ranks well above the way in which inframammalian animals learn; and consequently the rat excels greatly in further tests of the habit. It readily learns to reverse the direction of its learned turn where a given blind alley has been opened and its previously correct alternative closed; it readily learns to make use of new short-cuts which are opened in mastered mazes. The ability to use acquired behaviour in new situations is a particular mark of the mammal's superior capacity for organizing trial-and-error learning.

Space does not permit a theoretical discussion of selective learning, except for certain general remarks on the question of error-elimination. It was formerly thought that a simple punishment-reward theory was adequate, based on the assumption that punishment "stamps out" wrong acts while reward "stamps in" correct acts. Research has shown that, notwithstanding the importance of incentives and motivation in selective learning, this idea is over-simple and misleading. The fact seems to be that punishment and reward as such do not have any necessary automatic effects upon the nervous processes underlying learning. Known functions of the reward or punishment are to emphasize particular features of the situation, and to elicit given responses (*e.g.*, approach to a reward). Thus punishment is advisedly used only in mild forms, to elicit avoidance responses to certain parts of the situation (*e.g.*, to keep the animal on its stool in circus training), or to emphasize certain features. Strong punishment is inadvisable, for it opposes learning by calling out avoidance responses to the entire situation, including the trainer in the case of higher mammals.

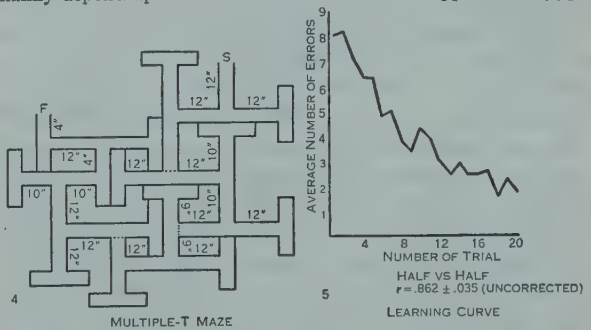
The Problem of Abridged Learning.—It is difficult to interpret a given act correctly unless its background is known. Once when C. Lloyd Morgan had been trying to teach a fox terrier to pull a crooked stick through a fence, unsuccessfully because the dog persisted in pulling the stick so that the crook caught between the fence palings, a passerby arrived just as the dog accidentally caught the crook itself and with a wrench broke it off. Having seen no more than a small part of the entire performance, he remarked, "Clever dog that, sir; he knows where the hitch do lie." The correction of this error, a typical result of superficial observation, is not to say that all solutions in all animals are limited to a laborious learning process. For the given animal may have hit upon the "correct solution" accidentally (as was true in this instance), may have mastered it through a gradual selective-learning process, or may have attained it through a superior short-cut process of which anthropoids (*see* PRIMATES) in particular are capable. The latter type of abridged solution is frequently called "insight."

Our interpretation of selective learning must be revised for mammals when the test situation itself is not entirely new. In this case the animal is less excited and behaves less erratically than in a strange situation; furthermore, the new solution is hit upon sooner because previous learning is influential. As was suggested above in the discussion of perception, it is characteristic of mammals and particularly of primates that habits such as a given pedal-pressing act may be applied in new situations, combined with different amounts of variable activity depending upon the animal and the newness of the problem. The higher mammal appears "to get the point of the problem" more readily, to have more "insight," the greater its previous experience in similar problem situations.

The ability to apply previous learning to shorten the solution of further problems is complex in mammals because of such short-cuts, but relatively simple in lower vertebrates because the capacity for short-cut solutions is virtually absent. Calling a more efficient type of solution "insight" does not explain it; actually, the term is descriptive since it merely emphasizes the presence of a "seeing into" the problem. It suggests a superior kind of organizing ability which is qualitatively superior to that of regular selective learning.

THE PROBLEM OF INTELLIGENT BEHAVIOUR

Intelligent behaviour is defined especially in terms of the animal's capacity for new appropriate modes of adaptation in problem situations. From this category, types of response which mainly depend upon unlearned factors for their appearance (typi-



FROM TOLMAN AND NYSWANDER IN "JOURNAL OF COMPARATIVE PSYCHOLOGY"

FIG. 4.—MULTIPLE-T ALLEY MAZE FOR TESTING RATS. S. STARTING ALLEY; F. POSITION OF FOOD BOX. FIG. 5.—AVERAGE ERROR RECORD FOR 25 RATS LEARNING THE ABOVE ALLEY-MAZE SITUATION

fied by insect adjustments) must be excluded, however adaptive they may be. Furthermore, although intelligent behaviour depends to some extent upon the readiness with which the organism may be conditioned, and more so upon its capacity for selective learning, these are not the most important criteria of "intelligence." Most critical is the animal's capacity for the special short-cut types of adjustment referred to above as "insight," frequently termed "higher mental processes." These necessitate a better command over the special relationships of objects and events than can be attained simply through learning.

Typical "Insight" Solutions in Primates.—The pioneer work of L. Hobhouse, M. Haggerty and others early in the 20th century indicated that the monkey solves various types of problems with greater facility than would be expected through selec-

tive learning alone. For example, in one of Haggerty's problems with monkeys, the subject had to climb the side of a cage and thrust a hand from below into an inclined chute to obtain fruit. After watching another individual solve the problem four times, one animal worked rather directly around the chute and soon had pulled the string in a manner suggesting that, as one would say for a human subject under similar circumstances, "he caught the point" of the problem sooner than he could have acquired it through selective learning. Later, especially in the work of R. M. Yerkes and W. Köhler, similar abilities were demonstrated in the chimpanzee in a higher state of development than in monkeys.

In the experiments of Yerkes and Köhler, chimpanzees were presented with problem situations such as food suspended high above the ground or placed beyond a fence, where it could not be attained by ordinary direct responses such as reaching or jumping, but required some special mode of capture. Although there were many failures and some animals never succeeded very well, the records were replete with instances in which chimpanzees had hauled in food by reaching out with a stick through the wire, or had attained suspended food by means such as stacking boxes or vaulting from a pole. In one of Köhler's tests a chimpanzee which had previously used single sticks only was given a problem in which food lying beyond the wire could be reached only by combining two short hollow bamboo rods. First there appeared inappropriate responses, such as simply reaching out with the arm alone, using the sticks singly, or using one bamboo piece to push the other toward the food. Such behaviour indicates that, although he is not working very appropriately, the animal is employing foreign objects as a means toward the end of obtaining the food—in other words he is using tools. At the end of an hour in this case, the result was apparent failure, since at that point the animal sat with his back to the food, idly handling the sticks. Somehow in this activity a critical change appeared, as follows:

> Sultan first of all squats indifferently on the box, which has been left standing a little back from the railings; then he gets up, picks up the two sticks, sits down again on the box and plays carelessly with them. While doing this, it happens that he finds himself holding one rod in either hand in such a way that they lie in a straight line; he pushes the thinner one a little way into the opening of the thicker, jumps up and is already on the run toward the railings, to which he has up to now half turned his back, and begins to draw a banana towards him with the double stick. (From W. Köhler, *The Mentality of Apes*, Harcourt Brace.)

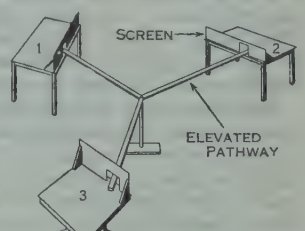
That the combined sticks were perceived and used as a true tool and not used simply by accident, was indicated by the fact that when the sticks became separated, the animal straightway reconnected them in a manner that suggested an understanding of their function together. (Pl. fig. 1.)

"Representation" as a Factor in Reasoning.—The solution processes of chimpanzees often resemble in simpler outline those characteristic of man when he is said to be reasoning. Animal psychologists have studied the lower-animal process in the attempt to find what is most essential to it. One approach, arising from early efforts to test the presence of ideas, is the *delayed-response* method. In its original form, after the animal had learned to go to food through whichever one of four adjacent doors was lighted, special tests were made. In each of these delay tests, the subject was first presented with a light over one of the doors, then after a given interval of time had to find the correct door without the distinguishing light. With primates, the animal was shown food under one of several cups, or saw food buried in one or more places, and after a delay he was permitted to show whether he could go directly to the hidden food.

Although the outcome differs according to procedure and situation, the general result of such experiments is that lower mammals such as the rat require a longer preparatory training, and are more likely to require keeping a given bodily orientation during certain kinds of tests, than are primates. In these tests, monkeys and chimpanzees can delay successfully over intervals of 24 hours or even longer. The general interpretation is that primates owe their superiority to a better ability to *represent* the absent object. That is, in some way the adjustment to the food in a given position is symbolized, so that it can be recalled after the interval of delay. This ability to hold the correct act over an interval is often interpreted as centring around an abbreviated form of the actual adjustment—lifting a box, for instance, might be represented by processes involving a slight tensing of arm muscles as when actually raising a box. According to this view, in comparison with man's great advantage of being able to represent absent things verbally, lower mammals are handicapped by the necessity of representing their adjustments in much less specialized ways.

In lower primates there is evidence for a fairly well-developed capacity for anticipating or dealing with *particular* absent objects. For example, in a delayed-response experiment with monkeys, in which a banana was given on some trials and lettuce (less preferred) on other trials, the subject became emotional and refused to take the lettuce if he had seen a banana concealed before the delay. Evidently the animal specifically anticipated a banana on such trials, for lettuce was taken readily in delay trials which were preceded by the showing of lettuce.

The ability to represent objects which are not immediately present is important for insightful problem solutions. This is suggested by instances such as that in which a chimpanzee, after having worked at a suspended-food problem for some time without success, suddenly turned after a jump and rushed around the corner of a building, returning with a box which he had often seen in that place. Although this ability certainly contributes to the possibility of short-cut solutions, it alone can not account for their occurrence. In particular, it does not account for their *newness;* for the mere recall of represented objects would be a duplicate of the original experience. In the higher primates, particularly, the newness of possible solutions is much more striking than in other mammals.



ADAPTED FROM MAIER & SCHNEIRLA, "PRINCIPLES OF ANIMAL PSYCHOLOGY" (MCGRAW-HILL BOOK CO., 1935)

FIG. 6.—MAIER THREE-PATH SITUATION FOR TESTING "REASONING" IN THE RAT. AFTER THE ANIMAL IS TRAINED TO RUN EVERYWHERE ON THE APPARATUS, WITHOUT FEEDING, SPECIAL TESTS ARE RUN. IN EACH TEST, AFTER A BRIEF FEEDING ON ANY ONE TABLE (E.G., 3), THE ANIMAL MUST FIND HIS WAY BACK FROM EITHER ONE OF THE OTHER TWO TABLES (E.G., 2 OR 1)

Testing Freedom from Stereotyped Learning.—That mammals differ considerably in their ability to discard specific learned behaviour when changes are required, was demonstrated by G. V. Hamilton. The subject, a mammal, was presented with four doors. Only one of the doors was open on a given trial, and this one was never the door open on the last trial. Only human subjects were able to discover this fact; but none of the monkeys, which often tried all four doors in succession on each trial, often without trying any one door repeatedly or neglecting any one door very long. The last type of behaviour, termed a *stereotyped habit* (because it is persistently repeated in a fixed, unchanging way), was most frequent in dogs, cats and horses,—especially in the horse. It is significant that making stereotyped responses, and persistently repeating errors, is a marked characteristic of behaviour in mammals from which roughly one-fifth or more of the cerebral cortex has been removed by operation. Such partially decerebrated animals are inferior to normal individuals on insight problems, much as the horse and other lower mammals are normally very inferior to primates on such problems.

This situation was adapted by Yerkes to the further investigation of plastic behaviour, in his *multiple-choice tests.* The animal was presented with a series of nine doors, with a row of five doors open on each trial, but always a different set of doors (to eliminate simple position learning). Food was to be found behind just one of the doors on each trial, and the subject's problem was to discover that the correct door was systematically related to the others in position. Sample problems were (1) always first at the right; (2) always second from the left; (3) middle door. Theoretically, the experimenter's aim here is to compare the level of intelligence of different animals, by starting with simple settings and increasing the difficulty until failure appears. Thus, in the

above problems starting with (1) as presumably the simplest, both the crow and the white rat solve (1) but fail (2); problem (3) was failed by the pig, but was solved by monkeys. The chimpanzee solves even more complex settings. With settings more difficult than (3), it is possible that success typically comes through an "abstraction" type of solution involving a mastery of relationships among the settings, or what Yerkes calls "ideational processes." To the claim of its advocates that the multiple-choice method affords a means of testing the comparative intelligence of animals, its critics object that the manner in which the method discloses the nature of ideational processes is not clear. Then too, the nature of this problem set-up seems to admit, for certain animals more than for others, the influence of factors opposing the use of intelligence. For example, multiple-choice problems solved with relative ease by chimpanzees were failed by orangutans because the latter tended to persist in wrong responses—possibly because of hampering emotional reactions rather than because of an intelligence below that of chimpanzees.

Relative Capacity for Indirect Solutions.—Many of the special problem-solutions described, even for mammals below primates, resemble the type which in man is recognizable as "perception of relations" or understanding. Numerous types of results indicate that mammals below primates are definitely inferior in this respect. The cat can learn to manipulate a lever, but neither cat nor dog can assemble or use a true tool as can many chimpanzees. Box-stacking in the chimpanzee may be considered a simple form of tool-construction, as may combining sticks to make a single long food-rake. Köhler emphasized the far greater ease with which primates correct their original direct responses to food and substitute more appropriate indirect ones. A hen when separated from food by a wire fence continues for a long time to rush about in zigzag manner close to the food, whereas going around the end of the fence to the food appears more readily in the dog, and far more readily in the monkey. Even when a roundabout route has been learned, the sight of food frequently holds the rat, cat or dog to the spot and prevents using the detour. The greater ease with which the chimpanzee can move away from the goal to reach it indicates a much better mastery of the relationship between its own position, the barrier and the goal. Its superiority to the monkey in this respect is indicated by the chimpanzee's frequent success and the monkey's failure in problems which require a subject to first push food away from him around a barrier before he can draw it in all of the way.

Reasoning as Reorganized Learning.—A feature of short-cut or "insightful" solutions frequently used to distinguish them from the more laborious and gradual solutions reached through selective learning is that the former type of solution often appears suddenly, after a period of apparently fruitless trial-and-error work. *Suddenness* in the appearance of the solution or of new attempts at a solution is especially notable in the performance of higher primates such as chimpanzees, less prominent in monkeys. This frequent abruptness with which the eventual solution comes should not be taken to mean that it occurs independently of previous learning and without more or less random and variable activity in the problem situation.

A useful conception of suddenly-appearing solutions is that they are the result of a completed reorganization of two or more patterns of response which have become available as a result of previous experience in the same problem situation or similar situations. For a time these may exist as relatively unitary adjustments, such as jumping to food and handling a box, which may be used together as one pattern more or less suddenly following numerous activities involving them separately in the food situation. N. R. Maier has offered a demonstration of this type of solution in a simple form in the rat. The animal is first trained to run from one table to another on the 3-way apparatus shown in figure 6, making the runs between each two tables with equal frequency and without feeding. Then in the test, the rat is first fed on a given table (*e.g.*, No. 3), after which he is carried to one of the other two tables (*e.g.*, 1). Purely on the basis of repeating learned responses, the rat in this case would turn with equal frequency to tables 2 and 3; however, the fact is that adult rats are able to return to the one food-table which is correct on the given trial with at least 80% success. The appearance of correct solutions, when a direct recall of learned responses would give chance scores, indicates a capacity for reorganizing items of learning which have been separate in previous experience. A more complex instance of such reorganization, not possible in mammals below primates, would be using a pole to poke food from a hollow cylinder, although previously sticks have been used only in general play and only the arm has been used in drawing out food from tubes. Maier has pointed out the qualitative similarity of such problem-reorganizations to reasoning in man.

MAN COMPARED WITH THE LOWER ANIMALS

Although man is not the most highly evolved animal in all organic respects, his psychological superiority can not be disputed. This must not be considered an absolute superiority, however, for most of man's mental advantages are also shared, although to a lesser extent, by his mammalian relatives.

Reasoning and Foresight.—Although reasoning as an identifiable ability is present widely among the mammals instead of being restricted to man as was once thought, it is limited in the lower mammals to a simpler form and plays a much smaller part in everyday adjustments than in man. Just as the novel use of past learning shows a greater influence upon the activities of great apes than of lower mammals, it is far more prominent in man than in his primate relatives.

One of man's particular advantages is his superior ability to demonstrate foresight, to reason with reference to a problem which will arise in actuality only at a relatively future time. "Time" for the lower animal is largely a matter of the present, and to relatively different extents, the past. The responses of lower animals may be conditioned to recurrent events, on the basis of rhythmic internal processes such as those of digestion, or particular external stimuli characteristic of a particular time of day or of given daily events. The discrimination of short intervals of time in terms of action has been demonstrated in lower animals such as rodents. Delayed-response tests show that their anticipations are also held to fairly short times and to a low level of complexity. Even in the apes the anticipation of future events and reasoning about them is characteristically restricted to specific occurrences of familiar types expected to recur in the relatively near future. The capacity to reason systematically forward to events over relatively long intervals of time requires a greater capacity for reorganizing past experience than is found in any animal below man.

Another way of putting it is that man can utilize his reasoning capacity to plan—that is, to combine and appropriately rearrange whole systems and sequences of reasoned and learned processes with reference to some goal which he expects to reach in the more or less distant future. In the chimpanzee, the simplicity of foresight is illustrated by food-expectancy, revealed in the disturbance shown when less preferred food is substituted for the originally exposed lure during a delay interval of a few hours. If the ape is capable of reasoning in the present to forestall a difficulty expected to arise in the distant future, the ability remains to be demonstrated.

Planning for future needs or future security usually requires not only foresight but also the use of reasoning in what may be called reflective thought. This is illustrated by a man reasoning about his own condition as he observes it in the present or expects to find it in the future, in relation to surrounding conditions present or anticipated. Differentiating and identifying the self in thinking, marked by the first effective use of personal pronouns such as "me" at about two years of age, is an important epoch in the development of human reasoning. This ability is on a far higher level than is an animal's merely reacting emotionally in a direct manner to phases of its own behaviour or appearance, as might a strutting male pigeon or a growling dog prepared to fight. The ability for personally redirected thought is a taking note of one's own condition in relation to the condition of other persons or objects, and through reasoning arriving at appropriate new procedures. This more elaborate type of involuted reasoning is an expression of the superiority in intelligent behaviour which

admits foresight. The fact that all men at times use this capacity poorly, and that some men never appear to use it, does not alter the strength of the comparison.

Spoken Language and Communication.—The process of communication, although frequently confused with the use of a language, must be distinguished from it as much simpler. Communication is involved whenever the behaviour of one individual influences others; whereas a true language exists only when an individual utilizes a special code or system of symbolic activities with the expectation of influencing the conduct of companions in given ways. The simplest type of communication is that in which the behaviour of one individual excites others incidentally through auxiliary effects such as chemicals exuded (*e.g.*, the reflex opening of an excited bee's scent gland) or through special tactual effects as when a termite colony is aroused by the head-rapping of excited individuals on gallery walls. From the category of true language we must also exclude the great variety of sounds and movements which throughout a large part of the animal series influences behaviour in activities such as mating. Effects such as the flashing of fireflies, the chirping of crickets, and the mating colorations, movements and sounds of mature males in many vertebrates from fishes to mammals, all are to be considered relatively incidental products of organically-excited behaviour to which species companions respond on an unlearned basis.

A step is taken toward language when the appropriate responses are learned or conditioned, as often happens in social groups of birds and mammals when the excited cries of one startled individual throw others into flight. Beyond that a very simple symbolism, that is, a learned special cue controlling another's behaviour, appears in mammals when activities which are at first mere accompaniments of emotional excitement (*e.g.*, barking and biting in a dog) appear in a reduced form after merely beginning the act has repeatedly produced flight or some other characteristic reaction in another. Thus, in time a dog learns to "threaten" merely by baring his fangs. Instances of such simple, discrete language activities are not uncommon in the everyday life of domesticated mammals, as for example the "begging" of a hungry dog and the mewing of a shut-in cat before a closed door.

Although primates below man seem to lack any system of symbols which can be termed a true language, on the basis of his extensive experience with chimpanzees Yerkes pointed out that—"Yet combined, the varied signs which are commonly observed serve to keep the animals in effective touch, well informed about one another's presence and attitude, and also about especially significant features of their environment." (From R. M. Yerkes and A. W. Yerkes, *The Great Apes*, Yale Univ. press.) In the chimpanzee one observes a great variety of sounds and movements which specifically influence others in given ways, although they appear more often as incidental features of the first animal's excitement (*e.g.*, the "hunger cry") than as "intentional" means of producing given acts in others. Yet it is well established that the chimpanzee is capable of learning to use gestures as special signs to initiate given behaviour in his companions, as when one taps the shoulder of a lagging companion in a laboratory task, or extends a hand to a new and partially accepted individual.

The general psychological superiority of man is emphasized by his capacity for a systematic code of language symbols. The breadth of this code for expressing meanings is apparent in the fact that its symbols are essentially nonmimetic; that is, the symbol itself (a word or number) is unlike the represented acts or objects. In contrast, the limited language activities of lower mammals are essentially mimetic, in that the symbol or sign is a part of the represented activity which has come to represent the whole. Even the chimpanzee, perhaps the best candidate for verbal language among lower animals by virtue of its linguistic accomplishments together with intelligence, somehow falls short of attaining such a language. Many experimental attempts have been made to teach chimpanzees true vocal-language symbols, without success. The explanation can not lie in a defective process of sound-production, for apes have a surprisingly varied vocal repertoire. The parrot is noted for its ability to learn an exact reproduction of frequently heard sound patterns; however, its utterances are to be considered skilled acts essentially devoid of any meaningful association with the objects or situations which may call them forth.

Factors Underlying Man's Mental Ascendancy.—Apparently, the mastery of verbal symbols even as separate signs calls for a building up of object-meanings and object-relationships which exceeds the resources of chimpanzee intelligence. Chimpanzee symbolic processes, although superior to those of other mammals, are rudimentary and lacking in versatility as compared with those of man. Although the chimpanzee can be taught to ride a bicycle, to use table utensils, and to mimic many particular human activities, the lengthy training process required shows that the uses of human objects are bound more particularly to given sensory properties and to given routines much more rigidly than in the older human child. The chimpanzee learns to use certain vehicles without being able to learn a single abstract symbol (the sound "ride") for the act as does the child, for he never succeeds in really mastering the general properties which different vehicles have in common. Investigation shows that at first the symbols of the human child are similarly limited by centring around particular situations and concrete uses; yet children advance to higher stages, while chimpanzees largely remain on the lower level.

Although some chimpanzees are able to reason out simple tool-using solutions, for the most part they combine objects into new unitary (and utilizable) forms only in crude and rudimentary ways. Their perceptual shortcomings, *i.e.*, their limitations in dealing with object-relations in organized meaningful ways, evidently prevent chimpanzees from interrelating numerous discrete solutions to form *tool principles* which might lead to the creation of more and increasingly improved new tools. Deficient in mastering single symbol-action patterns, the chimpanzee can not arrive at the use of symbols in serial patterns (*i.e.*, in word sentences) to express the interrelationships of varied experiences. Thus his episodes of reasoning are relatively isolated and discontinuous, and he seems incapable of passing on the results of any but the simplest and most routine experiences (*e.g.*, nest-building; parental guidance in locomotion) to further generations as tradition or social heritage.

Even so, the psychological difference between ape and man must be regarded on the whole as relative rather than absolute. This fact is brought home by the superiority of chimpanzee to monkey in functions which may be crudely designated as perception, response to training and memory, general adaptiveness and co-operativeness in new situations in which the chimpanzee stands well below man.

The psychological deficiencies of the chimpanzee as compared with man, and the monkey as compared with the chimpanzee, appear to be imposed particularly by the lesser development and elaboration of cerebral cortex in the lower primates. In the series: rat-dog-monkey-chimpanzee-man, not only is there a progressive increase in the proportion of cortex to body weight, but there is an increase in the number of cells and the complexity of the cortical ganglionic layers. Such increases in anatomical resources parallel an improvement in the capacity for complex functions centring around learning and the reorganization of learning. The validity of this relationship is supported especially by K. S. Lashley's discovery of a high positive correlation between the amount of intact cortex in rats and their performance in learning mazes of differing complexity, and N. R. Maier's finding that the loss of approximately 20% of cerebral cortex abruptly reduced to a low point scores made by rats in a simple reasoning test. That symbolic behaviour and the degree of its development is limited by the adequacy of cerebral correlation function, is emphasized for man by the low attainments of imbeciles in learning even the simplest word meanings, and by the progressive breakdown of symbolic verbal functions with advancing pathological degeneration of cortical tissue occurring in diseases such as paresis. The patient in such disorders becomes steadily more deficient in his ability to define and use words, and may finally reach a stage at which he sees once familiar objects without being able either to name them or recall their meanings.

Contrasts in Emotion.—Those organically aroused states

characterized by experiences of unpleasantness and pleasantness, and ordinarily spoken of as emotions, constitute perhaps the closest psychological relationship between man and lower animals. The experiments of W. Cannon in particular have shown that similar physiological changes such as impeded digestion, release of adrenin, and increased heartbeat occur in connection with strong emotional excitement in lower mammals such as the dog and cat much as in man. Similarly, more placid emotional conditions are characterized by organic changes such as facilitated digestion and slower heartbeat. Thus in what may be called the organic basis, the emotional lives of man and lower animals seem to have much in common.

Fundamentally, there is a close relationship between the outer cause of excitement and the nature of emotionalized response. In higher and lower animals alike, what may be called the strong emotions characterized by *interruptive* visceral changes such as impeded digestion, and impulsive or reflex external responses such as flight or fighting, are aroused by intense stimulation or sudden changes in stimulation. Conversely, gentle repeated stimulation calls out *vegetative* internal changes such as the facilitation of digestion, with the unlearned response of many invertebrate and lower vertebrate animals an approach of the entire organism toward the source of stimulation. In very young mammals the typical unlearned response to weak stimulation appears to be a reflex extension of the stimulated limb. Thus, primitively, the accompanying external behaviour occurs as a reflex, impulsive part of the general state of excitement. The evolutionary significance of the connection is clear; it is highly adaptive to be what Cannon has called on a "war footing" (*i.e.*, reflexly prepared) in the presence of strong stimulation and (whether the animal is capable of perceiving it or not) probable danger.

Because of the similarities in the external and internal aspects of emotional response in man and lower animals, analogies from human consciousness are tempting, such as inferring an experience of pleasantness when the emotional reaction involves approach or acceptance of an object and unpleasantness in cases involving withdrawal. This procedure calls for caution, however, in view of the fact that in the simpler animals the relationship between internal changes and external behaviour is fundamentally reflexive and unlearned. There is little to be gained in discussing whether the fish or octopus experiences "fear" in the human sense in its excited flight from the location of a large, suddenly-moved object, or whether ants licking their queen and a human mother patting her infant experience "love" in the same sense. The presence of radical perceptual differences, for one thing, makes the analogy questionable.

The most significant similarities to human emotional patterns appear, of course, in the other primates and especially in the chimpanzee, whose temperamental resemblance to man seems much closer than does his intellectual resemblance. Practiced observers recognize patterns meriting terms such as confidence, discouragement, annoyance, jealousy, friendliness or suspicion, and many others, appearing under comparable conditions in the ape and the young human child. These patterns are marked by varieties of external signs of emotionality, some of which are roughly similar in ape and child—including variable facial expressions; limb, head and body movements; and changes of tension. These may be described as crude similarities in emotional attitude toward the object or situation. The chimpanzee's whole body is involved as a rule, as in stamping and shrieking in rejecting something or approaching and attempting to pat or groom an accepted person, and in this sense it may be termed much more "dominated emotionally" than adult man.

Experiment shows that in the higher animals emotional responses become transferred to objects and differentiated according to the given animal's ability for conditioning and perceptual learning. Simplest of all is a direct conditioned-emotional-reaction, as when a punished dog pulls back, trembling and whining, at first sight of a whip; this is a literal transfer of the emotional response to particular objects and situations. It is characteristic of the lower mammals and the very young human child alike that dealing with objects tends to be dominated by such emotional reactions; that the perception of the given object can not be divorced from its emotional elements. Such impulsive emotion-determined reactions to phases of the outer world may be considered the antecedent basis of adult human experience.

In man rather fully and in the chimpanzee to a far lesser extent, the process of socialization and special training leads to a greater freedom from direct impulsive emotional reactions. Through general and special training, mimetic and symbolic, man becomes able to inhibit or reduce his emotional excitement, delaying or redirecting it in appropriate socialized ways. Thus an outstanding difference from lower animals is that man's emotional life is coloured by a highly specialized training in the faking, manipulation or suppression of the outward signs of emotional excitement. Specialized gestures and facial expressions appropriate to countless situations, as well as verbal patterns of diverse forms (*e.g.*, "these flowers convey to you my deep sympathy") express the complex modification through experience of originally direct impulsive reactions. Socialized perceptual training generally dominates in the trained adult, reinforced when necessary by reasoning, with the exception of occasional new situations of startling nature, or situations of unusual tension and provocation. The capacity for impulsive emotionalized behaviour is not lost by any means in adult life. Experiments involving problem-tensions of different degrees suggest that each individual has his limit of socialized resourcefulness, beyond which added strain may subordinate the resources of intelligence and training to emotional outbursts of a more or less impulsive, "primitive" sort.

Thus man differs from lower animals in the extent to which he can subordinate impulsive emotional reactions to the perceptual, meaningful nature of a situation. That this control depends upon the cerebral cortex dominating lower centres, as suggested by Hughlings Jackson, is shown by the relative loss of ordinary emotional restraints under the influence of cortex-inhibiting intoxicants like alcohol, or more permanently when brain tumours or injuries reduce cortical function in man. And in lower mammals such as the cat, after an operation disconnecting the cerebral cortex from the brain stem (presumably releasing lower centres from ordinary cortical restraints), there appear activities normally associated with emotional excitement such as snarling, biting, rapid panting and signs of marked visceral disturbance. It seems that the superior cortical equipment of man accounts for his superiority in acquiring highly specialized emotional controls much as it is responsible for his striking ascendancy in intelligent behaviour.

Capacity for Aesthetic Perceiving.—For the lower mammal, through learning, objects or situations may acquire direct emotional effects such as immediate soothing or immediate distress upon sight, as the perception of a dog disturbs a cat. The capacity appears first in a recognizable but clear form in the mammals. To be sure, in many lower vertebrates, even including some invertebrates, a bright and varying body coloration or interesting patterns of sound serve to attract individuals of the opposite sex. However, the appearance of such colours and sounds is due to physiological changes and not psychological factors concerning an attempt to influence others, and responses to them are unlearned and simple in nature. Neither the simple learned nor the unlearned cases may be considered truly aesthetic, in that the appearance of given attractive features or sounds, or responses to them, hinges upon the production of given emotional gratifications.

The properties of simple aesthetic perceiving may be recognized in the lower primates. Köhler reported that at times chimpanzees would hang material such as bits of plants or fruit skins about their necks or shoulders, to be worn until forgotten, apply materials such as clay to their own bodies or the surroundings and on numerous occasions engage in activities of a crude dancelike nature. Simple motion patterns were observed, such as the movement of a group in single file in a circular path. Or, one of a pair of chimpanzees would stand in place, stamping first with one foot and then the other, while its companion rotated with outstretched arms. Köhler considered these activities related to dancing in a rudimentary way, as the simple daubing and the use of objects on their bodies might be regarded as primitively related to human art. Chimpanzees thus appear to have the rudiments of aesthetic perceiving, since they evidently indulge in such activities because a crude emotional satisfaction is derived from them, and also because of their effect upon other individuals.

Although lower primates seem to possess a rudimentary capacity for art and aesthetic relations with the surrounding world, only man clearly exhibits the ability to create in a systematic manner visual patterns such as paintings, objects of adornment or sound patterns such as musical compositions, in the anticipation of producing emotional experiences on further occasions when these stimulus patterns are presented to their creators and others. Whatever capacity the chimpanzee may possess for personal adornment, dances and other aesthetic activities, it is on a low level of development. The chimpanzee revels in emotional experience in an immediate and present sense; however, the instances are relatively isolated and disconnected, because he is not capable of the highly organized abstract thinking which would unite emotional experiences of a given class into patterns used creatively for a greater future enjoyment. For this it is necessary to have some understanding of one's own personal relation to the situation, and a capacity for preparing to encounter the given class of situation in the future. Because only man possesses this capacity in a well-developed form, he is the one animal clearly capable of systematically comparing classes of objects in terms of their emotion-arousing effects, the only one fully capable of treasuring and resynthesizing emotion-provoking patterns. His superiority in bringing remote intervals of time together through foresight, in mastering and organizing meanings and symbols in reasoning, permits him to control very skilfully the nature of his environment in order to produce given emotional effects in himself and others.

Individual Differences and Abnormal Behaviour.—Normal behaviour may be defined as the pattern most characteristic of a given animal group. The major animal forms have been compared in terms of what capacities are normal or typical of them. Although in general this is a sound practice, it should be recognized that in each animal group from Protozoa to man, there are secondary variations in the species population away from the typical condition in every respect from degree of sensitivity to capacity for modifying behaviour. Generally these are predictable, in the sense that fewer and fewer individuals are found diverging more radically from the

general condition; yet the existence of individual differences within a group in all psychological as well as physiological and anatomical respects is a fundamental and important fact about animal nature. Whether the behaviour pattern is chiefly organized on an unlearned basis as in the insects, or a learned basis as in primates, individuals differ relatively from one another. Some bees are superior and others inferior to most bees in way-finding and food-gathering; not all chimpanzees can stack boxes or solve stick problems; and so on for every class of activity in every animal species.

The above types of individual differences are the regular and expected ones. Truly abnormal psychological deviations sharply divergent from the typical species pattern appear to be uncommon in the lower animals. To be sure there are numerous exceptional kinds of behaviour disorders attributable to pathological or disease conditions. Veterinary science is familiar with a large number of diseases, many of them affecting the nervous system, which distort behaviour in special ways. Thus the signs of rabies or "hydrophobia" in dogs are extreme emotional irritability with a tendency to wild running and indiscriminate biting; the presence of brain tumours may lead to exceptional sleepiness, reduced sensitivity, irritability or depression, or other extraordinary signs. In these diseases, however, whatever psychological difficulties appear are not the true causes of the disorder. Man appears to be the one animal given to incurring in his *regular* existence true mental disorders fundamentally psychological in nature.

It is true that under the stress of extraordinary emotional experiences, lower mammals may exhibit emotional disorders resembling in limited ways the human pattern known as neurosis. An example is the gun-shy dog, which has become extremely fearful in given situations, and perhaps in all unfamiliar situations as well, as a consequence of emotional shock. Disturbances resembling neurotic outbursts have been produced in certain mammals and even in birds and other lower vertebrates, by a modification of the Pavlov conditioned-response technique. A dog, for example, is trained to salivate when a circle is presented, but is shocked when an ellipse appears, then after training is presented with an ambiguous figure resembling both circle and ellipse. The figure tends to call out both learned responses; however, the animal can not make the response and inhibit it at the same time. A marked conflict condition results, with evident signs of great tension, trembling, excited and even violent movements, and typically a more or less complete inability to show any definite signs of his past training. In the face of marked difficulties and frustration in problem situations, where hunger is strong and no response adequate to get food, chimpanzees and other mammals are likely to show violent emotional outbursts and special difficulties such as negativism, inability to respond at all, or a tendency to respond irrelevantly or to leave the situation altogether. If such experiences are frequent, lower primates and human children alike develop responses such as temper tantrums and chronic sulkiness, and may acquire a regular habit of avoiding the issue in each difficult new problem by turning to evasive behaviour or excessive dependence upon others instead of attempting to solve the problem by learning or reasoning. It is quite possible that the frequent experiencing of strain-provoking problem difficulties and tension-arousing frustrations of normal motives (*e.g.*, food, sex) may set up in lower primates the type of personality disorder termed neurosis in man. Perhaps if systematic attempts were made to frustrate the motives of chimpanzees from an early age, as many human parents frustrate their children, chimpanzee personalities with the unenviable distinction of mimicking human "insanity" might well appear.

We may recognize some reasons why personality disorganizations such as neurosis frequently encountered in man are not common among his close animal relatives. One reason is that lower primates are deficient in redirected reasoning, hence are relatively free from the cumulative morbid burden of a pronounced "inferiority complex," for example. Deficient in foresight, they are largely if not entirely freed from the fearful anticipative types of thinking known as "worry" in man. When a chimpanzee is away from a frustrating problem situation, his shortcomings in symbolism prevent it from arising vividly to plague him in other situations. The absent situation virtually ceases to exist for him, and he is free to recuperate; whereas a human is far better able to recreate the situation with its strain, and even enlarge upon it in its absence. Moreover, the lower animal is protected from mental illness in other ways, also based upon his intellectual inferiority to man. If physical escape is possible he leaves the frustrating situation outright, without being held as fixedly by attitudes of personal prestige as man; or he hits upon and adopts as routine some irrelevant response. For instance, after a caged tiger has lost his first frantic responses to confinement, tension arising because of the clash between tendency-to-leave and necessity-of-remaining is reduced through activity such as the incessant circling of his cage in an identical path. The stereotyped behaviour is satisfying in that it displaces emotional tension and thus acts as a safety valve for the animal. This type of *fixation* is irrelevant in that it does not solve the problem of escaping, or getting food or whatever the real difficulty may be; however, it is a successful adaptation in the sense that it permits the animal to survive repeated frustration without becoming wrecked through emotional disturbances. Similarly, fixations such as characteristic delusions often appear in man, and may save the individual from the extreme types of personality disorganization popularly termed "insanity." (*See* also ANIMAL BEHAVIOUR.)

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(T. C. S.)

PSYCHOLOGY, HISTORY OF. The history of psychology is the history of thought about human consciousness and conduct; that is to say, about reason, perception and memory, and also about action, motives and the other determinants of action. On the one hand, the history of psychology merges with the history of philosophy whenever psychology is regarded as dealing primarily with reasoning, thinking, feeling and perceiving; on the other, it merges with the history of physiology when psychology is considered to be the science of that behaviour which is regarded as a function of the action of the nervous system.

GREEK PSYCHOLOGY

Early Theories.—In the 6th century B.C. the development of medical thought had led to recognition of the importance of the brain and the sense organs in reasoning and in perception, two functions which were distinguished from each other. There also appeared quite early the doctrine of the four basic temperaments, dependent on the admixture of the four bodily humours—the blood, the phlegm, the black bile and the yellow bile. Centuries later the temperaments corresponding to these humours were named, respectively, sanguine, phlegmatic, melancholic and choleric. In early Greek thought there was no recognition of a soul which is an agent in the activities of reasoning or perceiving.

The idea of a soul as something resident in the body but capable of existence apart from it came in with the Pythagoreans about the end of the 5th century B.C. Plato developed this conception, distinguishing between the nutritive, sensitive and rational functions of the soul, and assigning them, respectively, to plants, animals and men. He held that these functions represent a developmental hierarchy, each higher level including the lower, and that the development of reason in man may introduce conflict between reason, which is possessed only by man, and desire, which exists also at the animal level. Thus we find in Plato the conception of the soul's activity as constitutive of its basic functions, and the notion that simpler activities develop into more complex, sometimes giving rise to conflict. Such conceptions reappear from time to time in the history of psychology, notably in the psychology of G. W. Leibnitz (1704), J. F. Herbart (1825) and Sigmund Freud (1900), the line of development that led eventually to what is called dynamic psychology.

The Greeks also introduced the doctrine of empiricism into psychology, the doctrine that all the contents of the mind are derived through the senses. Heraclitus (5th century B.C.) held that all knowledge comes to man "through the door of the senses," and Protagoras (*c.* 484–411 B.C.) that the entire psychic life is made up only of sensations. The Stoics used the figure of the *tabula rasa*, the blank wax tablet of the mind upon which experience writes. This is the doctrine that was taken up later in the British school of empiricism.

The Greeks had also a theory of perception. Empedocles (*c.* 490–435 B.C.) supposed that objects give off from their surfaces or pores effluvia, which act upon the senses to furnish knowledge of the external world. Democritus (*c.* 460–370 B.C.) and Epicurus (*c.* 341–270 B.C.) described these projections as faint images, simulacra or eidola of the objects which, being conducted to the mind, give it acquaintance with the objects which they represent. This naive view that perception represents an object by being similar to it is so simple and attractive that it continued to persist, in spite of opposition, having been contradicted by Johannes Müller

(1801–58) and by various critics in the 20th century.

Aristotle.—Aristotle (384–322 B.C.) has been said to be the greatest mind in the history of thought. Certainly his recorded wisdom influenced the scholarly thought of Europe more completely and for a longer time than have the writings of any other one man. He was both philosopher and scientist, theorizer and empiricist, and the psychology found in his *De Anima* and other writings determined accepted psychological doctrine down to the end of the 18th century.

In Aristotelian doctrine the body has a *pneuma,* which is connate with it and pervades it. This pneuma (animus, spirit) effects the integration of the organism by its appropriate movement within the body. Aristotle seems to have believed that the pneuma moved within the blood vessels, for he knew nothing about the nerves. Later psychologists substituted "animal spirits" for the pneuma and assumed that the nerves were their conductors, but the basic idea of integration by an internal pervasive agent was Aristotle's. The soul, according to Aristotle, is the *entelechy* of the body; that is to say, it is the perfection of unity toward which the functions of the body are directed. This stress upon the unity of the soul and the importance of considering the total organism in the understanding of perception and action persisted through the ages into modern psychology and is the chief means of distinguishing psychology, which deals with total action, from physiology, which deals with the functions of parts.

Aristotle localized the psychic functions in the heart. That was an error. Plato and Pythagoras had been correct in placing them in the brain. Much later, Galen (*c.* A.D. 130–*c.* 200), one of the greatest physicians of antiquity, synthesized the two views by arguing that the animal spirits are stored in the ventricles of the brain, flow thence to the ventricles of the heart, whence they are distributed to the body by the arteries.

The specification of five separate senses is due to Aristotle. External forces, he held, act upon the body and their effects are transmitted by the pneuma to the sensorium, where the unity of the senses is preserved, as can be seen in such perceptions as those of shape and size, which are common to both sight and touch.

Aristotle distinguished clearly between the cognitive and conative aspects of the soul. On the one hand, he noted a cognitive series of functions from sensation to reason; on the other, a conative series from simple desire through wish to will. The basic conative drive Aristotle called *orexis.* In terms of it he derived a dynamic psychology, which for him included ethics.

Hellenistic Period.—After Aristotle there ensued the Hellenistic period, which was distinguished, among other things, by the brilliance of Alexandrian science in the 3rd century B.C. Herophilos (4th century B.C.) and Erasistratos (*c.* 304–258 B.C.) discovered the nervous system, the nerves leading to the brain and spinal cord. They even distinguished between motor and sensory nerves, a distinction that was not validated until 2,000 years later. In general, however, Alexandrian science did not promote psychology, for the mind was not then supposed to be understood in terms of natural law, and psychology and physiology became during the course of many centuries more and more widely separated.

The Stoics (*c.* 300 B.C.) contributed both the notion of instinct and of conscience, the latter signifying an inner sense of conformity with innate reason. In general, the Christian schools took over the pagan philosophy and with it Aristotle's psychology. By the 3rd century A.D. Plotinus (*c.* A.D. 203–270), promoting a return to Platonism, established psychology as a pure science of experience based upon introspection described without regard to underlying physiological processes. Augustine (A.D. 354–430) continued this tradition, establishing what came presently to be the accepted psychology of the Christian Church. Thereafter, through the middle ages, psychology consisted largely of a repetition and elaboration of the dicta of Aristotle and Augustine.

EARLY MODERN PSYCHOLOGY

All through the history of psychology we find a dichotomy in respect of which the various views and theories about mind and the definitions of psychology can be organized. In the absence of accepted terms, we may call the one the phenomenological approach and the other the mechanistic approach. The phenomenological approach to the problems of mind includes the description of immediate experience, directly as it comes to the observing person. It tends to regard mind as separate from the body and to get along with only minor reference to physiology. It is often an unexperimental psychology, being available to philosophers by their own introspection. The modern representatives of the phenomenological approach are Franz Brentano's intentionalism, Wilhelm Wundt's introspectionism, and Gestalt psychology. The mechanistic approach, on the other hand, deals more with causal relations than description. It is thus forced to look to bodily functions and physiological processes in order that it may subsume psychological events under natural law. Its modern representatives are U.S. functionalism, behaviourism and operationism. In general, up to the year 1910 and even later, the British and German traditions were phenomenological, the French and U.S. mechanistic.

Seventeenth-Century Psychology.—Plotinus and Augustine had left psychology phenomenological and descriptive. In the 16th century, with the tendency to recognize that causal principles determine behaviour, occurred the beginnings of a dynamic psychology. Niccolo Machiavelli (1469–1527) had effectively expounded the thesis that men are controlled more by their passions than by reason, and various other less well-known writers had developed that theme. Still later we find Francis Bacon (1561–1626) promoting a naturalistic view of man's conduct.

Thomas Hobbes (1588–1679), who published his *Leviathan* in 1651, was essentially a mechanist, a dynamic psychologist. He was primarily concerned with the conduct of man, especially his social conduct. Hobbes distinguished between innate motives and those that are acquired in experience. He observed how pleasure and pain, pride and fear, determine human action. He is perhaps, before John Locke, the originator of British empiricism, because of his stress upon the role of experience in establishing the nature of man; but mostly he was a social dynamic psychologist.

The great founder of the mechanistic tradition in psychology was René Descartes (1596–1650), a philosopher who also performed anatomical dissections and physiological experiments. He established in the common sense of the next three centuries the dualistic notion that mind and body are separate, that mind is unextended substance and body extended substance, the mind occupying the body and interacting with it at a determinate point in the brain. Thus, body affects mind, and mind body. Animals, who have, Descartes thought, no rational souls, are automata, machines which behave in accordance with their properties and the forces which act upon them. Thus, the history of reflex action, as basic to the mechanistic conception of mind, must be dated from Descartes. He called the total motion of the animal spirits along the nerves through the valves of the brain and out again along other nerves to the muscles *undulatio reflexa,* since the nervous system, in redirecting the course of the animal spirits to produce movement, may be regarded as "reflecting" them.

The mechanistic tradition was continued in France during the 17th century by the contributions of Nicolas de Malebranche (1638–1715).

Scientific cognizance was also being given at that time to some of the problems of visual perception. Leonardo da Vinci (1452–1519) had already discussed some of these problems—colour contrast, the relation of light and shade and of aerial perspective to the perception of the third dimension, the problem of the transparency of near objects in binocular vision (caused, of course, by the different angles at which the two eyes view the scene) and the similarity of the eye to a camera. In 1604 the astronomer Johann Kepler (1571–1630) noted that the crystalline object in the eye must be a lens and not the percipient organ, and that it must throw an inverted image on the retina. He, therefore, decided that the retina must be the percipient organ. Kepler then raised the question as to why we see right side up when the retinal image is upside down, falling into the common error of thinking that external objects must be represented by similar patterns in the brain. Later Descartes demonstrated, using the excised eye of a bull, that

the inverted image is actually formed by the lens at the back of the eye.

The century saw two other important discoveries in the field of sense perception. In 1638 Galileo (1564–1642) showed that the pitch of tones depends on the frequency of vibration of the air, that the ratio is two to one for the octave and three to two for the fifth. In 1672 Isaac Newton (1642–1727) presented to the Royal society his first paper on colour theory, in which he showed by experiments with a prism that white is a mixture of colours, a discovery that was at first met with incredulity by his scientific colleagues. Newton worked out the laws of colour mixture, and his *Opticks,* after a long delay, was published in 1704.

Eighteenth-Century Psychology.—The French mechanistic tradition was continued by J. O. de Lamettrie (1709–51), who published his *L'homme machine* in 1748; by E. B. de Condillac (1715–80), who is noted for his analogy of the human organism to a statue, which, provided with a single sense, acquires through experience the attributes of a human mind; and by P. J. G. Cabanis (1757–1808), who extended the knowledge of reflex action and argued—he was interested in the reflexes of victims of the guillotine—that consciousness is dependent only on the action of the brain and not of the spinal cord. Contemporaneous with Cabanis was M. F. X. Bichat (1771–1802), who has been called by some the founder of physiological psychology.

The important events of the 18th century occurred, however, on the phenomenological side of psychology, especially in connection with the development of British empiricism and associationism.

In a sense, British empiricism began with Hobbes, but its formal initiation was the publication in 1690 of the *Essay Concerning Human Understanding* by John Locke (1632–1704). Locke's argument was that the mind is constituted of ideas, all of which are gained from experience, most of them by way of the external senses, some of them by reflection, which is the inner sense by which the mind becomes aware of its own operations. Although Locke added a chapter on association of ideas to a later edition of his *Essay,* the doctrine of association became of importance only with his successors.

Bishop George Berkeley (1685–1753), famous for his subjective idealism, inverted Locke's proposition. The problem, he thought, is not how the ideas get into the mind from outside by way of the senses, but rather, since the mind knows nothing other than the ideas of which it is constituted, how we ever obtain a belief in the existence of the external world. Berkeley undertook to answer this question and many other related ones by an appeal to experience and a principle which is essentially that of the association of ideas. He also wrote a *New Theory of Vision* (1709), which contributed both to the systematic theory of empiricism and to the psychology of visual perception.

David Hume (1711–76) comes next in this line of descent. He differentiated impressions, which depend upon a present stimulation, from ideas, which are "faint copies" of the impressions. This is the distinction between sensation and image in later terminology. Hume also undertook to explain the concept of causation as resulting from the habitual sequence of the impressions of two events, thus reducing causation to association. Because Hume lent his great influence to the conception of ideas as mental elements whose compounding explains all of the more involved mental phenomena, he is often regarded as the chief enemy of holism, as it is found in the modern school of Gestalt psychology.

David Hartley (1705–57), while less important than his predecessors in this school, stands out because of the clear, simple and emphatic associationism which his *Observations on Man* of 1749 presents. Taking association from Locke and the notion of transmitted vibratory motion from Newton, he built up a system in which the laws of association of ideas were paralleled by laws of association of vibrations (correlated with sensations) and diminutive vibrations (correlated with ideas, images) in the nervous system. This sharp and uncompromising presentation of the associationistic principles, combined with a simple psychophysical parellelism of mind and nervous action, served to make the nature and implications of associationism clearer than could the more subtle exposition of an abler mind, like Hume's.

The French tended to take over associationism and combine it with their mechanistic psychology. Condillac's statue (*see* above) was supposed to build up its sensations in experience by means of associative principles.

Meanwhile in Germany there was G. W. Leibnitz (1646–1716), Locke's contemporary. Leibnitz's chief contribution to psychology was his insistence on the active nature of the mental units, his "monads," which are forever striving for development according to their pre-established nature. The association of ideas in the British school tended to create the picture of fixed mosaics of mental elements which make up the complexes of the mind. Leibnitz, on the other hand, remained on the side of a dynamic psychology, which insists that activity and purpose are basic in mental life. He believed that his monads develop independently, and that the results of their interrelations are simply coincidences resulting from a harmony pre-established among them and not from causal interaction. The conception of psychophysical parallelism between mind and body grew out of this Leibnitzian notion. Leibnitz also contributed to psychology the concept of apperception, which he held to be the consequence of the summation of many little perceptions. His notion that the apperception of the roar of the sea is the sum of the "petites perceptions" of the noise of every falling drop of water is well known. It gave rise to the concept of the threshold of consciousness as it is found in the writings of Herbart, in G. T. Fechner and psychophysics, in Freud and psychoanalysis.

After Leibnitz the development of German psychology passed into the hands of a number of less well-known men in the Berlin academy, of whom J. N. Tetens (1736–1807) is perhaps the best known. The chief contribution of these philosopher-psychologists was to stress the importance of feeling as a third primary category of psychology. Heretofore cognition and volition, knowing and acting, had constituted chief subdivisions in systematic psychology. Now the affective life was added as a third, and this threefold division of the subject matter of psychology—thinking, feeling and doing—continued as the standard classification all through the 19th century and well into the 20th.

PSYCHOLOGY IN THE 19TH CENTURY

The history of psychology in the 19th century can be viewed as a history of schools of systematic thought about the mind (associationism, introspectionism, intentionalism, evolutionism, functionalism) and of fields of experimentation and research (physiological psychology, experimental psychology proper, phenomenological observation, abnormal psychology and the mental tests in conjunction with the functional psychology of individual differences).

Associationism.—While the Scottish philosophers—Thomas Reid (1710–96), Dugald Stewart (1753–1828) and Thomas Brown (1778–1820)—are not properly classified as associationists, the theory of perception that developed under their thought contributed to the importance of associationism. Brown's theory is the culmination of the discussion. He distinguished between sensation and perception, holding that perception, unlike pure sensation, refers to or intends an external object. In perception the sensations that first arise suggest—by association, but Brown preferred the word "suggestion" to "association"—other sensations which specify the object which is intended. For example, the smell of a rose suggests the sight of a rose, which is enough to identify the object as a rose. In other words, meaning arises in perception by the compounding of two or more sensory elements, and that theory is really the core of associationism: meaning is given in consciousness by the associative compounding of ideas.

It was James Mill (1773–1836) who expressed this view in simplest and clearest terms in his *Analysis of the Human Mind* in 1829. In fact, he reduced the theory to an absurdity by carrying it to its logical conclusion. At the end of his chapter on association of ideas, he noted that the idea of any object is a fusion of the ideas of its components. "Brick is one complex idea, mortar is another complex idea; these ideas, with the ideas of position and quantity, compose my idea of a wall." Finally, he asked: "How

many complex ideas are all united in the idea of furniture? How many more in the idea of merchandise? How many more in the idea called Every Thing?" That was the difficulty: the associationists thought that the idea of everything must be a compound formed by association of every idea of a thing.

John Stuart Mill (1806–73), James Mill's son, made no such error. He avoided the difficulty by noting that a combination of elements often generates something totally new in the compound, so that the parts are lost and the new product gained. This is the theory that Wundt called creative synthesis, that others much later called emergence, that became still later the basis of Gestalt psychology. J. S. Mill also argued that the unrealized potentialities of association play their role in the mental life: an object is, he argued, the "Permanent Possibilities of Sensation"; that is to say, the sensations that it could arouse. As an object, it is believed to be permanent, in spite of the evanescent nature of experience, because these possibilities of sensation are permanent.

Alexander Bain (1818–1903) is the representative of associationism in the latter half of the 19th century. He combined with associationism the growing interest in physiological psychology. Herbert Spencer (1820–1903) represents an influential evolutionary associationism, a doctrine that worked in with the trend of thought in England after Charles Darwin's influence had become dominant. From this point associationism passes over into the introspectionism of Wundt and his followers.

Introspectionism.—Wilhelm Wundt (1832–1920) has been called the founder of the new scientific psychology of the 19th century. Certainly he was its vigorous promoter. He called it physiological psychology and experimental psychology. His *Grundzüge der physiologischen Psychologie* was a systematic text and also a general handbook of the new science, and it ran to six editions from 1874 to 1911. Wundt founded the first formal laboratory of psychology at Leipzig, Ger., in 1879. He started the first journal devoted to experimental psychology in 1881. For 40 years he was the most important and influential figure in German psychology.

As a systematist he was an elementist and an associationist, for he described the sensations and feelings that are the mental elements of psychology, and showed how they are compounded by association into ideas and perceptions (*Vorstellungen*) which are meaningful and refer to objects. The turn of events, however, put more emphasis upon Wundt's insistence that introspection—the verbal description of the immediate data of experience—is the chief method of psychology. Although Wundt called the new science physiological psychology, he was insistent that physiological processes parallel and do not constitute the psychic processes. The phenomena of consciousness, he held, are observable without reference to the body to which they belong.

Wundt's position was continued by Oswald Külpe (1862–1915) and E. B. Titchener (1867–1927). They were both his students. Külpe is best known for his attempt to apply the introspective method to the study of thought in the researches of his Würzburg school (1901–09), which showed—this appears to be the verdict of time—that introspection is inadequate to the observation of the unconscious directive tendencies which preserve the purposive nature of thought. Titchener went to the United States in 1892 and there upheld the Wundtian position for 35 years. There can be no doubt that U.S. functionalism was more clearly understood because it contrasted so strongly with Titchener's unyielding introspectionism. Titchener hoped that psychology could eventually get along without any relation to physiology.

J. F. Herbart.—The influence of Herbart (1776–1841) was so great during the first half of the 19th century that separate mention must be made of him. He defended a psychology founded upon experience, metaphysics and mathematics, and denied the possibility of experimenting upon mind. He conceived of ideas as active and struggling, one with another, for a place in consciousness. Thus, as we have already noted, he provided, in following Leibnitz, both psychophysics and psychoanalysis with the concept of the threshold of consciousness and also with the notion of unconsciousness that lies below the threshold. Much of Wundt's work was clarified by his opposition to Herbartian ideas.

Intentionalism.—The traditional psychology that had come down from Aristotle and Augustine was reformulated by Franz Brentano (1838–1917), a Roman Catholic priest and a psychologist of wide influence, as what is called act psychology or intentionalism. The contrast between Brentano's and Wundt's psychologies was heightened by the fact that both men published their crucial systematic texts in 1874. Brentano contended that the conscious mind is constituted of acts—ideating, judging, feeling ("loving-hating"). Wundt had divided mind into more static elements—sensations and the feelings. The acts, Brentano held, have objects which they "intend" or are directed upon, and these objects "inexist" within the act. If I see a green, then the act of *seeing* is the mental datum and the *green,* the object of the act, exists intentionally within the act, thus in part determining its nature.

Brentano's psychology claimed many followers in the late 19th and early 20th centuries, especially in Austria. Külpe's later systematic views were affected by Brentano's thinking, as was also the system of Carl Stumpf (1848–1936), who, holding the chair at Berlin, found himself in opposition to Wundt on many occasions.

In England, James Ward (1843–1925) was markedly influenced by Brentano. Ward distinguished between cognition, feeling and conation, finding all three present in the representative psychological act. G. F. Stout (1860–1944) followed the tradition of Ward, and William McDougall (1871–1938), who in 1919 transferred from England to the United States, upheld a purposive psychology that showed this same influence.

Evolutionism.—One effect of Charles Darwin's theory of evolution was to interest psychologists in mental inheritance and in the phylogenetic development of mind. In 1869 Francis Galton (1822–1911) published *Hereditary Genius,* a study which showed that men of eminence in England tend to be related. In those days the data were taken as demonstrating the biological inheritance of mental ability, although later it became evident that these great men owed their eminence at least in part to their education and their socioeconomic status. Darwin himself argued for the phylogenetic development of mind in his *Expression of Emotion in Man and Animals* (1872). Thereafter the versatile Galton conducted other studies on mental inheritance among persons of ability and on the resemblances of twins. He advocated the inventorying of the abilities of the British nation, inventing some simple tests whereby such an inventory could be made (or so he thought). He coined the word "eugenics," meaning by it the improvement of the race by selective parenthood.

G. J. Romanes (1848–94) carried on this interest in England by his studies of animal intelligence and his books on mental evolution in both animals and man. He coined the term "comparative psychology" for the study of the relationships between the minds of different animal species. C. Lloyd Morgan (1852–1936) carried comparative psychology further, and this field of endeavour was then taken up in the United States (*see* PSYCHOLOGY, COMPARATIVE).

British evolutionism also found support in the United States. J. M. Baldwin (1861–1934) was the Romanes of the U.S., with two important books on mental evolution. G. Stanley Hall (1844–1924) admitted that his many interests in the different phases of human capacity were held together by his abounding faith in the importance of evolution. James McK. Cattell (1860–1944), directly influenced by Galton, coined the term "mental test" in 1888 and lent his support to the development of the psychology of individual differences. In the United States evolutionism formed the background of functionalism.

Functionalism.—In the 1880s and 1890s the United States had the temper of a young nation, a nation still imbued with the practical spirit of conquering a continent. It sent its psychologists to Wundt at Leipzig that they might learn the best of what was new in psychology, but U.S. psychology never accepted the pedantry of the German approach to the subject. The Americans were bound to be practical and functional, to see mind in terms of its use for the survival of the organism in the struggle of the race for existence and in the social competition of the individual

for success. Hence, the United States accepted evolutionism enthusiastically and created its own psychology, which was functional.

William James (1842–1910), pioneer of psychology in the United States, introduced the functional approach to the problems of the mind in his *Principles of Psychology* of 1890. Cattell, as has just been noted, supported a functional psychology in his advocacy of the use of mental tests in the 1890s and later. The formal school of functionalism was, however, founded by John Dewey (1859–1952) about 1896 and was continued at The University of Chicago by James R. Angell (1869–1949) and his associates.

Functional psychology admits the data of both consciousness and behaviour to its domain, for it is primarily concerned with what enables the organism to adapt to the varying conditions of its environment. Functional psychology is the psychology of the "Is-for," as Titchener remarked, the psychology of how to be successful, and thus it is appropriately American. The school disappeared after Dewey and Angell left Chicago, and behaviourism was ready to replace it (*c.* 1916). Nevertheless, the spirit of functionalism, since functional psychology is a natural medium for physiological psychology, animal psychology, differential psychology, normal psychology and applied psychology, came to stay and has characterized most of the psychology of the United States from the beginning. (*See* section on *Functional Psychology* below.)

Physiological Psychology.—The century saw great progress in nerve physiology. In 1811 Charles Bell (1774–1842) distinguished between sensory and motor nerves, showing that the two kinds of nerves have separate roots at the spinal cord. François Magendie (1783–1855), the French physiologist, discovered independently in 1821 this same fact, which is called the Bell-Magendie law. As electrical currents and galvanometers became available in the 1840s, the electrical properties of nervous conduction came to be investigated, and the mysteries of the animal spirits were dissipated by the accumulation of observed facts. In 1850 H. L. F. von Helmholtz actually measured the velocity of the nervous impulse along a nerve, a discovery which met at first with as much incredulity as Newton's report in 1672 that white is a mixture of colours.

There was also a great deal of work on the localization of functions in the brain. F. J. Gall (1758–1828), a brain anatomist of considerable ability, formulated the theory of phrenology about 1800, the theory that temperament can be assessed from a study of the conformation of the skull, since the development of crucial areas in the brain would be reflected in the shape of the skull. The popularity of this view was not readily destroyed by the scientific opposition which it received. Pierre Flourens (1794–1867) undertook experiments upon animals to determine more exactly the functions of the various parts of the brain, discovering about 1825 that certain gross areas are essential to certain functions but that fine localization is often (perhaps always) missing. In 1861 Paul Broca (1824–80) discovered the speech centre in the left cerebral hemisphere, and then in 1870 G. Fritsch and E. Hitzig localized motor centres precisely by electrical stimulation of the brain. The last quarter of the century saw the growth of a firm belief in exact cerebral localization, a belief somewhat weakened by the discoveries of the 20th century.

Johannes Müller (1801–58), sometimes known as the father of experimental physiology, affected psychology by his doctrine of specific nerve energies, which he first published in 1826. The doctrine was really a theory of sensory quality, for Müller sought to demonstrate that the sensory quality aroused by stimulation depends on the particular nerve excited and not directly on the nature of the stimulus. Pressure on the eyeball produces a sight, light on the skin elicits warmth and electricity on any nerve arouses the peculiar quality ("energy") that belongs to the nerve. Later Helmholtz extended this doctrine to differences of quality within a given sense, even seeking in the inner ear a means whereby each one of several thousand distinguishable pitches could be put onto a corresponding nerve fibre. Later research indicated that the specificity of different nerves and fibres lies not in a peculiar nervous energy but in the points in the brain to which the fibres lead. (*See* also PSYCHOLOGY: *Physiological Psychology.*)

Experimental Psychology.—Experimental psychology (*q.v.*) proper began with sense physiology, the study of how sensory experience is dependent on stimulation of the sense organs, which is what Fechner later called psychophysics (*q.v.*). Newton's discovery of the laws of colour mixture and Galileo's finding about the dependence of tonal pitch on stimulus frequency were psychophysics. In the 19th century the increased interest in sensory physiology advanced psychophysical investigation greatly.

Research on vision predominated. Thomas Young (1773–1829) published his theory of colour vision in 1801, the theory that Helmholtz later established. The poet, J. W. Goethe, in 1810 published his *Zur Farbenlehre,* an elaborate, dictatorial phenomenology of colour; its immediate influence was great because of the enormous prestige of its author. J. E. Purkinje (1787–1869) also wrote a phenomenology of vision (1819, 1825) which contains the first accounts of several important phenomena; for example, the "Purkinje phenomenon" of the changes of hues as illumination shifts from daylight to night vision. Johannes Müller's first important book (1826) was on visual physiology.

In 1834 E. H. Weber (1795–1878) published his experiments on tactual sensibility, experiments which included his finding that magnitudes of stimuli that are just noticeably different in perceived intensity bear a constant ratio to each other. G. T. Fechner later named this principle Weber's law (*q.v.*). It is only approximately true.

The century's two most important experimental psychologists were Fechner and Helmholtz. Fechner (1801–87) was, by way of his *Elemente der Psychophysik* of 1860, the founder and promoter of psychophysics, and some say of experimental psychology, although that distinction is generally reserved for Wundt. Fechner was obsessed by his realization that it is possible to measure sensation as well as the sensory stimulus, and to state in an equation the relationship between the two measures. He described, developed and formalized the three fundamental psychophysical methods of sensory measurement. He named Weber's law and worked out the quantitative relationships which it implies. He established the concepts of the absolute limen (just noticeable sensation) and the differential limen (just noticeable difference between sensations), and the methods of measuring them. In short he put sensory psychology on a quantitative basis.

H. L. F. von Helmholtz (1821–94) made the greatest factual contribution of any one man to experimental psychology. The results of his observations and thought appear in the three volumes of his *Handbuch der physiologischen Optik* (1856–67) and the one volume of his *Lehre von den Tonempfindungen* (1863), which for more than half a century remained respectively the standard reference works on visual and auditory psychophysics.

Fechner's methods and Helmholtz's facts helped Wundt in the founding of experimental psychology. The last quarter of the 19th century saw the founding of many psychological laboratories, first in Germany and then in the United States. Wundt's demonstrational laboratory in 1875 was the first to be created, and his institute at Leipzig in 1879 was the first formal laboratory; William James also had an informal laboratory at Harvard college as early as 1875. Research followed the founding of the laboratories—first on sensation and perception, then on action, then on memory and learning, with the bare beginnings of an experimental psychology of thought and attitude showing before 1900.

Abnormal Psychology.—The more important part of the history of abnormal psychology (*q.v.*) would consist of a history of witchcraft, animal magnetism, hypnotism, hysteria, psychoanalysis and neurosis. Many of the neurotics of the 17th century were considered to be sorcerers or witches. Late in the 18th century F. A. Mesmer (1754–1815) discovered that he could exercise over other persons a peculiar power which he called animal magnetism and which others came later to call mesmerism. Toward the middle of the 19th century James Braid identified this state with some of its scientific conditions, calling it neurypnology which later became hypnotism (*q.v.*). In the last quarter of this century

J. M. Charcot (1825–93) at the school of the Salpêtrière near Paris undertook the study of hysteria, a neurotic state in which the extreme symptoms resemble the symptoms of hypnosis. Charcot thought that only hysterical persons could be hypnotized, but in that belief he was wrong. Charcot's place as the foremost psychopathologist of France was taken by Pierre Janet (1859–1947), who published the classical text on hysteria in 1892.

Sigmund Freud (1856–1939) was also for a brief time a student of Charcot, but Freud's development of the method and concepts of psychoanalysis were his independent doing.

Psychoanalysis (*q.v.*) may be said to have got under way with Freud's publication of his book on the interpretation of dreams in 1900. Its further development and the emergence and establishment of the dynamic psychology of neurosis, which made use of many psychoanalytic terms and concepts, are largely a history of events in the 20th century.

The history of abnormal psychology is, of course, related to the history of psychiatry (*q.v.*). In Germany Emil Kraepelin (1862–1915), one of Wundt's pupils, contributed notably to psychiatry and to the classification of the abnormal states with which psychiatry deals.

Differential Psychology.—We have seen how Galton became interested in individual differences in mental capacities and formed a scheme of inventorying the British nation in order to assess its psychological resources. He invented a number of simple mental tests and Cattell, in the United States, made up some more and promoted their use. Galton's and Cattell's tests were for the most part simple tests of sensory and motor capacity and did not adequately measure intellectual and scholastic abilities. In France Alfred Binet (1857–1911), assisted by Victor Henri, was developing certain concepts of personality and tests of intelligence for children. Out of that work there emerged in 1903 Binet's intelligence tests, which, because they measured more important intellectual capacities, were accepted in preference to the sensory and motor tests. The history of intelligence testing, and later of testing for special abilities and aptitudes, belongs, however, to the 20th century.

PSYCHOLOGY IN THE 20TH CENTURY

For the most part the history of the psychology of the first half of the 20th century is given in the special articles on psychology.

(*See* PSYCHOLOGY and cross references there cited.) The following paragraphs give the general perspective.

Schools.—The century began with introspectionism and functionalism well established in the United States, introspectionism and intentionalism dominating the psychology of Germany, abnormal psychology important in France and evolutionism in England. Gestalt psychology began in Germany about 1912 as a reaction against Wundtian introspectionism, and its leaders came to the United States in the 1930s after Adolf Hitler came to power. Behaviourism began in the United States about 1913 as a protest against both introspectionism and functionalism, but actually behaviourism was not inconsistent with functionalism, and presently it took over the practical and mechanistic values that had been the occasion for functionalism. The attack on old-fashioned analytical introspectionism was successful, and in the late 1920s Gestalt psychology and behaviourism found themselves practically in possession of the field. With their missions thus more or less accomplished, both these schools tended to die out or at least to lose their aggressiveness during the 1930s. Psychological operationism came in at this time to supplant behaviourism as a more sophisticated mechanistic view of psychology, and the outstanding systematic issue in the early 1940s seemed to be whether the Gestalt psychologists could save consciousness, as observed in direct experience, for psychology, or whether the operationists would succeed in having it reduced to the behavioural terms which define the manner of its observation. In general, the operationists tended to support physiological psychology, whereas the Gestalt psychologists relied more often on the modern substitute for introspection which they call phenomenology. (*See* BEHAVIOURISM; PSYCHOLOGY; *see* also special sections on *Functional Psychology* and *Gestalt Psychology* below.)

Trends.—The first half of the 20th century was marked by the shift of leadership in psychology from Germany to the United States, by a decrease in the importance of schools and an increase in the importance of scientific research, by the diversification of psychology into many special fields, each possessed of its own techniques and special knowledges, and by the growth of applied psychology in its various professional aspects, in England and Germany as well as in the United States.

Experimental psychology, the general scientific psychology of sensation and perception, feeling and emotion, learning and thought, response and action, remained the expanding core of modern psychology, although it could scarcely be said to dominate a subject which now had so many special fields. *Animal psychology*, which began the century as an independent field of research, became amalgamated with experimental psychology, at first under the influence of behaviourism, and later because most of the experiments in general psychology, especially the experiments in the field of learning, could be conducted more efficiently with animal subjects. I. P. Pavlov's researches on the conditioned reflex re-enforced this association. *Physiological psychology* required operative techniques and was likewise fairly independent of experimental psychology at the beginning of the century, but also became fused with it. By 1940 the distinctions among these three fields had almost disappeared. (*See* ANIMAL PSYCHOLOGY; EXPERIMENTAL PSYCHOLOGY; PSYCHOLOGY: *Physiological Psychology.*)

Differential psychology developed steadily from the beginnings of mental testing with Galton, Binet and Cattell. Up to about 1920 the testing of "intelligence" was the most important activity in this field. About that time psychologists began to realize that social, economic and educational factors can affect ability to do well in an intelligence test, and that biological inheritance is less important than had been supposed. C. E. Spearman in England began in 1904 the development of those statistical correlational methods of the analysis of abilities that later resulted in factor analysis. These improved methods of analysis turned attention away from general intelligence toward the factoring out of the personality those special abilities and aptitudes which function independently in the organism's struggle for success. It is obvious that a great deal of the development of differential psychology has thus been functional and in the interests of applied psychology. (*See* DIFFERENTIAL PSYCHOLOGY; INTELLIGENCE OR UNDERSTANDING.)

Abnormal psychology was quite distinct from general psychology for fully three decades of the century. Since it dealt with the functional disorders and thus with motivation, it got ahead with the problems of personality much faster than did general psychology. *Psychoanalysis* also constituted an attack on the problems of motivation and personality, and its ideology came largely to be accepted by psychiatrists and psychologists, even when they repudiated its techniques and certain of its tenets. It was this development of abnormal psychology throughout the first three decades of the century that gave rise in the 1930s to a vigorous dynamic psychology. (*See* ABNORMAL PSYCHOLOGY; PSYCHOANALYSIS.)

Dynamic psychology arose because of the great interest in human motivation. By 1925 it was beginning to concern psychologists more and more. Dynamic psychology provides a general background for many applied psychologies, like *clinical psychology*, and the techniques of counselling and guidance. *Child psychology*, although it grew out of evolutionism and the interest in genetic psychology in the late 19th century, has been essentially dynamic psychology, and child guidance has become an important branch of applied psychology. (*See* CHILD PSYCHOLOGY; PSYCHOLOGY: *Clinical Psychology.*)

Educational psychology was also principally a growth of the 20th century. It was stimulated by the development of psychological tests and by the general acceptance of the concept of intelligence as the chief intellectual dimension of maturation in childhood and adolescence. Educational psychology has been, of course, closely associated with child psychology and dynamic

psychology. (*See* PSYCHOLOGY: *Educational Psychology.*)

Social psychology has its roots in the *Völkerpsychologie* of the Germans in the 19th century and in the work of certain French writers, especially Gabriel de Tarde and Gustave le Bon. In 1908 William McDougall's *Social Psychology* based social behaviour on the instincts, of which he furnished a classification. After that time social psychology became dependent for its theoretical structure upon those primitive drives or needs which the dynamic psychology of any given period could provide. In the 1930s social psychology was becoming applied, notably through the development of public-opinion polling and the analysis and control of propaganda. In World War II the techniques of the social psychologists were used broadly for the assessment and control of opinion and attitudes and for the gathering of psychological information about large social groups. In such undertakings social psychology was found to be closely related to social anthropology and to certain modern empirical movements in sociology. (*See* section on *Social Psychology* below.)

Applied psychology was the term used for psychotechnical endeavour prior to 1920. Thereafter the special applied psychologies began to make their appearance. We have already noted the modern concern with educational psychology, with clinical psychology, with counselling and guidance of adults and children (as well as the aged) and with applied social techniques. In addition to these there was some development of *legal psychology* and, after 1920, a great deal of interest in *industrial psychology* which, apparent first in England, was promoted subsequently in the United States and greatly furthered by the successful use of psychology in World War II. Industrial psychology is concerned with the selection and training of personnel, and the establishment of the most efficient conditions for work. Efficiency depends upon the proper design of machines, the reduction of fatigue, the promotion of good health and the maintenance of good morale in the relation between worker and employer. Thus, industrial psychology makes use of many of the principles of perception, sensorimotor co-ordination and learning which general psychology develops, and of dynamic psychology, differential psychology and social psychology. (*See*, in addition to the cross references just cited, INDUSTRIAL PSYCHOLOGY; PSYCHOLOGY: *Legal Psychology.*)

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(E. G. BOR.)

FUNCTIONAL PSYCHOLOGY

Functional psychology is that point of view which emphasizes the biological significance of mental activities, holding that conscious processes, like organic activities, appear and function in response to the needs of the total organism in achieving a more adequate adjustment to its environment. The movement which bears the name functionalism had its roots in the Darwinian evolutionary viewpoint, the biologically oriented psychology of William James, the instrumentalism of John Dewey and the interest in animal psychology. Under the leadership of James R. Angell and Dewey, functionalism, from 1894 on, became the dominant viewpoint of the laboratory of experimental psychology at The University of Chicago. Though its leaders had no intention of developing a unique school, their viewpoint became crystallized through the necessity of defending it against attacks. In stressing the role of conscious processes in everyday living, they seemed to their critics to violate the doctrine, then current, of mind-body parallelism. Their assumption that mental functions develop in response to the organism's adjustmental needs was criticized as teleological; yet, biologists had adopted a similar assumption with impunity. Their attempt to deal with mental functions introspectively met criticism on the ground that functions are meanings, not content, and cannot be objects of introspection. Functional psychology, however, never limited itself to the introspective approach; it investigated activities in terms of what they accomplished, the end product, utilizing both introspection and objective observation. The objection that functionalists use the term function ambiguously, at one time meaning the *process,* at another the *end* served by it, was answered by Harvey A. Carr, who followed Angell as director of the Chicago laboratory. He pointed to a common identity of these two usages in the mathematical term "function," which implies a contingent relation, whether of act to structure, or of means to end. Hence, the distinction made by R. S. Woodworth between primary and secondary functionalism was unnecessary. Carr made mental activity the subject matter of psychology, avoiding any dualistic implications of the term by identifying it with that entire group of psychophysical processes involved in adaptive behaviour; *i.e.*, acquiring, retaining, organizing, evaluating, and subsequently utilizing experiences in the guidance of conduct. By opening the way for the study of behaviour as a legitimate part of psychology and by insisting that mental activity be considered in its practical everyday setting, functionalism paved the way both for the behaviouristic movement and for the phenomenal expansion of the applied branches of psychology in the United States.

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(A. G. BS.)

GESTALT PSYCHOLOGY

Gestalt psychology deals with mental facts which are ignored when merely analytical procedures are used in psychology. That such facts exist was first discovered in perception. For instance, in customary analysis a visual field was regarded as composed of local sensations, each of which corresponded to a local physical stimulus. But in 1890 Christian von Ehrenfels, an Austrian psychologist, remarked that in this description of the field many visual characteristics such as round, angular and slender were omitted. For their occurrence neither single stimuli nor mere sums of such stimuli can be made responsible. This becomes particularly obvious if, in a given case, all individual stimuli are changed in the same proportion. The characteristics in question are not affected by this measure. When presented in a changed colour, in a different place or in another size, an object remains about as round, angular or slender as it was before. Von Ehrenfels added that in the dimension of time, analysis meets with the same difficulty. Thus, in music the major and the minor characteristics of melodies belong to the melodies rather than to individual tones. Since visual shapes (Gestalten) are the most obvious instances of such phenomena, Ehrenfels called the whole class Gestalt qualities.

But analysis in the customary style also ignored the entities which have such attributes. In vision, for example, retinal stimuli represent a mere mosaic. And yet visual Ehrenfels qualities are for the most part attributes of specific objects such as things and figures. What is the nature of these units? Some authors maintain that the units are established by intellectual processes. However, while intellectual activities may interfere with given objects, there is no empirical evidence that such activities form the objects in the first place.

In 1912 M. Wertheimer was led to a much more radical solution of the problem. He denied the existence of sensory elements as parts of perceptual experience. According to him, the nervous system tends to give a unitary answer to the total stimulating situation with which it is confronted at a given time. But far from being uniform, this answer is for the most part quite articulate. In certain areas the unitary character of the response is greatly enhanced, while at the same time these areas are relatively segregated from their environment. Thus, things, figures,

etc., originate. In the temporary dimension the same happens: from the unitary course of experience particular events tend to be segregated which are to this extent analogous to objects. Such events and objects again need not be uniform. Just as they are relatively segregated members of the total field so they may have parts of their own. This term parts, however, now has a particular meaning. Genuine parts of a sensory field or of its objects involve, qua parts, inclusion in the larger units in which they lie. They are experienced as referred to these larger entities. They must also be distinguished from the arbitrarily chosen elements into which traditional analysis would split sensory experience. From the new point of view, analysis is justifiable only if it deals with the genuine parts of a field.

In Wertheimer's writings the specific units or entities which appear in a field are called Gestalten. Although this terminology corresponds to common usage in German it greatly disturbed psychologists in England and in America who translated Gestalt as "shape" (which it may also mean in German). In Gestalt psychology, the substantival connotation of the term plays a much more important part than its adjectival meaning, which refers to shapes rather than to the entities which have shapes. In English, the process of articulation is commonly called organization of the field, a term which may also be used for the outcome of the process. According to the dictionaries, the word "structure" has about the same two meanings as Gestalt has in German.

Although the stimuli which impinge upon sensory surfaces constitute a mere mosaic, there are always factors in this mosaic which give the process of articulation a particular direction. These factors are the formal relations which obtain among the stimuli, such as, for instance, their proximity in space and in time, the degree to which they resemble one another, etc. Other conditions being equal, organization tends to form compact and more or less homogeneous structures rather than widely scattered and heterogeneous units. Again, the process is likely to segregate objects with smooth contours rather than irregularly shaped entities.

From the basic conceptions of Gestalt psychology a great many specific investigations and theoretical discussions developed. Particularly interesting are those in which the new point of view was defended against a rival thesis: the thesis that, after all, elementary sensations are the real material of the sensory world, and that only learning about the unitary objects of the physical and practical world makes things out of sensory atoms. This theory cannot explain the fact that the outcome of sensory organization may be at variance with our knowledge of objects in the practical sense. Thus, well-known objects are not seen, and strange things are seen instead, when the principles of organization favour existence of the latter. Experiments have shown that previous experience has a certain influence upon the organization of given fields. But far from proving that learning fabricates things out of sensory elements, these experiments demonstrate only that familiar forms of organization tend to modify subsequent processes of articulation.

Organization ought not to be interpreted as a mere formation of agglomerates. In the first place, the characteristics of things are generally affected by their inclusion in larger organizations. In other words, organization involves interaction. Such interaction seems to explain colour and brightness contrast, most so-called optical illusions and, also, several perceptual constancies. As an example: When the illumination of an object and of its immediate environment changes, stimulation in the area of the object and its background is correspondingly altered. Nevertheless, the colour of the object tends to remain virtually unaffected. According to the Gestalt psychologists, this constancy of object colour is brought about by interaction between the object and its environment. They claim that, under the circumstances given in a case of constancy, this interaction operates against the effects of changed local stimulation, and thus exerts a compensating influence.

In the second place, organization gives its products characteristics of their own, such as the Ehrenfels qualities. It is, however, not only segregated objects as such which exhibit particular characteristics of this kind. The same holds for their parts. Thus, a certain point in an object is a corner only within this larger unit, a line is a boundary only with reference to a segregated area, etc. One particular characteristic of this class has become famous by an investigation of E. Rubin (1921). He called attention to the difference between figure and ground, between the substantial appearance of objects and the looseness of their homogeneous environment. Equally important is A. Michotte's discovery (1941) that, under certain conditions of successive stimulation, causation is directly experienced as a characteristic of organized developments.

Organization in Physics and Physiology.—Since, as a rule, perceptual organization does not originate within experience, it must be processes in the sensory nervous system which are responsible for the formation of perceptual units, for the change of their characteristics by interaction and for the emergence of Ehrenfels qualities. Thus, Gestalt psychology is under obligation to show that organization occurs in the realm of physical facts; that some particular facts of this kind occur in the nervous system; and that physiological organization in this sense actually underlies all instances of organized experience. As to the first point of this program, such eminent physicists as C. Maxwell, M. Planck and A. Eddington have sometimes clearly stated that a purely analytical approach may not be able to do justice to all phases of physical nature. Actually, whole sets of physical processes are never treated in what could properly be called an analytical fashion. The epistemology of physics has merely failed to recognize this fact, although it is implicit in the physicist's own work. It was first made explicit by W. Köhler (*Die physischen Gestalten in Ruhe und im stationären Zustand* [1920]). He showed that all instances in which physical materials or processes distribute themselves under certain limiting conditions fulfil the principal criteria of organization. For instance, if water streams through a system of interconnected pipes, the flow in each pipe depends upon the flow in all other pipes. For, if an obstruction is introduced in one pipe, the flow in the others is immediately affected. Similarly, if an electric current flows in a network of wires, the self-distribution of this flow is maintained in the system as a whole. Any local change of conditions is at once reflected in a redistribution of the current everywhere. In other words, a physical self-distribution is relationally maintained and relationally determined. This is clearly shown in the mathematical expressions which serve to describe such a process. In any formula which refers to local events within the total distribution, these events are related not only to corresponding local conditions but also to the conditions in all other parts. More particularly, the determining conditions appear in the form of their ratios so that physical self-distributions remain unaffected if all local conditions are varied in the same proportion. Obviously, this agrees with the criterion which Ehrenfels used when he first called attention to Gestalt characteristics.

In connection with psychological problems, it must be emphasized that physical organization is not restricted to self-distributions which occur in conducting networks. On the contrary, this concept applies most readily to instances in which processes distribute themselves within continuous media.

In trying to indicate what particular processes actually underlie organized experience in perception, Gestalt psychologists propose a change in neurological theory. They do not believe that brain function is limited to the propagation of nerve impulses along separate fibres. Köhler developed a theory of vision according to which organized function in the brain is a matter of electric currents. These currents are supposed to distribute themselves in the brain tissue as a continuous volume conductor. The theory is supported by the fact that organized processes in perception have specific aftereffects which can readily be explained on this ground. The general direction in which Gestalt psychologists attempt to develop neurological theory is indicated by the term "isomorphism." The term means that the facts of organized experience and the brain processes which underlie these facts have precisely the same structures. It would, for instance, follow

that to any symmetry in perception there corresponds the same symmetry in the functional interrelations of the underlying process, that segregated units in perception are associated with functional units in brain dynamics, etc.

Organization in Higher Mental Processes.—An early extension of Gestalt psychology beyond the field of perception referred to such concepts as memory traces, association and recall. This development was natural because, when experiences are reactivated in memory, they are on the whole organized in the same sense as are the facts of perception. Gestalt psychology assumes that memory traces are direct products of the processes which underlie primary experience; in other words, that human experience writes down its own history in the nervous system. In the course of time, however, the traces are supposed to undergo changes as a consequence of their inherent dynamics. Interaction within the realm of traces seems to be of the same kind as that which is responsible for primary organization. Any condition which makes for particular clearness in perception also favours retention in memory, and any factor by which clear segregation in experience is impaired strongly operates against recall. This thesis has been amply verified. It has also been shown that the concept of association by contiguity must be given a new interpretation. According to classical association theory, the connection between remembered items is quite analogous to the way in which places are connected by roads, or objects, say, by strings; *i.e.*, the connection as such is assumed to be indifferent to the nature of the connected items, and vice versa. Gestalt psychology maintains that associations are after-effects of the specific interactions which occur in primary organization. From this point of view, associations must depend upon the characteristics of the items in question because all interaction is a function of the nature of the interacting objects. More particularly, the factors which make for strong perceptual organization of items in pairs must at the same time be factors which favour strong association. Experimental tests have corroborated this conclusion.

A similar reasoning has been applied to the concepts of recognition and recall. Facts in present experience reactivate facts of the past in a highly selective way. It seems that recall begins with a process in which a present experience makes contact with the trace of a similar past event. The way in which similarity here operates as a selecting factor is comparable to the fashion in which resemblance makes for specific organization in perception. From this the conclusion is drawn that recall is initiated by a fact of organization in which a new process interacts with a trace of a similar event in the past. Thus, perception, retention, association and recall are given a unitary interpretation.

The most important extensions of Gestalt psychology refer to higher mental processes. Much in contrast with the view which scientists have of their subject matter, the psychological field exhibits many phenomena of experienced nexus. David Humes's statement that "all events seem entirely loose and separate" does not hold in psychology. According to the German philosopher W. Dilthey, all awareness of relations, but particularly of dynamic relations, proves conclusively that connections among experiences may themselves be experienced. Moreover, such connections tend to have the character of being understandable. When two tones of sufficiently different intensity are given in succession, there may be immediate awareness of the fact that the second tone is louder or softer. This relation is experienced not as a third thing by itself but as being necessary in view of the nature of the tones. In a similar way an emotion is felt to be the adequate and understandable answer to its object; a conclusion emerges as following from its premises, etc. As interpreted by Gestalt psychologists, this means that not only in perception, but also in many other psychological situations, causation is directly accessible to observation, and that it then proves to be identical with the fact that the nature of a given situation requires a certain event to happen. Gestalt psychologists can, therefore, say that in experience certain occurrences "make sense" while others fail to do so. With a more subjective expression, they claim that man may have insight into the "ought" of facts. Thus, in Gestalt psychology, the term insight does not refer to a mental power, nor is it necessarily related to new discoveries. Rather, it is a descriptive term which designates a peculiarity of certain forms of experienced nexus.

In this fashion, the Gestalt psychologists relate the concept of value to that of organization. For it is only within organized mental situations that the phenomenon of requiredness is experienced. The school concludes that ethics, aesthetics and logic deal with, and systematize, principles of requiredness which are implicit in experiences of nexus, but are, in common experience, blended with merely factual admixtures.

On such grounds, Gestalt psychologists have begun to investigate learning and thinking as facts which are directly related to organization. Learning, they declare, is often much less an acquisition and retention of given contents than a development of new contents; namely, of new structures in perception and conception. It is not, of course, denied that learning in this sense involves retention of the new structures. But it is stressed that, before the question of retention is raised, the psychologist ought to realize precisely what is being retained. Some theories of learning ignore the organization which given materials tend to undergo when we learn something about a situation. Often, this is the most important achievement in learning, and without it retention would be of little avail.

M. Wertheimer and K. Duncker applied these concepts to the problem of productive thinking. In such thinking a material and a goal are given while the right way from the situation to the goal is not yet available. With sufficient motivation, such a situation tends to reorganize itself so that either the given material changes its structure or the goal is seen in a new light. As a result, relations which played at first no part in the situation may suddenly become entirely obvious. With their appearance the principle of the solution often emerges. To take one of Wertheimer's examples: The task of computing the sum of the terms of an arithmetic series will be greatly facilitated if the even progress of the series in the ascending direction (*i.e.*, the original structure of the material) is replaced by the conception that from the two ends of the series toward the middle the terms increase and decrease at the same rate. Once this is seen, the series readily splits into a known number of quantitatively equivalent pairs of terms, and the result of their sum can be directly found by multiplication. It will be seen that in productive thinking of this kind the reorganization of the field as a whole and the discovery of the main principle of the solution precede the recognition of any particular steps in which the actual solution is eventually realized. Measures of detail are taken only as required by that principle, and in this sense the solution is found "from above" (Wertheimer). In this respect, the Gestalt psychologists' interpretation of thinking differs widely from that given by associationists, who regard both the concept of organization and that of requiredness with suspicion, and interpret the course of thinking "from below"; *i.e.*, as a play of associations which, in conjunction, happen to give the whole solution. From the point of view of Gestalt psychology, it remains to be seen for what reasons problem situations tend to reorganize themselves in more or less adequate directions when the motivation is sufficiently strong.

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SOCIAL PSYCHOLOGY

Social psychology deals with those elements in the ideas, emotions, attitudes and habits of individuals which derive from, and relate to, the fact that man lives in social-cultural relations with his fellows. It studies the behaviour of individuals in so far as their behaviour stimulates others or is itself a response to the behaviour of others. Two main areas of interest emerged in this field: One has to do with the place of social-cultural influences in the rise and functioning of the personality (*q.v.*); the other has to do with the mass or collective aspects of man's thought and conduct.

The Social-Cultural Genesis of Personality.—One basic concept of social psychology, especially as it relates to the development of the personality, is *interaction* or the *social act;* that is, an act which is not completed without the intercession or qualification by the act of another. The earlier systematic psychologists usually took the view that the fundamental habits and thought patterns of the individual are built up, through learning, on the basis of innate neuromuscular potentials, including the drives, and that only later does the individual add social features to his mental and behavioural repertoire. This atomistic viewpoint is rejected by the interactionist school. It agrees with individualistic psychology regarding the importance of biologically inherited drives, of neuromuscular maturation and of learning. But its central theme is that the individual is more or less socially and culturally conditioned at every point from birth on.

This position is defended, first, on the ground that man as a member of the mammalian family is born into a social situation, involving at least the mother and the infant himself. Second, in the early months and years the new member is socially dependent on other members for his food, shelter and bodily protection. Third, within this interactional framework even strictly individualistic, biological reactions such as concern elimination, posture, locomotion and sleep become socialized or conditioned through the tuition of others. In fact, within this social matrix all the basic skills and knowledge develop. The internal organization of stimulus-response patterns (that is, perception, reasoning and concept formation) are all affected by the interplay of the growing child and those who surround him. And in this development communicative as well as overt physical interaction has a part.

Not only is the social impact, as such, basic, but the parents and others bring to the child their culture patterns. These consist of the more or less standardized and expected ideas, attitudes and habits which serve to direct the child's learning and to provide him the content and meaning of his varied experiences. Thus, while the fundamental drives and mechanisms of adjustment are derived from species inheritance, the learning process is social, or cultural, or both, at every step of the way.

The interactionist position derives from the work of J. M. Baldwin, C. H. Cooley and especially George H. Mead and John Dewey. According to Baldwin, the self or personality develops from the give and take of the infant and child with those about him. This he termed the "dialectic of personal growth," operating through imitation, suggestion and accommodation (habit). Cooley's phrase "the looking-glass self" summarized his view that self-feeling, illustrated in pride or mortification, rests upon one's image of himself as he has derived it from others.

It was George H. Mead in *The Journal of Philosophy* (1922) who stated the process of personality formation in interactional terms without positing inherited social instincts. In his words: "The self arises in conduct when the individual becomes a social object in experience to himself. This takes place when the individual assumes the attitude or uses the gesture [or word] which another would use and responds to it himself or tends to so respond. . . ." The growing child introjects into his own stimulus-adjustive-response system the reactions of other individuals with reference to him. He calls out in himself their attitudes and responses as well as his own toward himself. This duplication of the actions of others Mead called role-taking.

At the outset, roles are highly specific. For example, in his play a child may assume the mother's or father's tones, words and actions toward his toys, dolls and his real or imaginary playmates. In his fantasy he may play many parts. At one moment he is a buyer, at another the clerk making a sale; he may be a gangster for a minute and a policeman arresting himself the next. In taking such roles language has a central place. The child talks to himself as others have talked to him.

Yet roles do not remain entirely specific. The repetition of the same or similar drives and situations leads particular roles to become generalized. An early general role centres around his age, status and function within the family. The chief general roles of the adult male in our society are those of husband-father-breadwinner, good citizen and solid churchman.

The social self, however, is not merely a reflection and reorganization of ideas, attitudes and habits which one picks up from others. At all times the drives and action patterns of the individual are present and serve as the dynamic and unique elements in personality. Mead held that these drive-action elements and the specific or general roles together "constitute a personality as is appears in social experience."

If one's ideas, attitudes and habits derive from integrating the roles of others with one's own drive-action systems, it follows that mind itself must be a social product. The chief medium by which mind is built up is communication through gesture and language.

The thinking function arises as the child rehearses and reorders the interactions—overt and verbal—which have gone on between him and others or which he has observed among those around him. Dewey has aptly pointed out the dramatic (that is, interactional) character of our mental processes. And the investigations of many child psychologists give concrete evidence of the social foundations of the sense of self and of the thought processes.

Language as the vehicle of communication sets up expectation or incipient action in the person spoken to, and likewise, in terms of introjection, anticipatory response patterns in the individual speaking. Meaning depends on one's perception and conception of the object of communication as it functions in the other's experience as well as in his own. So, too, the respondent must perceive or conceptualize the idea as it operates in the speaker. As Dewey says in *Experience and Nature* (Open Court Publishing Co., 1925): "To understand is to anticipate together, . . . to make a cross-reference which, when acted upon, brings about a partaking in a common, inclusive, undertaking." In short, meaning always falls within the self-other configuration.

Many social interactionists tended to neglect the place of the content of ideas, attitudes and habits in personal development. But this need was met chiefly from Freudian psychologists in collaboration with cultural anthropologists.

The aim of the culture-personality studies is to compare critically the way in which the basic drives and capacities of the new generation are moulded by culture—chiefly at the hands of family members and primary groups; that is, to modify and elaborate them into adult motives, roles and other elements of the self. For example, certain studies show that the masculine-feminine roles as defined in western culture are quite differently organized among other peoples. So, too, co-operative-affectional in contrast to conflictive-aggressive patterns differentially affect personality formation. Among primitives like the Arapesh, Zuni and Hopi, and among certain Christian sects, such as the Amish and Mennonites, the individual is trained from birth on to be sympathetic and helpful of those around him. Rivalry and personal push are punished. The result is a rather quietistic, mild and nonaggressive person. In contrast, the highly competitive societies like those of the Kwakiutl Indians or the modern United States induct their children into a set of values and habits which stress intense interpersonal struggle, ambition for status and monetary rewards. Or, in militaristic countries like imperial Japan and nazi Germany, the child, especially the male, was brought up in aggressive, conflictive patterns of thought and action.

This does not mean, of course, that aggressive responses are entirely lacking among the Pueblo Indians or among the pietistic sectarians. But they are suppressed and sublimated. Yet among the Zuni vicious gossip provides an outlet for interpersonal antagonism. And some, at least, of the U.S. quietistic sectarians have been known for their sharp competitive business sense.

These comparative analyses show that personal sense of security, presence or absence of inner tensions, the emphasis on introvertive or extrovertive values and activities and other elements of the personality will be greatly influenced by such differentials in training.

A provocative approach in this field was that of A. Kardiner and R. Linton, who examined both primitive and civilized societies in an effort to discover "a group of nuclear constellations in the indi-

vidual" designated as "the basic personality structure." By applying psychoanalytic concepts to known differences in early child training, especially in the mother-child, father-child and sibling interactions, they traced the integration of ideas, values, attitudes, and habits which form the distinctive modal personality features of all members within any particular society-culture milieu.

The co-operation of workers in psychology and anthropology in tracking down the cultural sources of personality differences marked a step forward toward a science of personality. But there remained many unsolved problems of data, analysis and interpretation. No theory of modal or basic personality for all members of a given society can get around the solid facts of individual variation and uniqueness. These differences are based on biological variability as to drive, emotion and intelligence potential, on deviations in acquired skills and knowledge and on variations in interpersonal conditioning at all points. As to the latter, it can be shown that not all social learning is necessarily culturally controlled or directed, unless culture and all interaction are defined as completely synonymous. There is, especially in the early years, a good deal of social learning which occurs outside the framework of the cultural norms and expectancies, and this learning plays a part in the formation of the personality.

Collective Psychology.—Collective psychology deals with group behaviour, in small as well as larger aggregates such as is found in crowds and audiences, in responses to changes in fashion, in public opinion and propaganda and in various manifestations of leadership. However, there is no special psychology of so-called crowd mind or collective consciousness.

The interactions of individuals in small groups has been studied in order to get at social behaviour which involves, among other things, dominance-submission relationships, degrees of conscious intimacy or hostility among group members, and objects of common or different identification. It is often assumed that generalizations derived from the study of small groups may be applied to similar activities in larger groups. This assumption, however, had not been completely proved at mid-20th century.

Turning to the larger aggregates, a crowd is a relatively temporary congregating of interacting individuals in a limited space. Its typical spatial arrangement resembles the disposition of iron filings around a magnet. There is a centre or focus of attention around which individuals stand or move in varying degrees of verbal, auditory and bodily participation. Unlike the usual face-to-face interactions, the interstimulation of the crowd members is of shoulder-to-shoulder kind.

As to responsiveness, crowds may be further defined as passive or active, the former illustrated by a transitory grouping of pedestrians to watch a dogfight, the latter by the intense emotions and agitated actions of a crowd celebrating the news of a victory, taking part in a lynching or fleeing a fire in panic. Psychologists have given most of their attention to the action crowd.

The principal psychological characteristics of the individual in an action crowd are, first, the expression of strong emotions of love, hate and rage, associated with the basic values of life and security; *e.g.*, bodily survival, sex, property, race, religion, class status and national honour. Second, there is intense ego-expansion in terms of all-or-none, absolutist convictions. Third, a sense of self-righteousness overrides one's habitual sense of guilt and shame. Also, the crowd-man quickly identifies himself with some in-group which stands opposed to some out-group.

Men under these conditions release hidden and suppressed motives. In so doing imitation (*q.v.*) and suggestion (*q.v.*) play a large part, especially in adding a crowd-stimulus or social facilitation to that of the deep-seated drives. Suggestibility and imitative training in copying and conforming to others lead to the inhibition of critical attitudes in favour of doing unwittingly what those around one are doing. There also develops a strong sense of safety in numbers. The prestige and power of numbers fosters anonymity and the "impression of universality." Finally, long training in deference and obedience to leaders and symbols of authority makes for adherence to the emotion and action stimulated by the leader of the crowd. Such interactions as rhythm of bodily movements, whispering, shouting and pushing all add to social facilitation. In short, there is a summation of primary and crowd stimuli which impels the mass along its particular course of action.

It is often said that the crowd-man loses all morality and decency. By traditional standards this is correct; but the self-righteousness of mobs is well known. There arises a primitive morality of survival and group solidarity which temporarily replaces customary conscience. This rudimentary morality even persists, when the violence is over, in the rationalizations which people give for their participation in a mob or panic.

However, a crowd does not act entirely outside the framework of culture. Clearly all kinds of mobbish behaviour have their roots in the faiths and values of the participants. On the American frontier the lynching of cattle thieves was an accepted form of social control. So, too, the lynching of Negroes in the south. Even the periodic mass violence of race and religious riots in the United States, the near east and in India have their original motivations in the values of race, class and religious differences.

An *audience* is an institutionalized crowd which meets for a more or less specific purpose at a predetermined time and place. The polarization and interactional forms vary with the kind of audience. Most audiences may be classified as information-seeking, recreation-seeking and conversional. The first is characterized by a rational aim and function; the other two are loaded on the side of emotion and action.

The psychology of the audience is revealed, first, in the preliminary tuning or prior stimulation, as through advertising and conversation designed to draw out the participants. Second, there are some initial interactions at the time the group forgathers but before the central function begins. Third, the speaker or performers must gain rapport or attention to bring about close identification with the activity. In the informational audience this tends to be by means of logical imagery and abstract ideas. In the other two it is usually a mixture of the rational and the irrational.

Fashion is a prevailing usage, mode, style or manner of expression or presentation of certain cultural elements which are open to, or subject to, relatively rapid change. Fashion operates chiefly with respect to clothes, architecture, furniture and modes of transport and communication. *Fad* refers to more superficial, more fleeting and more bizarre forms of such things as decorations or slang. The word *craze* is usually applied to highly transitory, though often widespread, forms of bodily activity, such as certain dances, miniature golf or unconventional gestures or postures.

For the individual, being in fashion provides a curious but pleasing mixture of personal distinction and group conformity. It at once sets one apart from the masses but gives evidence of adherence to one's class by virtue of others also following the fashion parade.

To understand public opinion the meaning of both "public" and "opinion" must be clear. As an adjective, "public" means that which is known, actually or potentially, to all members of a community. As a noun it refers to a relatively large aggregation of persons, not necessarily contiguous, loosely associated together by some common interest. There is not just one public, the political, but actually various publics concerned with any focus of wide community interest. "Opinion" is a judgment or belief based admittedly on ground short of full proof or certainty. Public opinion, then, consists of judgments about some topic of interest in a given public at some particular time and place. It is usually expressed in words and is often related to deeper and more permanent attitudes and values.

The crucial matter of public opinion is its formation and change. While there are some situational variations, the formation of public opinion follows certain stages through time. The first is the rise of an issue or problem confronting a given public. The second is the conversation and discussions by members and leaders who try to define the issue more sharply and perhaps offer some tentative solutions. The third stage appears with the taking of definite positions as to the nature of the solution and the means of attaining it. The final stage is the arrival at consensus. This may mean a compromise of opposing views or it may mean the

acceptance by the majority of the views of one side. Consensus may be expressed by written memorials to legislative bodies or executives, by public opinion polls and by legal voting. The overt execution of any decision belongs to action programs and lies outside the strict process of opinion formation.

In democratic societies the formation of public opinion follows this general pattern. Under totalitarianism, opinion formation tends to be restricted to the élite of the dominant party or to party members only. It is not a function of members of the wider community or society. However, this does not mean that amorphous and less vocal publics may not influence opinion formation at any step. Dictatorial governments usually "have their ears to the ground" though they may, by propaganda, attempt to determine the nature and direction of any popular ground swell.

In contrast to conditions in simpler, rural societies, public opinion in highly industrialized, urban societies raises many questions of manipulation and control by political and special interest pressures.

Under such modern conditions propaganda and censorship have especially important bearings on the formation of public opinion.

Propaganda is the deliberate use of symbols, chiefly through suggestion and persuasion, with a view, first, to changing and controlling opinion, attitudes and values, and ultimately to altering overt action along predetermined lines. Also propaganda may be open and obvious to the recipient as in advertising or a public health campaign, or thoroughly hidden and disguised as in the promotion of a revolution or a war.

The essential mechanism of propaganda is suggestion, the aim being acceptance, not logical reflection. Yet in analyzing propaganda it is necessary to know the motive and purpose of the operator, the symbol content he uses and the responses of his would-be recipients in order to find out to what extent their opinions, attitudes and habits have been altered.

Successful propaganda must be related to motivation and culturalized attitudes and habits. While the particular situations vary, among the more common facts which the propagandist must bear in mind are these: (1) It must be linked to basic motives of those to whom it is addressed; (2) the primary appeals should be emotionalized symbols of promise and satisfaction; rarely, and for selected audiences, may rational appeals be used; (3) both the issues and the proposed solutions must be simplified; the promotional artist deals in whites and blacks, in good and evil, not in the intellectual elaboration of a topic; (4) systematic and rhythmic repetition of these few and simple elements is usually effective; (5) innuendo, indirection and implication are frequently preferable to direct statement, especially in the early phases; (6) once the desired motive and bias are established, blunt, declarative and unsupported statements may be used as well as exaggeration, startling accusations and outright falsehood; (7) finally, short-run propaganda may be directed to all age groups, but that designed for more complete and lasting indoctrination should be directed to children and youth. They are the most suggestible since their basic values and attitudes are less deeply rooted.

The tactics just cited deal with the intent and stimuli of propaganda. Accurate knowledge about the effects on those to whom it is directed is more difficult to secure. However, we have some information on the influence of deliberate planting of content in newspapers and of exposure of young people to selected propaganda through the films or radio. The results show that within the limits of previous social-cultural learning changes in opinions and attitudes can be effected. There is little if any valid data on the influence of such experimental propaganda on later overt conduct.

Yet, it would be a mistake to hold that propaganda is ineffective. Campaigns to repeal the Corn laws in Britain, the abolitionist, prohibition and populist movements in the United States, Communist and fascist agitation and its use in war—all exemplify its importance.

Leadership is a universal feature of social interaction. It means the determination of certain responses of another or others in line with the leader's wishes.

Attempts to classify dominant individuals are common but difficult to support objectively. Some writers take their cue from differences in leadership role and status under varying situations. There is the dual classification of leaders into executives, or men of action, and thinkers, or men of thought. Some writers require more than two categories, as in the division into executive, dominant, persuasive and expert leaders, or into headship, voluntary leadership and status forms of dominance.

Classifications which attempt to get at psychological characteristics also face difficulties. Followers of Carl Jung's typology often divide leaders into introverts or extroverts; others use Ernst Kretschmer's schizothymes or cyclothymes. But most attempts to use these types empirically lead to further assumptions of mixed types as well.

So, too, psychologists who approach personality from the angle of specific traits and attitudes have trouble in deriving any common clusters of these elements which might characterize all leaders, or, for that matter, even those within such social categories as those noted above. One writer tabulated the 79 distinct traits cited in 20 separate studies of leadership. Of the total list, two-thirds of the traits were named but once, and only 5% had as many as four traits in common. The most common trait cited (in ten studies) was intelligence. Initiative was noted by six; extroversion and sense of humour, each by five; and enthusiasm, fairness, sympathy and self-confidence, each by four. Much careful research needs to be done before any satisfactory generalizations can be made about the psychological traits or types which characterize the dominant individual.

Regarding the relation of psychological characteristics to occupational or other social roles, there is some evidence that men of introspective, introvertive make-up tend to be more successful in science and the arts and that out-going, extrovertive persons are more successful in administrative roles. But cultural expectancies and differential circumstances may serve so to disguise the deeper motives, attitudes and values that any one-to-one correspondence of psychological make-up and social role is difficult to find. Men of the introvertive order are found in executive positions. Furthermore, since mixed types are probably more common than so-called pure types, most individuals may adapt themselves to one role or another without undue inner tension.

The qualities of leadership are definitely affected by the ideas and reactions of followers. The latter invariably attribute certain ideal qualities and powers to the leaders. This sets up expectations as to conduct on the part of leaders which they must follow, or seem to follow, if they would retain their dominance. This projection of ideal qualities is doubtless the reason why the traits of leadership are nearly always put in laudatory, admiring terms. Negative and derogatory traits seldom appear in listing the characteristics of leaders.

Methodology.—Though by no means well-ordered as a logical system, social psychology has developed points of view, hypotheses and methods of empirical research which, in time, should produce a body of systematic knowledge adequate to provide predictions and control of human conduct.

The principal scientific approaches to social psychology are the case- or life-history method and the use of statistical techniques. An attack on the problems in this field by strictly experimental methods has only recently begun.

The aim of the life history is to discover and analyze the social-psychological processes, operating through time, which cause the emergence or modification of roles, statuses, traits, opinions, attitudes, values and other elements of the personality. In some studies there is an attempt to reconstruct the whole course of personality growth on the assumption that this will permit a fuller understanding of adult behaviour.

The data for the case study are protocols of oral interviews or formal and informal writings of the informant. Interviews may be prolonged in time and demand special skills, as in psychoanalysis, or may be relatively short. Free-association techniques or direct questioning may be used in either to elicit forgotten and unconscious memories necessary to reconstruct the genesis and meaning of the factors in personality growth. Formal written reports may

be secured by questionnaires or outlines likewise designed to bring out memories of past events. Informal written documents consist of free-flowing autobiographies, letters and diaries or the protocols from projective tests.

The life history is open to question, first, in terms of the assumptions that this device will lay bare the genetic and functioning processes; second, as to the validity of memories on which the data depend; and, third, as to the standardization of procedures, since the difficulties of communication of meaning unwittingly qualify the responses of both informant and observer. Fourth, generalizations are often made on too few cases and with complete neglect of sound sampling.

Yet the case study provides an understanding of motivation and meaning which is often not obtainable through so-called more exact techniques. A combination of statistical and case methods, as in some of the projective techniques (*see* PERSONALITY), should, in time, contribute valuable data to a science of social psychology.

The quantitative study of personality derives from the measurement of intelligence. Taking their cue from mental testing, psychologists and sociologists developed a large number of questionnaires and scales in an effort to measure the manifestations of personality by tapping a wide variety of traits, attitudes and opinions. Usually there are a series of statements arranged in such form that the respondent may mark his agreement or disagreement and perhaps the intensity of his attitude toward each item. An index is then determined by summation of the separate responses or by using such measures as the standard deviation of the distribution. However, the problems of developing equal and interchangeable units on the scale and of composing the scale so as to measure one dimension or cluster of traits, attitudes or opinions at a time have not yet been satisfactorily solved.

While the more adequate scales are statistically fairly reliable, validity is frequently neglected. The basic test of validity is a high positive correlation of measured trait, attitude opinion or value with overt behaviour. All too often it is not clear just what outside criteria, if any, were used to validate a questionnaire or scale.

Although public opinion polls and market analyses usually handle the matter of sampling reasonably well, most studies of traits and attitudes do not. Almost all of them use high school and college student populations, not adults outside. Even so, there is seldom any concern with the representativeness of the sample of this particular universe.

Both from the standpoint of contributing to a scientific knowledge of total personality and of perfecting instruments for predicting specific behaviour, the tests of motives, attitudes, opinions and values have much ground to cover. Yet, with more careful attention to matters of units, reliability, validity and sampling, we may expect, in time, a body of substantive objective generalizations in social psychology.

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PSYCHOPHYSICS, the science that deals with the determination of the relation between the mental and physical worlds, or, more specifically, of the relation between sensation and its stimulus.

The word is generally used with reference to the quantitative determination of the latter relationship.

History.—Psychophysics was established by Gustav Theodor Fechner (1801–1887), who coined the word, invented the three fundamental methods, conducted elaborate psychophysical experiments, and began a line of investigation that still persists in experimental psychology today. Fechner's classical book, *Die Elemente der Psychophysik* (1860), may be looked upon as the beginning, not only of psychophysics, but also of experimental psychology (*q.v.*) itself. Fechner, trained in physics, became interested in his later life in metaphysics, and cast about for a way of relating the spiritual to the material world. He hit upon the notion of measuring sensation in relation to its stimulus. Ernst Heinrich Weber (1795–1878), the physiologist, had discovered that the just noticeable differences between the intensities of sensation always bore, when stated in the increment of stimulus necessary to produce such differences, an approximately constant ratio to the total magnitude of the stimulus. This fact, properly speaking, is Weber's law: if two weights differ by a just noticeable amount when separated by a given increment, then, when the weights are increased, the increment must be proportionally increased for the difference to remain just noticeable. Fechner chanced upon Weber's law and undertook to use it for the measurement of sensation. If R be the stimulus (*Reiz*), and S be the resultant sensation, and Δ signify an increment of either, then Weber's law becomes $\Delta R/R=a$ constant, for the just noticeable difference. Fechner went further and assumed that all equal increments of sensation must be proportional to the same ratio, $\Delta R/R$, that is to say, $\Delta S=c\Delta R/R$, where c is a constant of proportionality. If this equation is integrated, if R be measured in terms of the threshold stimulus (the value of stimulus at which S is zero or just ready to appear), and if the constant be changed to k for common logarithms, we have $S=k \log R$.

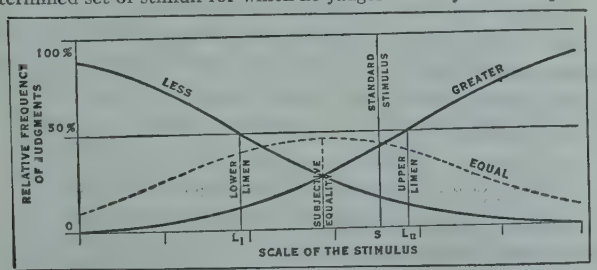
This particular formula Fechner named Weber's law, although it is really Fechner's law and is thus sometimes called the Fechner-Weber law. It expresses the simple relation that the magnitude of a stimulus must be increased geometrically if the magnitude of sensation is to increase arithmetically. For Fechner it meant that the relation between the spiritual and material worlds is statable, and that there is therefore only one world, the spiritual; but for physiologists and for many philosophers it meant the measuring of sensation in relation to a measured stimulus, and thus the possibility of a scientific quantitative psychology. Fechner got his conception of psychological measurement from Herbart, but he was really refuting Herbart in demonstrating that psychology can be experimental.

Fechner's original work stimulated much research and much controversy. It was argued against him that it is introspectively obvious that sensations do not have magnitude (the quantity objection), that "a scarlet is not just so many pinks." This difficulty was met by the Belgian, J. L. R. Delboeuf (1831–1896), who developed the concept of the sense-distance, holding that sensations, although not complex magnitudes, are separated by variable distances which can be compared as "greater," "equal," or "less," the three categories of judgment which the psychophysical methods require. In Germany, Georg Elias Müller (1850–1934) undertook an elaborate criticism of Fechner and an extension of his work. In America, E. B. Titchener (1867–1927) made a historical and practical exposition of psychophysics in the second volume of his *Experimental Psychology* (1905). More recently F. M. Urban, then also in America, improved one of the methods and developed the concept of the psychometric

function. Other well known psychophysicists are W. Wirth in Leipzig, and William Brown and G. H. Thomson in England.

Limens.—Psychophysics makes extensive use of the concept of the threshold or limen, of which there are two kinds. (i.) The *stimulus limen* is that value of stimulus which terminates a sensory continuum. The visible spectrum is limited by a stimulus limen in the reds (*c.* 800$\mu\mu$ wave-length of light) and another in the violets (*c.* 400$\mu\mu$). Tones range between the limen for the lowest audible tone (*c.* 16 vibrations per sec.) and the limen for the highest audible tone (*c.* 20,000 vs./sec.). The stimulus limens for intensities of weights, sounds, brightnesses, and other sense-qualities have been determined, but depend upon so many factors that no simple statement of their values is possible. Stimulus limens have also been determined for size and for duration. In the case of illumination, the size, duration and intensity of the stimulus are interrelated; a very small stimulus has to be more intense to be perceived. (ii.) The *differential limen* is that difference between two stimuli which marks the boundary between sensed difference and sensed equality. It is often confused with the just noticeable difference, although in fact it is a statistical quantity for the theoretical point between what is just noticeable and what is just not noticeable. In fact both limens are statistical values, for the variability of the conditions of excitation cannot be controlled and what is sensed at one time may not be sensed at another. Hence the limens are averages or mathematically determined points where the sensation is as often sensed as it is not.

Methods.—There are three fundamental methods of psychophysics, all of which Fechner invented. (i.) In the *method of limits* (method of minimal changes, of least perceptible differences) the stimulus is varied serially (usually by discrete steps) until a change is noticed. For example, to determine the stimulus limen of intensity, imperceptible intensities are presented in increasing order until the stimulus is first sensed; then a descending series from perceptible to imperceptible is observed; and finally the results of many such series are averaged. For the differential limen there are always two stimuli, of which one, the standard, is kept constant, and the other, the variable, is altered until a difference between the two appears or disappears, according to the direction of change. Here the limen is the distance from the standard to the average point of change, and there are always both an upper differential limen and a lower, since change can be noticed on either side of the standard. (ii.) In the *method of average error* (method of production) the experimental subject himself changes, by means of appropriate apparatus, the stimulus continuously, usually until subjective equality with a standard has been reached. Since subjective equality is not physical equality, the results yield an average or constant error for the subject and also a variable error about this average. (iii.) In the *constant method* the subject is presented at random with a predetermined set of stimuli for which he judges in every case the presence or absence of sensation or of the difference between the sensations. Because of the variability in the conditions of excitation his judgments are not always the same for the same stimulus, but it is found that, as a difference increases, the frequency with which the difference is perceived increases. When enough judgments have been taken, these relative frequencies can be plotted in a *psychometric function*. The figure shows the case of the differential limen. Reading from left to right, the frequency with which the variable is judged "less" than the standard decreases, the frequency of the judgments "greater" increases, whereas the remaining cases, the equality judgments, are maximal at the centre. The liminal values of the stimulus are taken as those values where the probability of the judgment "less" or "greater" is as likely as it is not, *i.e.*, the points on the scale of the stimulus corresponding to the points where the abscissa for 50% crosses the psychometric functions. The limens are the distances of these values from the standard stimulus (the distances L_1 to S and L_u to S) and one of them may even be negative when subjective equality deviates widely from the standard. Subjective equality is usually taken as the point where the judgments "less" and "greater" are equally likely, *i.e.*, the intersection of the two psychometric functions. It is customary (as in the figure) to fit to the observed frequencies for the psychometric functions smooth ogives of the normal probability integral, sometimes called the phi-function of gamma; but this curve is only an empirical approximation and has no theoretical significance.



Weber's Law.—The Fechner-Weber law implies that all differential limens of intensity should bear a constant ratio to the standard stimulus, whatever its value, and for this reason the psychophysical methods have been used most extensively to test the law and to determine these ratios. In general it may be said that the experiments indicate that the law holds approximately, although not exactly, within the middle ranges of intensity, but not for very small or very large intensities. Thus it appears that the liminal ratio for visual brightness is about 1/100, that is to say, illumination must be increased by 1/100 of its amount for a change to be perceived. The liminal ratio for lifting weights with the hand is about 1/40 and for pressure on the skin about 1/20. For tone the value is about 1/10; and for smell it ranges as a rule between 1/4 and 1/3. *See* DISCRIMINATION, SENSIBLE.

Results.—There is a very large body of quantitative results on liminal determinations. For theoretical purposes the constant method with weights, lifted by the hand, has been most used. The psychophysical methods, however, lie at the basis of nearly all quantitative methods of experimental psychology, especially those that deal with sensation. In its mathematical theory psychophysics is identical with the statistical methods that psychology uses in social measurements and with mental tests, and the boundary between the psychophysical and the statistical methods is thus quite properly becoming dim.

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PSYCHOSIS. Strictly speaking, the term psychosis means a state of mind, a concrete psychical process or a mental act; but it is generally used to signify an abnormal state of mind. This definition needs qualification, however, since the technical use of the term in psychiatry is confined to certain forms of mental disorder which can be distinguished from states of congenital mental deficiency on the one hand, and from "borderland" conditions or neuroses on the other. A distinction should be made between "psychosis" and "insanity," which in popular and legal language signifies that an individual, owing to his state of mind, is unable to manage himself or his affairs, is in need of care and control and is not to be held accountable to society for his actions.

Psychosis, on the contrary, is a strictly medical term; it refers to a type of mental illness with certain intrinsic characteristics, assuming various forms, and is the result of a variety of causes. It does not necessarily lead to serious disturbances of behaviour, and there are many individuals who though not insane in a legal sense are nevertheless the subjects of a psychosis.

Psychological Considerations.—Though it is convenient to divide mental disorders into different categories based upon their causation, clinical characteristics or course and outcome, so many transformations of the clinical syndromes occur that no hard and fast division into separate disease entities is possible.

It is desirable to differentiate between leading types of psychoses, and between psychoses and other types of behaviour disorders, especially the neuroses which include those maladaptations known as phobias, hysterias and obsessions. Although both psychoses and neuroses may have some similar features in their historical development and in their dynamic defenses, there are differences in both the quantity and quality of their dynamic systems. The psychotic has ego functions which are damaged in one or more spheres, especially in the ability to maintain object relationships with things or people. Since he cannot cope with his environment, data are falsified in order to obtain some kind of mastery. The neurotic does not grossly distort the facts of the environment but rather tries at first to work out his conflicts within himself and then only secondarily "acts out" his conflict. The neurotic, as it were, remains in touch with people, whereas the psychotic often seems distant, strange or even bizarre. The psychotic often seeks infantile pleasures of a rudimentary, often undisguised, type. He expresses many emotions, especially hostility, more openly than the neurotic. He has less need for defensive refinements or ambivalence (*i.e.*, simultaneous opposing emotions toward the same object). Projecting his own beliefs upon others and impugning improper motives to them is much more common than repression. Anxiety is usually not so well organized in the psychotic and he shows much less shame, guilt and sensitivity about his own or other people's performance. Modulated expression of personal needs, which are compatible with conventional practices, are often lacking in the psychotic, so that he may then be in danger of injury or arrest. The psychotic may exhibit behaviour of infantile origin utilizing archaic language and motility, delusions of grandeur, somatic symptoms, destructive fantasies about the self, other people or the world. Delusional systems and hallucinations are considered to be attempts by the damaged organism at restitution. Incomplete repression often causes the psychotic to be severely distressed by primitive wishes. Under stress the psychotic may resort to gross flight and massive withdrawal including suicide rather than to defensive symptom formation as in the case of the neurotic. It is generally agreed that most persons will exhibit neurotic defenses under stress, especially if that stress is specific for the person concerned. It is also generally agreed that most persons will not utilize psychotic mechanisms except under extremely devastating conditions. Those who employ psychotic defenses under relatively moderate stress are apparently much more susceptible than the nonpsychotic population. It is not certain just wherein this susceptibility lies in spite of many attempts to prove that heredity, constitution, or body-build are the crucial factors.

Groups of Psychoses.—Psychoses are ordinarily grouped into the organic and the functional. The organic psychoses may have many causes (alcoholic psychosis, general paresis, senile dementia) but have one factor in common, *e.g.*, a physical disorder of the brain. The signs and symptoms vary with the amount and distribution of the physical involvement and the individual personality response of the patient. Patients become sad, elated, suspicious or destructive, not only because of the loss of cortical control through loss of tissue, but because of the underlying personality organization. The functional psychoses have come to be regarded as reaction types, ways in which a patient attempts to deal with his problems. The early attempts to create distinct clinical disease entities, which are both chemically and psychologically identifiable, remained unsuccessful in the 1950s, although many workers persisted in this hope. In practice the reaction types seem to have many mixed features if they are carefully studied over a number of years. The manic-depressive reaction is characterized by severe change in mood, possibly alternating at times, with intervals of normality. The process may never recur after a single attack. The schizophrenic reaction-type is likely to be more persistently disruptive of the patient's relations to other people; but optimistic, skilful therapy has repeatedly demonstrated that favourable results are possible, especially if other life circumstances are also conducive to recovery. Other types of functional psychoses are being recognized as more or less related to those two basic forms: schizophrenia with obsessional defenses, pseudoneurotic schizophrenia, depressive psychoses with hysterical defenses.

Complex forms of criminality, and even psychosomatic diseases, may also prove to be related to psychotic mechanisms, but much more quantitative work will be required to demonstrate the relationship of the various factors to each other.

Causation and Treatment of Psychoses.—A psychosis is a disorder of behaviour, and represents a failure of function at the psychological level. Psychiatry (*q.v.*) thus differs in its subject matter from general medicine; the former deals with disturbances in the reactions of the organism as an integrated whole, and the latter with disorders of special systems of organs. Since the behaviour of an individual, whether normal or abnormal, depends upon an infinity of factors—the nature of his life situations, the state of his organism, and the whole of his past history, both personal and ancestral—it is impossible to select one factor as explanatory of the total reaction. The problem of causation in the psychoses is thus dissolved in relativity, and in each case an endeavour is made to seek out, and remove where possible, any factors, either physical or mental, which seem to be exerting an unfavourable influence upon the behaviour.

There is a general tendency to approach the problems of mental disorder from the standpoints of biology, pathology and general medicine, as it is recognized that the psychoses must be the outcome of a malfunctioning organism. Many psychoses, indeed, have definite relationships to diseases of the nervous system and of the bodily organs, as well as to general disturbances caused by infections, exhaustion and drug intoxications. Modern treatment attempts to take advantage of all new drugs or physical methods to the advantage of the patient. The demonstration by Julius Wagner-Jauregg (1917) that malaria could "cure" general paresis, and the addition of dilantin for the control of epilepsy set up patterns which have had numerous progeny. Outstanding was the introduction of insulin as a coma-inducing agent by Manfred Sakel in 1933 in the treatment of schizophrenia and the use of metrazol as a convulsant by Ladislas J. Meduna about the same time (1935) for the same purpose. Although later years of experience greatly sobered expectations of benefit from these methods unless substantial psychotherapy is also done, these methods did have the virtue of stimulating interest in the personal care of the patient. Insulin came also to be used in the less drastic sedative sleep treatment. The older Cloetta-Maier "Dauer-Schlaf" (sleep treatment) never became popular, nor did the newer methods of electrical sleep treatment gain wide acceptance. The most widespread treatment after its introduction in 1937–38 by Ugo Cerletti and Lucio Bini has been electroshock. This proved to be unusually useful in the depressive reaction types, especially in patients in middle life. Unfortunately it is not a cure-all even here. Large daily doses are employed in severe cases. Shock therapy has altered both hospital and out-patient clinic practices considerably, for it makes possible a more economical management of the suffering patient in selected cases.

There are no satisfactory neurophysiological explanations for the changes observed, although the cerebral metabolism and circulation are altered. A number of psychological stresses result from severe physical stress and these may contribute to the therapeutic change. It has been observed over many years that some patients would respond with a renewed interest in living if their life was threatened. Some patients respond to physical illness with increased anxiety and dependence which causes them to appeal for help. If this is available they may progress to an independent status. Others seem to regard the physical threat as a fitting punishment for past wrongdoing and improve rapidly. Another theory is that the old defenses are damaged, thus permitting the patient to learn new ones if the means for this is available at the time. Most therapists believe that psychotherapy is an essential part of the total treatment.

John F. Fulton and Carlyle F. Jacobsen in 1935 reported the behavioural changes in two chimpanzees following bilateral removal of the anterior lobes. The animals operated upon had shown less irritability and over-reaction to frustration.

During 1935–36, Egas Moniz and Almeida Lima performed the operation on human subjects for the relief of severe anxiety states. In succeeding years there was increasing opportunity to observe the after-effects of this operation, which is done principally on schizophrenics who can be characterized in many cases by

loss of interest, energy, initiative, spontaneity and sense of humour, and increasing inertia, vacuity and denial of injury. Much work was done to improve the selection of appropriate patients for the operation and also to alter the operation so that the improvement would be maximal and the damage minimal. There are many different types of such operations without clearly demonstrated superiority of any one of them. The follow-up care after the operation with attention to all of the patient's important problems remains one of the most important elements in the treatment. With increased therapeutic experience and some success in severe cases of functional psychoses came a better balanced and more realistic optimism about the psychological meaningfulness of the organism's abilities to adapt to both inner and outer stresses.

Even though genetic, biochemical, and neurophysiological elements may exert powerful influences on the potentiality for the development of a psychosis and on the capacity for recovery, it has been amply demonstrated that in most patients much improvement is possible by skilful psychological treatment. (*See* NEURASTHENIA.)

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PSYCHOTHERAPY: *see* PSYCHIATRY.

P.T.A., THE, the common designation of the U.S. National Congress of Parents and Teachers, was founded on Feb. 17, 1897, as the National Congress of Mothers. Later broadened to include both parents and teachers, the organization by 1936 had attracted to its ranks about 2,000,000 adults. Ten years later the membership was nearly doubled, and by 1953 almost 8,000,000 individuals were organized in more than 38,000 local P.T.A. organizations.

With the general objective of uniting "the forces of home, school and community in behalf of children and youth," the P.T.A. carried on programs in many fields of endeavour, such as parent education, health, juvenile protection, music, art, safety, mental hygiene and recreation. The P.T.A. also advocated enactment of measures to provide federal aid to education.

A major P.T.A. project in many communities was the sponsoring of school lunches.

Publications include *National Parent Teacher: The P.T.A. Magazine; National Congress Bulletin; National Congress Proceedings* (annual) and other publications of special interest to members.

Legislation Program.—The legislation program of the P.T.A. as adopted in Sept. 1952 by the National Board of Managers was, in part, as follows:

Federal Aid for Education.—"The federal government should appropriate funds to supplement those raised by local and state governments to provide adequate educational opportunities for all children and youth. . . . Such funds should go to publicly controlled, tax-supported schools only . . . with provisions ensuring . . . minimum federal and maximum local control and encouragement to the states to put forth their best efforts to equalize educational opportunities within their own boundaries."

Child Care Centers.—"Child care centers should be made available to children of employed mothers; adequately staffed and supervised by appropriate agencies; and jointly financed by public funds and parents' fees or by funds from public or private agencies."

Surplus Materials.—"Educational, medical and recreational materials and supplies purchased but no longer used by the armed forces should be released to the proper public agencies . . . for use in developing programs of education, health and recreation throughout the United States."

Library Service.—"Public library service should be extended to all people on an equitable basis with special emphasis on needs in rural areas . . ."

Merit System.—"Child welfare services should be administered by persons qualified to do so. Accordingly we support the extension of the merit system for public employees."

Child Labour.—"Federal legislation should give necessary protection to child workers, with special emphasis on the establishment of (a) a basic minimum age of sixteen for employment; (b) a higher minimum age for employment in hazardous occupations; and (c) a minimum wage provision for minors."

(*See* also PARENT EDUCATION: *United States.*)

PTAH was, in ancient Egyptian religion, the chief deity at Memphis, where Ptah's temple, which included the temple of Apis and others, was one of the main structures.

A human-headed god with a Semitic name, "the Opener," he was represented as a mummy. He was a legendary creator of the universe.

Ptah, who was a moulder or maker of things, was originally a god of artisans, and was hence called by the Greeks Hephaestus (*q.v.*), the name of the lame Greek god of fire who was considered the patron and divine smith of craftsmen.

BY COURTESY OF THE AMERICAN MUSEUM OF NATURAL HISTORY

WHITE-TAILED PTARMIGAN, OR MOUNTAIN GROUSE (LAGOPUS LEUCURUS), SHOWING SUMMER PLUMAGE

PTARMIGAN (*Lagopus*). A gallinaceous bird of several species inhabiting arctic and subarctic regions. In its northern range the plumage becomes pure white; in the southern part the summer plumage of reddish brown barred with black is assumed.

The feet are covered with hairlike feathers which aid in walking over snow. From 6 to 12 eggs of various shades of buff marked with brown are laid in a depression in the ground. (K. P.)

PTERIA, the ancient capital of the "White Syrians" of northern Cappadocia, which Croesus of Lydia is stated by Herodotus to have taken, enslaved and ruined, after he had declared war on Persia and crossed the Halys (Kizil Irmak). Thereafter he fought a battle near the city and retreated across the river to his ultimate defeat at Sardis in 546 B.C. Pteria is mentioned by no other ancient authority. The identification of Pteria with the modern Bogazkoy or Boghaz Keui, about 100 mi. E. of Ankara, once taken for granted, is quite uncertain. The extensive ruins near Bogazkoy are much older and belong to the 2nd millennium B.C. when the Hittite power was flourishing in central Asia Minor. Pteria is probably to be sought elsewhere, in a district nearer to the Black sea.

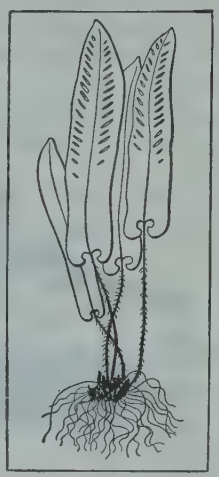
PTERIDOPHYTA, one of the groups comprising the ferns and their allies, of the second great division of plants, the Archegoniatae, the other being the Bryophyta (*q.v.*).

The Pteridophyta thus share with the Bryophyta a middle position between the essentially aquatic Thallophytes and the essentially terrestrial Spermatophytes. Much of their special interest centres round that fact. They include plants well represented at the present day; but many already existed in the early land vegetation of the Devonian period, now known only as fossils; they appeared in greater profusion as fossils of the coal, and many of these early types continued on into the Mesozoic age while their correlatives are included in the flora of the present day. Thus their geological history supports the conclusion that they take a middle position in the evolutionary progression of plant life, in which a transition from life in water to life on land was a striking incident.

Hofmeister first showed that there is essential similarity underlying the life histories of mosses and ferns, and that the same scheme, in modified form, extends to the seed plants also. Since this is so, an account of the Pteridophyta may fitly be introduced by a brief record of the life history of a fern, as an example of the Archegoniatae generally, and of the Pteridophyta in particular. There are two periods in each normally completed life cycle of these plants when the individual is represented by a single cell; and these punctuate the limits between two distinct bodily phases,

or generations as they are called. One of these is the leafy *fern plant* which every one knows; the other is a small green scale-like body, delicate in texture, called the *prothallus*, which escapes the observation of most people, though actually common enough. The former is sexless, but bears *spores* in large numbers; it is the *sporophyte* generation. The latter is the sexual generation, and, since it produces *gametes*, it is called the *gametophyte*.

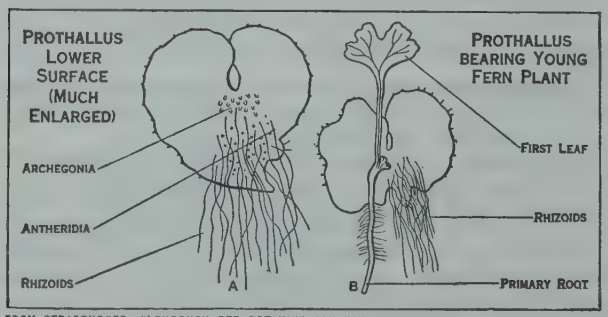
Life-history of a Fern.—The fern plant varies in size from a minute herb to a tree-like body, 60 or even 80ft. in height. It consists of a stem bearing characteristic leaves, usually of large size and delicate outline; the shoot thus constituted is attached by roots to the soil, the whole being traversed by conducting tracts. Since the green leaves serve a nutritional function, the plant is able to subsist as a perennial land-plant (fig. 1). On the leaves the *sori* are borne, of various form and position. In the hart's tongue or the common shield fern they appear as dense groups of brown *sporangia* seated on the lower surface, and covered while young by a membranous indusium. Each sporangium is a stalked capsule containing numerous minute, dry and dusty spores, which are violently ejected when ripe, and each is then liable to be carried away individually by the breeze. The spores are unicellular propagative organs.



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 1.—HART'S TONGUE (PHYLLITIS SCOLOPENDRIUM)

Each spore germinating on moist soil may grow into a prothallus or gametophyte (fig. 2), which never grows large, though being green it is physiologically independent. It bears the *sexual organs* or *gametangia*, usually on its lower surface (fig. 2, A). Near its base are the male gametangia or *antheridia*, which when ripe consist each of a protective wall of cells surrounding numerous spermatocytes. When bathed by external water (rain or dew) the wall ruptures, and each spermatocyte emits a single spiral *spermatozoid*, which moves in the water by lashing cilia (fig. 3). Near the indented apex of the prothallus the female gametangia or *archegonia* are formed (fig. 2). They are flask-shaped organs, also protected by an external wall; each contains a row of three

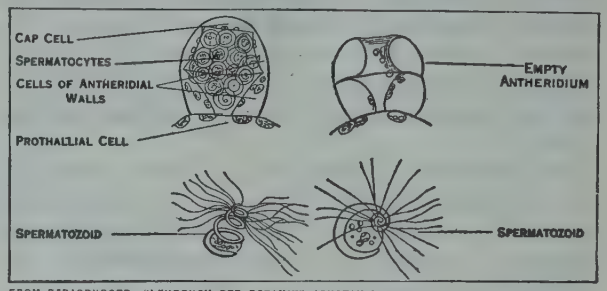


FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 2.—PROTHALLUS OF SHIELD FERN (DRYOPTERIS FILIX-MAS)

cells, of which the lowest and largest is the ovum or egg, sunk in the tissue of the parent (fig. 4). When ripe the archegonium also ruptures on access to external water, the distal cells of the wall parting so that an open channel filled with mucilage leads down to the rounded egg. *Fertilization* (*syngamy*) consists in the fusion of the spermatozoid with the egg to which it is attracted by soluble substance diffusing from it into the water that bathes the open archegonium. The result of that fusion is the *zygote*, which is the starting point for the development of a new fern plant. This new individual appears first as a spherical mass of delicate cells, nursed in the cavity of the archegonium; but it soon bursts out with its first leaf and root, and its apical bud ready to grow into a new fern, while the prothallus rots away (fig. 2, B).

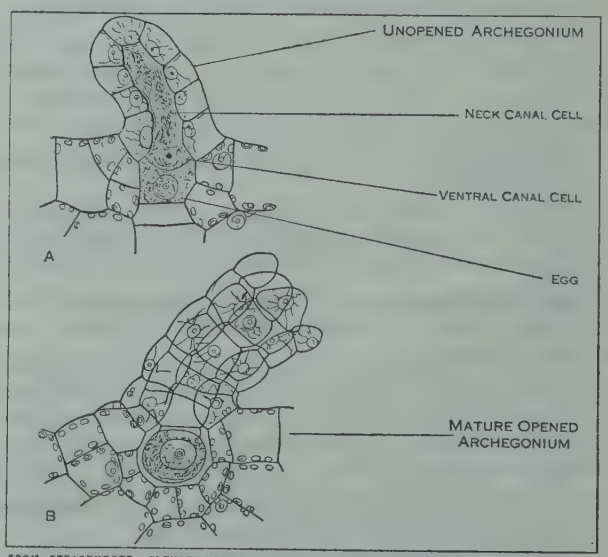
The central feature in syngamy is the *coalescence of the male and female nuclei;* the resulting fusion-nucleus is then *diploid*, with the *2n* number of chromosomes (*see* CYTOLOGY). That character is then maintained throughout the tissues of the sporophyte. On the other hand, when the fern-plant comes to maturity and forms sporangia, the cells that are to form the spores undergo



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 3.—ANTHERIDIUM OF POLYPODY (POLYPODIUM VULGARE)

a nuclear change, called *reduction* or *meiosis*, by which they resume that simpler constitution possessed by the nuclei of the prothallus, and described as *haploid* (*n*). These events normally alternate in regular succession, and they constitute that *nuclear cycle* which underlies all normal life-histories of the Archegoniatae. They stamp structurally the distinction of the two alternating generations. Such alternation, in one form or another, appears in all plants that show sexuality. The Pteridophyta illustrate the cytological cycle with unusual clearness, since the two somatic phases (viz., the haploid prothallus and the diploid fern plant) are so unlike, and so markedly independent the one of the other during their adult existence. It seems probable that in the course of evolution some simple form of alternation present in an algal



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 4.—ARCHEGONIUM OF POLYPODY (POLYPODIUM VULGARE)

ancestry has been regularized and standardized in the Archegoniatae in accordance with a passage from the relative uniformity of aquatic life to the more varied vicissitudes of life on land. In the Bryophyta the gametophyte was more adaptive, and became the dominant generation; on the other hand, in the Pteridophytes, as also in all the higher land-plants, the sporophyte became specialized as the dominant land-living organism. But the Archegoniatae themselves were never wholly emancipated from dependence on external liquid water. They show their amphibious character by their zoidiogamic fertilization; and this confirms their position as primitive land-plants.

For the most part the Pteridophyta are like the Bryophyta in

possessing only one type of spore (*homosporous*); but they produce these in enormous numbers. A common shield fern may ripen over 50,000,000 of them in a season. This is a primitive mode of propagation characteristic of early vegetation.

On the other hand, some few Pteridophyte-types such as *Selaginella* and *Isoetes*, and those curious little fern-derivatives styled collectively the Hydropterideae, possess sexually-differentiated spores, and are described as *heterosporous;* numerous smaller spores (*microspores*) bear each a rudimentary male prothallus, while a few larger spores (*megaspores*), or only a single one, produce each a massive female prothallus. In this they show a state of specialized advance along lines that have led to the final success of the flowering plants. The Pteridophytes as a whole present the paradox of a great division of the vegetable kingdom that has achieved success by force of numbers, rather than by the more refined methods of physiological adjustment and of propagation even in the higher plants. These paragraphs, of necessity rather technical, will suffice to introduce the Pteridophyta, Vascular Cryptogams, or fern-allies as they are sometimes called. They are represented by six natural groups or classes of organisms, of which four include forms both living and fossil, but two are known only as extinct and very early fossils. Such facts at once confirm their position as representing a primitive vegetation. They may be arranged in rough sequence according to their complexity of form and structure; but this must not be understood as conveying any definite view as to affinity.

CLASSIFICATION

I. Psilophytales, comprising only fossil types of simple conformation, from early Devonian rocks.

II. Psilotales, represented by two genera of living plants, *Psilotum* which is intertropical, and *Tmesipteris* which is confined to Australia.

III. Sphenophyllales, containing extinct Palaeozoic fossils of small size, which hardly extended into the Mesozoic period.

IV. Equisetales, including only the single living genus of the horsetails (*Equisetum*), but largely represented also by Palaeozoic fossils often of dendroid form (Calamariaceae).

V. Lycopodiales, or so-called club-mosses, well represented at the present day by the large genera, *Lycopodium* and *Selaginella;* also by *Phylloglossum* and *Isoetes*. But in the Palaeozoic period there existed the giant Lepidodendroid trees, as well as allied plants of humbler dimensions.

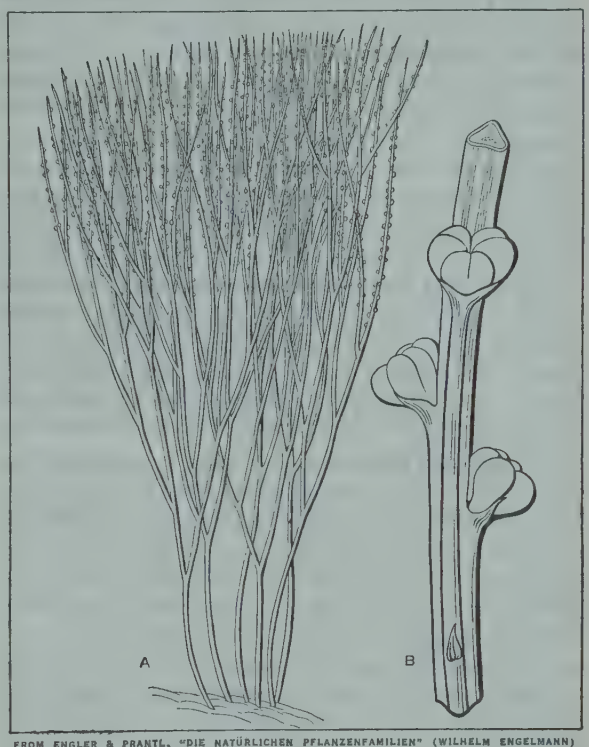
VI. Filicales, or ferns; these comprise not only the living ferns, with about 150 genera and over 6,000 species, but also a rich sequence of fossils, from the Palaeozoic Coenopteridaceae to the most recent strata.

FROM KIDSTON & LANG IN BOWER, "FERNS" (CAMBRIDGE UNIVERSITY PRESS)

FIG. 5.—HORNEA LIGNIERI

A newer scheme of classification treats the higher categories in a somewhat different manner. The phyla Pteridophyta and Spermatophyta (Seed Plants) are united into one group, the Vascular Plants or Tracheophyta. This includes four subdivisions: (1) the Psilopsida, including the Psilophytales and Psilotales, (2) the Lycopsida, including the Lycopodiales, (3) the Sphenopsida, including the Equisetales and Sphenophyllales and (4) the Pteropsida, including the Filiciniae, the Filicales of the above treatment, and also the Gymnospermae and Angiospermae, the two large groups of seed plants.

I. Psilophytales.—This new class of plants was constituted by Kidston and Lang to receive certain fossils of early Devonian time, discovered by Dr. Mackie at Rhynie in Aberdeenshire. Its name is taken from the old genus *Psilophyton* of Dawson, and the class now comprises a number of other genera of like age, more recently discovered, forming together a very distinctive flora. But of these only the sporophyte is known (fig. 5). The vegetative system consists of upward-growing, forked, aerial shoots that spring from a rhizome sometimes creeping, sometimes tuberous and mycorhizic; sometimes the underground branchlets are rootlike, forking in the substratum (*Asteroxylon*). The erect shoots are cylindrical, and were evidently green, covered by an epidermis, with stomata, and they are traversed by conducting strands of simple structure. Various superficial growths, often with the appearance of thorns or prickles, are borne upon the larger branches, as in *Psilophyton* and *Asteroxylon*. The plants



FROM ENGLER & PRANTL, "DIE NATÜRLICHEN PFLANZENFAMILIEN" (WILHELM ENGELMANN)

FIG. 6.—PSILOTUM TRIQUETRUM. (A) HABIT OF PLANT, SHOWING DICHOTOMOUS BRANCHING (B) PART OF A SHOOT

were of low stature, and growing gregariously they must have looked rather like grass. The genera *Hornea, Rhynia* and *Asteroxylon,* described by Kidston and Lang were so well preserved that their structure is as well known as though they were modern plants. The class stands conspicuously apart as leafless and rootless vascular plants.

The most distinctive feature of the class for diagnosis is that the large sporangia, protected by a wall of many layers and containing numerous homosporous spores, are terminal on the vegetative twigs. The early existence thus demonstrated of leafless, and rootless and homosporous vascular plants, with distal sporangia of primitive construction is a fact of the first comparative importance. It is true it does not demonstrate any nearer connection with the Algae, but as regards other relations the new facts are highly suggestive. Long ago it was remarked that the widest gap in the sequence of plants was that between the Bryophytes and Pteridophytes. It is within this gap that the newly discovered fossils take their natural place, acting as synthetic links for the whole sequence of land-living, sporangium-bearing plants.

II. Psilotales.—The Psilotales are represented by two living genera, *Psilotum* and *Tmesipteris,* of which both generations are now known. They form a natural family of the Psilotaceae. By their features they appear remarkably isolated among living plants, and their nearest affinity is to be sought among the Psilophytales and Sphenophyllales, both being classes of plants long extinct. These two genera appear in fact as living fossils.

They live epiphytically, or in soil rich in humus, and are rootless. The green, more or less shrubby shoot is fixed in the substratum by much branched leafless rhizomes, which are infected

by a mycorhizic fungus. The saprophytic nutrition by these is supplemented by photosynthesis in the green leafy shoots. In *Psilotum* the aerial stems bifurcate, bearing small and simple scaly leaves, which however pass upwards into bifid "sporophylls," and between the two teeth is seated a large trilocular synangium, containing numerous homosporous spores (fig. 6). *Tmesipteris* resembles it in general character, but branching is infrequent, the leaves and "sporophylls" are larger, and the synagium has only two large loculi. The anatomy of the green stem of *Psilotum*, with its epidermis and stomata, its photosynthetic cortex and conducting protostele, is on the same general plan as that of *Rhynia* or *Asteroxylon;* the bifurcation and presence of minute leaves, and the rootless mycorhizic base all support the comparison with the Devonian types of Rhynie.

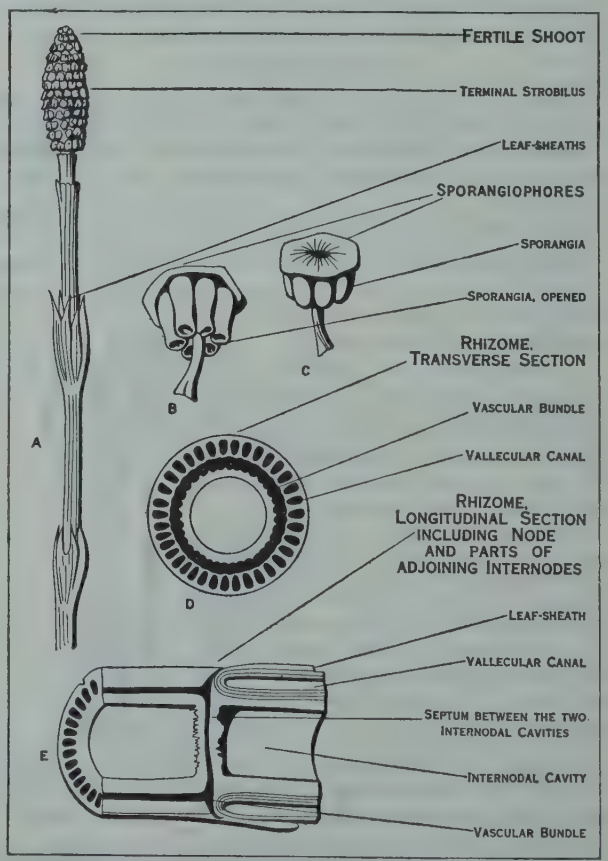
The prothalli of both genera have been discovered since 1914. They are colourless, nourishing themselves saprophytically through fungal agency. In fact these primitive plants conform in their life-cycle to what is seen in many primitive ferns and Lycopods. Moreover, the embryology has been traced in *Tmesipteris;* there is neither suspensor, nor root, nor cotyledon. The embryo with its apex directed, like that of the Bryophytes towards the neck of the archegonium, soon bursts its way out, proceeding to branch distally and form a leafless rhizomic system from which aerial shoots arise later. Such details of the gametophyte link the Psilotales, and indirectly the Psilophytales, with other Pteridophytes as regards alternation on the whole; but the rootless and leafless embryo presents a state that finds its nearest comparison with the Bryophyta.

III. **Sphenophyllales.**—The two genera *Sphenophyllum* and *Cheirostrobus* are the representatives of this class, but in more or less loose association with them are such types as *Pseudobornia* and *Hyenia;* these suggest that the articulate type of land-plants, which they all illustrate, in common with the horsetails, was well represented in the primary rocks. The existence of the Sphenophyllales extended from the Upper Devonian to Triassic time. (For details of Sphenophyllales *see* PALAEOBOTANY.)

IV. **Equisetales.**—Those Pteridophyta which have their appendages disposed in successive whorls, with long internodes intervening between them, have been designated the Articulatae. In the distant past this type was strongly represented by the Sphenophyllales, and by the Calamariaceae and others. But it is familiar to us to-day as it is seen in the horsetails, included in the cosmopolitan genus *Equisetum*, the only species of Equisetaceae, and the only living representatives of the Equisetales. These are semi-aquatic plants; they vary in height from a few inches to 30ft. or more, and are rhizomatous, with erect shoots arising from richly branched, subterranean stems, which are themselves rooted in the soil. The habit of the plants depends upon the method of branching of the shoot rather than upon the foliage, for the leaves are minute (microphyllous), and closely appressed to the stem that bears them. Each whorl of them forms a sheath closely investing the base of the next higher internode, while the teeth projecting upwards from it are all that represent the individual leaves. Their position alternates in successive nodes (fig. 7). The internodes are fluted, the ridges being continuous downwards from the next higher leaves; consequently those of successive internodes alternate. The number of the leaves in a whorl may vary according to the size of the stem, from three to 20 or 30. This is the scheme of the shoot in all species of *Equisetum*, and the shoot is constantly of radial construction. In some species the branching is sparse (*E. limosum*); in others it is profuse (*E. sylvaticum* and *maximum*), and the branches may themselves branch again repeatedly. Their number and the degree of secondary branching defines the habit, and justifies for the more bushy types the familiar name of horsetails. The branches arise in the axils of the leaf-sheaths, but they alternate with the leaves themselves. Many of those initiated remain dormant. A root is found at the base of each bud, but it also is frequently dormant, especially in aerial shoots. The structure of the underground rhizome is on the same plan as that of the aerial branches that it bears. Thus the whole plant consists of a succession of shoots, each with a dominant axis, whorls of subordinate leaves, and accessory roots.

In the transverse section of an aerial internode the sinuous outline shows the projecting ridges and depressed furrows of its fluted form, though this is less evident in the rhizomes (fig. 7, D). The centre of the section is occupied by a large air-cavity, surrounded by the remains of the pith. A circle of isolated vascular strands, corresponding in number to the leaves in the next whorl above, is in most species enclosed by a sinuous endodermis, which thus delimits the stele (*E. arvense*, etc.). Outside this lies the cortex, marked by an equal number of large air-cavities, which alternate with the vascular strands, and correspond to the furrows of the fluting. The vascular strands themselves are opposite the projecting ridges, and are extended upwards into the several leaf-teeth. Between the ridges are regions of green chlorophyll-parenchyma, while the whole is invested by a well-marked epidermis, with curiously elaborate stomata: these are ranged along the furrows, and so are opposite the photosynthetic tissue. The anatomy is clearly that of a semi-aquatic plant with its reduced vascular tissue and large air-spaces.

The sporangia of *Equisetum* are borne upon lateral appendages of the axis, sporangiophores, which are disposed in whorls, and are associated in definite strobili or cones, borne distally (fig. 7, A). Each sporangiophore consists of a stalk that expands into a peltate disc, from the inner surface of which some

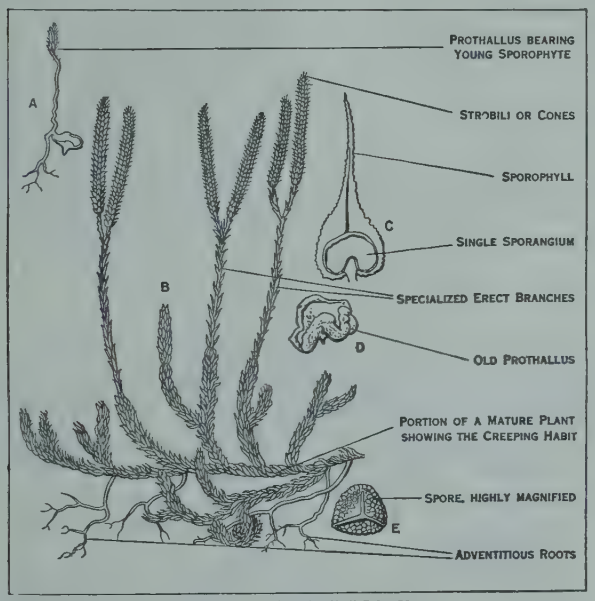


FROM (A, B, C) STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 7.—LARGER HORSETAIL (EQUISETUM TELEMATEIA)

six to nine large sporangia hang parallel with the stalk (fig. 7, B, C). A single vascular strand passing through the stalk supplies a branchlet to each sporangium. These arise as massive growths from the first, and each produces a large output of homosporous spores (eu-sporangiate). The spores themselves are large; in ripening the outermost layer of the wall of each splits along spiral lines, giving rise to four elaters that straighten out when dry, and close round the spore in damp air. They are effective in forcing open the sporangium, which dehisces by a longitudinal

slit: and those of different spores hooking together, the spores are grouped in germination, a matter of importance since the sexes are usually borne on separate prothalli. The spores germinate at once, producing each a green prothallus, which may be filamentous, flattened, or irregularly lobed. The smaller bear sunken antheridia, each with numerous spermatocytes, from which spermatozoids are liberated on access of water. The larger bear archegonia. The conditions of syngamy and formation of the embryo are essen-



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 8.—A CLUB-MOSS (LYCOPODIUM CLAVATUM)

tially as in ferns; but here the embryo has its apex directed to the archegonial neck (exoscopic), and it grows out directly into the apex of the young plant, successive whorls of leaves arising laterally upon it; a root derived from the basal region fixes the young plant in the soil. Notwithstanding the differences of detail, the life-cycle of a horsetail is comparable as a whole with that of a fern.

A greatly added interest in *Equisetum* arises from comparison with allied fossils; for not only were these numerous and of early occurrence, but they attained dendroid proportions, while some were heterosporous. They are grouped as the Calamariaceae, which will be specially treated elsewhere (*see* PALAEOBOTANY).

The Equisetales, thus comprising the Equisetaceae and the Calamariaceae, form a natural and closely related class, of which the nearest affinity was with the Sphenophyllales, but with some degree of relation also with the Psilotales; all of these being sporangiophoric Pteridophytes.

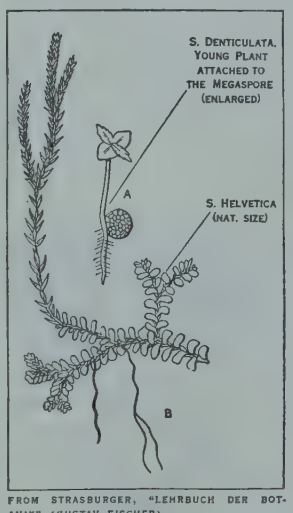
V. **Lycopodiales.**—This class comprises a considerable number of species now living widely distributed upon the earth, and known as *club-mosses;* though they are in fact vascular plants, and quite distinct from the true mosses. They are all relatively small, and indeed insignificant as features in the present flora, compared with the fossil types which, though they may have included a number of relatively small species, comprised also some of the largest plants of the forests of the coal period. It may be that among the lycopods no actual diminution in size took place as time went on, but rather that the types which were always small survived, while the giant members of the group became extinct.

The features which all club mosses have in common are that the leaves are relatively small and simple in form (*microphyllous*), while the sporangia are seated singly, one in the axil of each leaf of the fertile region, or spreading outwards on its base. This marks off the Lycopodiales clearly from the sporangiophoric Pteridophytes on the one hand, and from the Filicales on the other. As in the former, however, the axis is dominant in the adult shoot, and forks equally or unequally. According to the position assumed by the stem the habit of living club mosses is upright or pendent; but frequently, as in the stag's horn moss common on Scottish hills, with its creeping stem rooted in the soil, and bearing upright fruiting branches (fig. 8, B).

The class is divided systematically according to the presence or absence of a *ligule,* which is a small scale-like body borne on the upper surface of each leaf, near its base. Those in which no ligule is present, the ELIGULATAE, include *Lycopodium* and *Phylloglossum,* together with certain early fossils designated *Lycopodites;* those which possess a ligule, the LIGULATAE, include *Selaginella* and *Isoetes,* and with these are associated the fossil Lepidodendraceae and Sigillariaceae. The distinction is accentuated by the fact that the former are all homosporous, the latter heterosporous.

A. Lycopodiales Eligulatae. Lycopodium comprises about 100 species of small plants of varied habit, creeping, shrubby or epiphytic. The construction of the shoot is uniformly microphyllous, the bifurcating stem dominating the conformation of the whole plant. The leaves are simple and small, and in some species uniform throughout the plant. In others the sterile leaves are larger than the membranous sporophylls, the latter being associated in definite strobili, or cones (fig. 8, B). The former probably represent the more primitive type. Each of the isolated sporangia is seated at the base of its sporophyll; it is large, and kidney-shaped, with a short massive stalk, and it dehisces like an oyster-shell, in a plane parallel to that of the leaf. The arrangement of the leaves is sometimes in regular whorls, but frequently it is according to some more or less interrupted spiral scheme. The plant is fixed at its base by roots which spring endogenously from the stem, and show bifurcation.

The stem of *Lycopodium* is seen in transverse section to be surrounded by a bulky and often indurated cortex, and traversed by a stele continued to the apical cone itself, while from each leaf a minute vascular strand passes to its periphery. In the young stem there is a solid woody core, surrounded by phloem and ill-defined sheaths. But in fully-grown stems the core may be invaded by tracts of phloem, moulding it into a cruciform or stellate transverse section, or even separating it into distinct radiating plates, or permeating it to form a sort of woody sponge.



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 9.—A CLUB-MOSS (SELAGINELLA)

The sporangia are massive from the first, and vary slightly in spread along the leaf-surface, a point of interest for comparison with the ligulate types. Each produces after the usual tetrad-division a large number of homosporous spores, which germinate slowly. The prothalli produced from them, and the embryology that follows, vary more than is usual in a single genus. The prothallus sometimes grows at soil-level and is green (*L. cernuum*); but often it is underground and wholly saprophytic (*L. clavatum,* fig. 8, D, A). Whatever its form, the sex-organs are massive and deeply sunk, and both are present on the same prothallus. The antheridia produce numerous biciliate spermatozoids; the archegonia vary in length of neck, and sometimes have numerous canal-cells. But the egg is deeply seated, and produces an embryo with a suspensor. This thrusts the embryo deep into the prothallus, where it often develops juvenile characters of importance for comparison. The most striking of these is the swollen "protocorm," a tuberous growth seen in *Hornea,* and present also in *Phylloglossum.* Bursting out from the prothallus the embryo develops shoot and root, the former in the underground types finding its way upwards to the soil-level (fig. 8, A).

B. Lycopodiales Ligulatae. *Selaginella* comprises about 500 species, widely spread through the tropics, some native on temperate hill stations. The latter, chiefly of exposed habit, have radial symmetry, but most *Selaginellas* are dorsiventral and live under shade. The genus shares the leading features of *Lycopodium,* but it differs in the presence of a ligule and in the fact that all the species are heterosporous.

Various *Selaginellas* are favourite greenhouse plants, and the fanlike spread of the delicate branches with their dimorphic leaves is well known (fig. 9, B); also the strange rhizophores springing from points of branching of the shoot, which turning downward give rise to the true roots, being themselves organs of indeterminate morphological nature. It is unnecessary to describe the vegetative organs or their anatomy in detail; the chief comparative interest lies in the propagative process.

The sporangia are borne on radially constructed distal cones. A single sporangium, similar to that of *Lycopodium,* is borne just above the insertion of each sporophyll, with the ligule protecting it from without. The microsporangia are brownish when ripe and the megasporangia pale in colour, and both may be borne on a single cone. They appear all alike up to the stage when the numerous spore-mother-cells are formed. If all the spore-mother-cells undergo tetrad division, numerous microspores resembling those of *Lycopodium* result. But in a megasporangium only one, or at most a few of them, form tetrads, and the resulting spores are large with a rugged wall; the number matured in a single sporangium may vary from one to four, or some multiple of four. On germination each microspore produces a small number of spermatozoids from a very reduced prothallus; but the large megaspore forms a more bulky prothallus, which, projecting from the disrupted wall, bears archegonia. One of these on fertilization develops an embryo with a suspensor. The essentials of the process are as in *Lycopodium,* though the details are different. As the sporeling develops its leafy shoot grows upward and its root downward; with the megaspore attached laterally the whole has the appearance of a seedling of some flowering plant (fig. 9, A). This is clearly an advance upon *Lycopodium.*

The other genus, *Isoetes,* is peculiar in habit and in habitat, yet shares many of the characteristics of *Selaginella.* It contains about 50 species of tufted herbs, mostly living at the bottom of freshwater lakes, though a few are amphibious or terrestrial. The plant consists of a short, massive, lobed stock, bearing crowded awl-shaped leaves of considerable length. Each bears a ligule on its upper surface, and when fertile, as any one of them may be, a large cakelike sporangium lies between this and the axis. Roots with dichotomous branching arise from furrows between its lobes. The sporangia are heterosporous, and propagation is essentially similar to that in *Selaginella;* but there is no suspensor, and the spermatozoids are multiciliate.

A chief interest in these Ligulate types lies in their comparison with the Lepidodendraceae and Sigillariaceae, for these are also ligulate and heterosporous (*see* PALAEOBOTANY). These fossils attained dendroid dimensions, and, though the primary vascular system was not unlike that of the modern Lycopods, they often differed in having secondary growth with an active cambium. In *Isoetes* there is a sluggish secondary growth in the short stock, which itself shows certain analogies with the Stigmarian trunks of the gigantic fossils. Since any of the leaves of *Isoetes* may be fertile the whole plant appears as a strobilus of the same nature as *Lepidostrobus,* seated upon a Stigmarian base. In fact *Isoetes* is like a telescoped, but still living, fossil.

VI. **Filicales.**—The Filicales may be held as comprising all the living Megaphyllous Pteridophytes, together with such fossils as show essentially similar characters. But the mere fact that their leaves are relatively large in proportion to the stem that bears them is not a sufficient diagnosis. Some Lycopods (*Isoetes, Sigillaria*) share this character, and megaphylly is possible in any of Pteridophytes. But as a matter of fact, excepting *Isoetes,* none such are now living other than the Filicales. The most distinctive feature of ferns, however, is that *on the relatively large leaves many sporangia are borne, either singly or in groups* (*sori*).

Ferns are represented at the present day by about 150 genera and 6,000 species. Some are minute, others attain considerable size as tree ferns; but none can be reckoned among the largest of living plants, nor is there fossil evidence that ferns ever attained extreme dimensions. Their geographical spread is general; a few are arctic, but ferns increase in numbers both of species and of individuals toward the equator. Most are mesothermal hygrophytes (*i.e.,* they flourish under moist conditions with a moderate temperature), and the majority are shade-loving. Hence their headquarters are in the mountains of the tropics, where they form a considerable part of the undergrowth below the forest canopy. But their habitat is variable; some specialized types are actually aquatic, while others are able to withstand conditions of moderate, some even of extreme, drought. Ferns are much richer in genera, species and individuals than any other living Pteridophytes. They present the climax of successful development in homosporous vascular plants. They show also a high degree of variety both in their vegetative and their propagative characters; these provide good diagnostic features for their classification. They have a full and long palaeontological history that stretches back to Palaeozoic times. The geological record can therefore be used as a valid check upon the conclusions drawn from the comparison of living types.

It has been said that the Palaeozoic period was the age of ferns, and it is true that "fernlike" leaves were then common. But it has now been shown that many of these belonged to seed plants ranked as Pteridosperms, a class long since extinct, which also had fernlike leaves (*see* PALAEOBOTANY). It is not improbable that they represent a stock more distinct from ferns than the similarity of their foliage would suggest, for they had advanced early to seed formation. It may be left as an open question whether or not both may have had far back in their evolution some common origin.

The life history already described at the opening of this article holds for ferns generally, so that the grouping and natural classification of the class must depend upon differences of detail other than the life history itself. A general comparison of them led long ago to the recognition of eight main families, which may here be placed in the reverse order to that first given by Mettenius (1856):

I. Ophioglossaceae.	V. Gleicheniaceae.
II. Marattiaceae.	VI. Hymenophyllaceae.
III. Osmundaceae.	VII. Cyatheaceae.
IV. Schizaeaceae.	VIII. Polypodiaceae.

This grouping in linear sequence places the more robust types first and the more delicate last, while the rest take middle positions. The former were styled by Karl von Goebel the *Eusporangiate ferns,* in which the sporangium is from the first a massive body, in the formation of which many cells co-operate; in the latter each sporangium arises from a single cell, and those ferns in which this is so were styled *Leptosporangiate.* Intermediate states exist, and these suggest that the whole series constitutes an evolutionary progression. If this is true the question arises which is the more primitive and which the more advanced state? The importance of this question is enhanced by the fact that the sporangium is a mere index of a general difference of organization of the two contrasted types. In point of fact *the Eusporangiate ferns are relatively robust in their general constitution, while the Leptosporangiate are relatively delicate.* Thus the question is whether there has been in the course of evolution a progression from a robust to a delicate state, or the reverse. Since the Eusporangiate ferns find their correlatives in the fossils of Palaeozoic time and are relatively few today, while the specialized Leptosporangiate ferns are absent from the Palaeozoic rocks and comprise the bulk of living ferns, it is concluded that the general progression has been from a more robust ancestry toward a more delicate and precise constitution.

Having perceived this general scheme of progressive refinement, it cannot be assumed that the 150 genera and 6,000 species have formed a simple sequence. In testing the question of their relationships it will become necessary to revise the methods in use by systematists, whose aims were primarily classification. They worked as a rule upon few criteria of comparison, drawn almost

exclusively from the sporophyte generation. A more exact comparison will be necessary not only as regards external form, but also of internal structure and development, both of the vegetative and the propagative organs, and it must be extended to both generations. The larger the number of the criteria used in comparison the more trustworthy will be the conclusions drawn from them. The criteria currently used in the comparison of ferns are these:

1. The external morphology of the shoot.
2. The initial constitution of the plant-body as indicated by segmentation.
3. The architecture and venation of the leaf.
4. The vascular system of the shoot.
5. The dermal appendages.
6. The position and structure of the sorus.
7. The indusial protections.
8. The characters of the sporangium, and the form and markings of the spores.
9. The spore-output.
10. The morphology of the prothallus.
11. The position and structure of the sexual organs.
12. The embryology of the sporophyte.

By the combined use of these criteria it has been possible to revise the natural groupings of ferns, sometimes amending but more often upholding the decisions of the earlier systematists. The main conclusions may be stated as follows: The *Eusporangiatae* include the living Ophioglossaceae, Marattiaceae and Osmundaceae, together with the fossil Coenopteridaceae (*see* PALAEOBOTANY). All these are Palaeozoic types, though they overlapped into the Mesozoic, and some representatives have even survived to the present day. With them are to be associated also the Schizaeaceae, Gleicheniaceae and Matoniaceae, all of which figured prominently in the Mesozoic, and are well represented among living ferns. In addition to many archaic features of the vegetative system they all possess relatively massive sporangia, which originate simultaneously, being produced either singly or in small numbers in the sori. They are collectively styled *Simplices*. Each sporangium has a relatively large spore-output.

The Ophioglossaceae and Marattiaceae appear to have ended blindly and left no further derivatives. But derivative phyla may be traced by comparison from each of the Schizaeaceae, Osmundaceae, and Gleicheniaceae, while to the Matoniaceae so closely allied to the Dipterids, another phylum may be ascribed. The Schizaeaceae with their solitary marginal sporangia lead to the marginal Dicksoniaceae. The Osmundaceae have many features in common with *Plagiogyria*, while the superficial Gleicheniaceae link on to the Cyatheaceae, these being distinguished by their superficial sori from the marginal Dicksoniaceae. In both of these last-named families the sorus has become "*gradate*," *i.e.*, after the distal sporangia have been formed on the receptacle, a sequence of further sporangia follows *in basipetal sequence*, the effect of which is that the drain of nutrition is spread over a longer period of time. This may well have been a real factor in the success of these families.

A third state of the sorus, which has a like effect to the last, and may either be initiated independently or by transition from the gradate, is the "*mixed*" state, where sporangia of different ages are irregularly *interpolated between those already present*. This is the final condition seen in the evolution of the Leptosporangiate ferns, and is found in all the more advanced types.

From such intermediate stocks as those mentioned some *six derivative phyla of advanced Leptosporangiate ferns* may be distinguished, each centring round some well-known genus. Two of these comparison shows to have been derived from the Dicksoniaceae, viz., the Davallioid ferns centred round *Davallia*, and the Pteroids round *Pteris*. The Gymnogrammoid ferns are naturally grouped round *Gymnogramme*, and may probably be traced from the Osmundaceae, with *Plagiogyria* as a suggestive link. The Cyatheaceae probably gave rise on the other hand to the Blechnoid ferns, with *Blechnum* as a central type; and the Dryopteroids round *Dryopteris*. Lastly, a quite considerable number of genera may be traced as Dipteroid derivatives, from an ancestry suggested by *Matonia* and *Dipteris*. Thus at least six main evolutionary sequences of advanced Leptosporangiate ferns, with more or less pronouncedly "mixed" condition of their sori, may be referred in origin to types already distinct in Palaeozoic, or certainly in Mesozoic time. Each of these will have pursued its own phyletic advance independently of the others. Comparison reveals that most of them, or in some respects all, show parallel features of advance in form, vascular structure, soral characters, and sporangia, and particularly in the reduced spore-output from each sporangium. There is thus wide evidence of independent *homoplastic, and even convergent evolution* in the several phyla. In no respect is this clearer than in the distinctive feature of heterospory: for the Marsileaceae are referable in origin to a Schizaeoid source, while the Salviniaceae, whatever their actual relation, were of distinct origin from the Marsileaceae.

This brief abstract of the present position of the phyletic study of the Filicales can do no more than suggest how the matter stands to-day. Of all the Pteridophyta the ferns yield the most consecutive results. The living representatives of all the rest appear as isolated survivals, illuminated by fossil evidence, often as fragmentary and isolated as theirs. They raise as many evolutionary questions as they solve. It is only in the Filicales that it is possible, by placing together the evidence from palaeontology and that derived from the living flora, to reconstruct a story which, however incomplete, is sufficiently consecutive to serve as a basis for evolutionary opinion. The sum of it is for the ferns, as also for other Pteridophyta, that they have held their own to the present day as a class which has made the best of their amphibious existence by help of profuse production of homosporous spores. But from the point of view of descent, they have led on directly to no further type of land vegetation. The sources of this must be sought elsewhere.

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FROM THE CHALLENGER REPORTS (H.M STATIONERY OFFICE)

FIG. 1A.—CEPHALODISCUS DODECALOPHUS. AN ILLUSTRATION OF A FEMALE AS SEEN FROM IN FRONT. (AFTER McINTOSH)

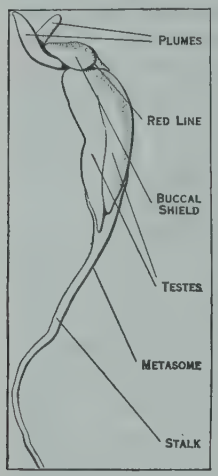
PTEROBRANCHIA. The most strikingly novel discovery of the "Challenger" Expedition was a mysterious animal, dredged from 245 fathoms in the Straits of Magellan. It was described as *Cephalodiscus dodecalophus*, in 1882, and was at first placed in the Polyzoa.

In 1903 it was announced that *Cephalodiscus* had been found by the Swedish Antarctic Expedition, from the original locality southwards to the Antarctic sea; and that it had been discovered off Borneo (near low-water mark), Celebes and Korea.

It was later recorded from new Antarctic or Sub-Antarctic localities, and off New Zealand, South Africa and Ceylon.

The study of the anatomy of this surprising animal revealed the unexpected fact that its affinities are with *Balanoglossus* (*q.v.*), and so the Pterobranchia are included as a class of the Hemichordata (*q.v.*).

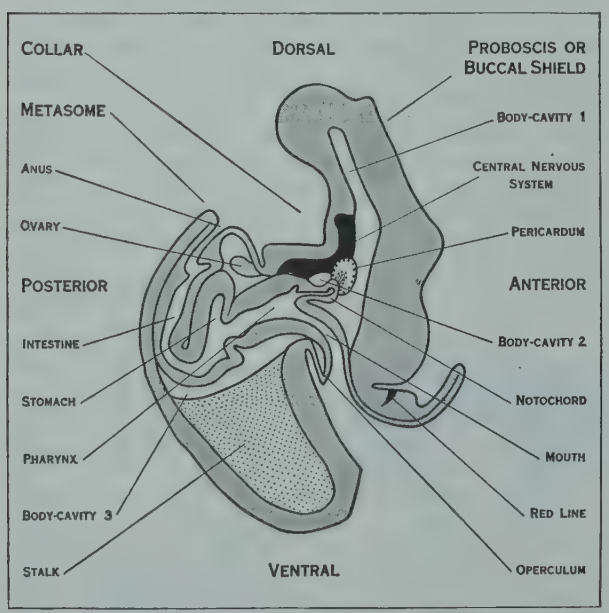
A colony of *Cephalodiscus* inhabits an orange, gelatinous dwelling (*coenoecium*), from a foot to half an inch long. The branches, from two inches to one tenth of an inch across, are composed of numerous laminae, including Foraminifera or other bodies, sometimes so numerous as to mask the gelatinous walls. The animals occur in large numbers, and are from 7 to 1mm. in length, without the stalk, which is very extensible. They can wander on the surface of their dwelling, the lower end of the stalk remaining attached to the wall of the tube, to facilitate retraction.



FROM G. F. HARMER, "MONOGRAPH ON THE SIBOGA EXPEDITION" (MAX WEBER)

FIG. 1B.—A MALE (SIDE VIEW)

The body consists of the three regions characteristic of *Balanoglossus:*—(1) the "proboscis" or "buccal shield" (fig. 2), used as a crawling organ. A crescentic red line, near its lower edge, is distinctive of the genus; (2) the "collar," its front edge produced above into 3–9 pairs of plumes, each with two series of tentacles, and at the sides and below into a large "operculum"; (3) the third segment or "metasome," with the stalk. Each segment has its own body-cavity, unpaired in the proboscis, paired in the other two segments (figs. 2, 3). The first body-cavity opens externally by two "proboscis-pores," on the buccal shield, near its junction with the collar. The second cavities extend into the operculum and the plumes, each opening by a "collar-canal," immediately behind which is a "gill-slit," leading from the pharynx to the exterior (fig. 3). From the upper wall of the pharynx a "notochord" projects into the proboscis-cavity, where there is a "pericardium," corresponding with that of *Balanoglossus*. The central nervous system is in the dorsal region of the collar and of part of the proboscis.



FROM S. F. HARMER, "MONOGRAPH ON THE SIBOGA EXPEDITION" (MAX WEBER)

FIG. 2.—CEPHALODISCUS DODECALOPHUS, MEDIAN SECTION OF AN ADVANCED FEMALE BUD

The third body-cavities contain the alimentary canal and reproductive organs. The anus is on the upper side, the mouth being below, between the proboscis and the operculum. The young alimentary canal (fig. 2) is shortly U-shaped, but in the adult the U is much longer, passing ventrally down the body, the long axis of which is dorso-ventral. The two ovaries or testes open dorsally, in front of the anus, and the oviducts (at first mistaken for eyes) are highly pigmented. The eggs have much yolk, and development commences in the tubes. In certain species the colonies are either male or female, while in others both sexes occur, and an animal may have an ovary on one side and a testis on the other. The males resemble the females except in *C. sibogae* (fig. 1, B), in which they occur with neuter individuals without functional reproductive organs. These males have a single pair of plumes, with no tentacles, the alimentary canal is vestigial and the operculum has been lost. The three segments, their body-cavities, the collar-canals and the central nervous system are normal, but the third segment is mainly occupied by the two testes. The males are probably nourished by vascular connection with the neuters; and blood-vessels have been observed in this and other species. The buds, often in considerable number, remain connected by their stalks with the parent stalk until a late stage, but ultimately become free.

The species of *Cephalodiscus* are most easily recognized by the form of their coenoecium. The number of plumes is not always quite constant, but is a useful character. About 13 species are known, referable to three sub-genera:—*Demiothecia,* with a single cavity extending throughout the colony; and *Idiothecia* and *Orthoecus,* in which each animal, with its system of buds, occupies a separate tube, nearly always isolated from its neighbours. The coenoecium is branched in *Idiothecia,* discoidal or plano-convex in *Orthoecus. Rhabdopleura,* the only other Pterobranch, resembles *Cephalodiscus* in form and structure, but is almost microscopic. It was first described from Norwegian and British seas (in rather deep water), but it occurs from Greenland to the Antarctic sea, including the Azores, the Malay archipelago, Ceylon, New Zealand, Australia and Tristan da Cunha. Several species have been described.

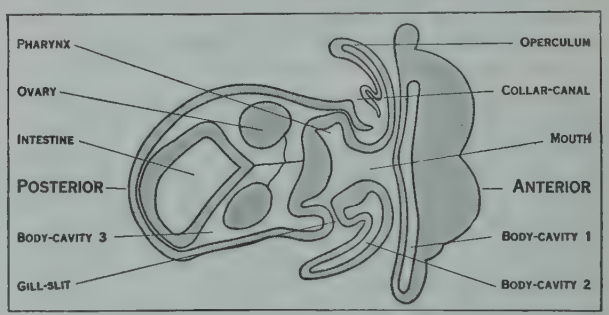


FIG. 3.—CEPHALODISCUS DODECALOPHUS, LONGITUDINAL (FRONTAL) SECTION OF THE FEMALE, SHOWING THE LEFT COLLAR-CANAL AND THE RIGHT GILL-SLIT (AFTER HARMER)

Rhabdopleura has no doubt been simplified, in correlation with its reduction in size. There is only one pair of plumes and gill-slits are not present. In most other respects it agrees with *Cephalodiscus,* to which it is clearly allied. The elongated, cylindrical tubes are about 2–3 mm. long and a quarter of a millimetre in diameter. Each arises vertically from a tube closely attached to a solid object; and all the tubes are composed of laminae, which form distinct rings in the erect parts. The budded individuals do not become free, their stalks remaining connected by a cord. Its jet-black colour, in the adherent part, and the ringed tubes are features easily recognized.

BIBLIOGRAPHY.—C. J. van der Horst, *Bronn's Tier-Reichs,* vierte Bd., abt. iv (1927–39). (A) *Cephalodiscus:* W. C. McIntosh, and S. F. Harmer, *Challenger Rep.* xx, pt. lxii (1887); S. F. Harmer, "Pterobranchia," Monogr. xxvi *bis, Siboga Rep.* (Leyden, 1905); W. G. Ridewood, *Brit. Antarct.* ("*Terra Nova*") *Exp. 1910,* Zool. iv, pt. 2, 11 (history and list of known specimens) (1918); W. G. Ridewood, *Ann. Mag. Nat. Hist.* (9) v, 407 (key to species) (1920); (B) *Rhabdopleura:* A. Schepotieff, *Zool. Jahrb. Abt. Anat.* xxiii, 463; xxiv, 193 (Jena, 1906, 1907). (S. F. H.; X.)

PTEROCLIDAE: *see* SAND-GROUSE.

PTERODACTYL, a term familiarly used for any member of the order Pterosauria, or winged reptiles. The pterodactyls are extinct flying reptiles found in rocks of all ages from the Lower Lias or perhaps the Rhaetic to the Upper Cretaceous. They fall into two great groups distinguished from one another by the

presence of a long tail with a horizontal fin at its tip, in the one, and the lack of a tail in the other.

The best-known form is *Rhamphorhynchus* from the Solenhofen slate of Bavaria and probably the Kimmeridge clay of England. *Rhamphorhynchus* has a head about 3½ in. long, with a mouth opening very widely and armed with long, slender, sharp-pointed teeth. The eye, which is placed above the articulation of the lower jaw, is very large, and like that of many birds has a series of bony plates lying in its wall. The paired nostrils lie far back in front of the eyes. The neck, which is some 2 in. long, was flexible, and the head was carried at right angles to the neck. The body is small, about 4 in. in length by 1¼ in. in diameter. The tail is enormously long (15 in.) and although built of many joints, is stiffened by ossified tendons so that it must have moved as a whole. The wings are stretched membranes made by folds of skin held out by

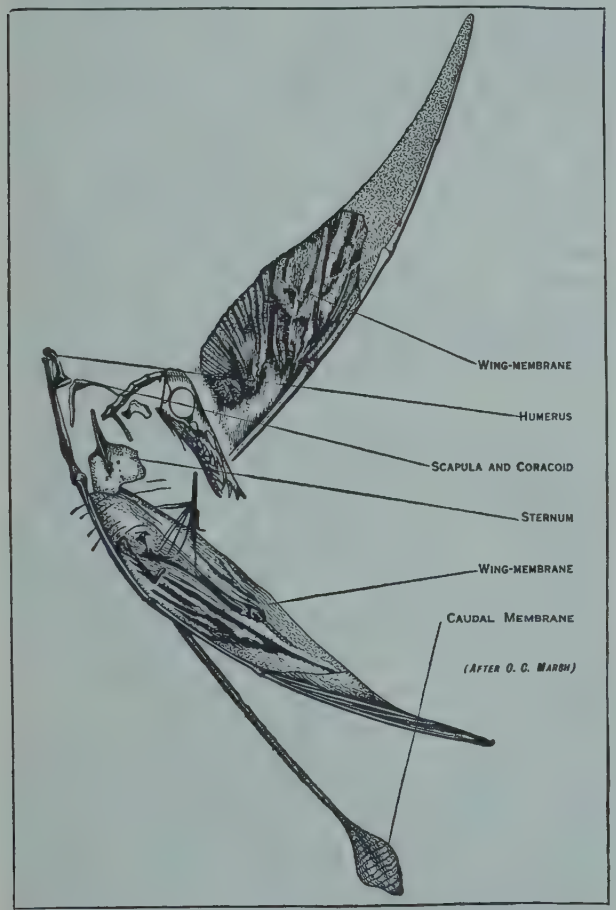


FIG. 1.—RHAMPHORHYNCHUS PHYLLURUS FROM THE SOLENHOFEN LITHOGRAPHIC STONE, WITH THE GREATER PART OF THE WING MEMBRANE PRESERVED

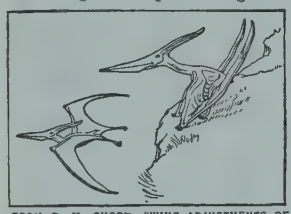
the greatly elongated forelimb, and especially by the enormously extended fourth finger; the width across the wings when fully spread is some 25 inches. The bony finger lies practically at the forward edge of the wing, the membrane which forms the rest of the structure being only some 2 in. from front to back, and passing backwards along the side of the body to the hind leg. The extremity of the tail bears a horizontal flap of membrane. The three first fingers of the hand are free and provided with large claws; they stand out in front of the wings and must have been used for holding food or for help in landing. The knees included in the wing membrane stand straight out from the side of the body, the lower leg is long and there are five slender toes, the first being always curiously bent inwards and downwards. The other four toes seem to have been connected by a web.

Rhamphorhynchus was covered with a smooth skin usually without scales, but the top of the head bore a tuft of hairlike protuberances. The animal appears to have lived like a seagull on fish, and it is exceedingly difficult to understand how it could ever have risen from land or water after alighting.

FROM E. STROMER "REKONSTRUKIONEN DES FLUGSAURIERS RHAMPHORHYNCHUS GEMMINGI" (SCHWEIZERBART, STUTTGART)

FIG. 2.—RECONSTRUCTION OF THE SKELETON AND WING MEMBRANE OF A PTERODACTYL, RHAMPHORHYNCHUS SEEN FROM BELOW

The group of tailless pterodactyls was represented in Jurassic times by *Pterodactylus,* a small type in which some species were no larger than a sparrow. In the Cretaceous the long-tailed forms were extinct, but descendants of *Pterodactylus* had persisted and grown greatly in size. They are best represented by *Pteranodon* from the Kansas chalk. This creature had a wingspread of 18 ft. and its head (measured from the tip of the snout to the summit of a great crest which rises from the occiput) is nearly 4 ft. in length. It was perhaps the largest flying animal of which we have any knowledge. Despite its great size it was extremely light, the wing bones consisting of a bony layer no thicker than a visiting card, surrounding an air space which might be more than an inch in diameter; even the bone of an albatross is a crude and heavy structure in comparison. The remains of these giant animals are found in the Kansas and English chalk commonly enough to show that they flew at a distance of some hundreds of miles from land. The brain of these large pterodactyls is extraordinarily like that of a bird, and its characters are such as to suggest that they practically lacked a sense of smell and depended on sight for the capture of their food. *See* REPTILES. (D. M. S. W.; X.)



FROM G. H. SHORT, "WING ADJUSTMENTS OF PTERODACTYLS" (ROYAL AERONAUTICAL SOCIETY)

FIG. 3.—PTERANODON GLIDING, AND ABOUT TO COMMENCE A FLIGHT

PTEROMA, in architecture, the colonnade at the side of a classic temple.

PTERON, in architecture, a term used by Pliny the Elder for the peristyle or colonnade of the tomb of Mausolos; loosely and rarely used for any surrounding colonnade or peristyle.

PTOLEMAEUS, of Alexandria, surnamed Chennus, Greek grammarian during the reigns of Trajan and Hadrian. According to Suïdas, he was the author of an historical drama named *Sphinx,* of an epic, *Anthomeros,* in 24 books (both lost) and a *Strange History.* The last is probably identical with the work of which an abridgment has been preserved in Photius (*cod.* 190).

See editions of Photius's abridgment by J. Roulez (1834); and in A. Westermann, *Mythographi graeci* (1843); R. Hercher, *Über die Glaubwürdigkeit der neuen Geschichte des Ptolemäus Chennus* (Leipzig, 1856); J. E. Sandys, *Hist. of Classical Scholarship,* 2nd ed. (1906).

PTOLEMAIS, an ancient city on the coast of Cyrenaica, 70 mi. N.E. of Bengasi, and 28 mi. N.E. of Teuchira (Tocra). Its modern name is Tolmeita or Tolmetta. Of the city walls nothing is preserved, excepting a massive gate on the west, with two towers, at the end of the road from Barce (mod. El Merg). At the further extremity of the town is a fine Roman bridge. Little of the town remains but some very large cisterns.

See *Ministero delle Colonie, Notiziario Archeologico,* i, 114–154 (1915).

PTOLEMIES, a dynasty of Macedonian kings who ruled in Egypt from 323 to 30 B.C.

PTOLEMY I (Πτολεμαῖος), the founder, son of Lagus, a Macedonian nobleman of Eordaea, was one of Alexander the Great's most trusted generals, and among the seven "bodyguards" at-

tached to his person. He plays a principal part in the later campaigns of Alexander in Afghanistan and India. At the Susa marriage festival in 324 Alexander caused him to marry the Persian princess Artacama; but there is no further mention of this Asiatic bride in the history of Ptolemy. When Alexander died in 323 the resettlement of the empire at Babylon is said to have been made at Ptolemy's instigation. At any rate he was now appointed satrap of Egypt under the nominal kings Philip Arrhidaeus and the young Alexander. He at once took a high hand in the province by killing Cleomenes, the financial controller appointed by Alexander the Great; he also subjugated Cyrenaïca. He contrived to get possession of Alexander's body which was to be interred with great pomp by the imperial government and placed it temporarily in Memphis. This act led to an open rupture between Ptolemy and the imperial regent Perdiccas. But Perdiccas perished in the attempt to invade Egypt (321). In the long wars between the different Macedonian chiefs which followed, Ptolemy's first object was to hold his position in Egypt securely, and secondly to possess the Cyrenaïca, Cyprus and Palestine (Coele-Syria). His first occupation of Palestine was in 318, and he established at the same time a protectorate over the petty kings of Cyprus. When Antigonus, master of Asia in 315, showed dangerous ambitions, Ptolemy joined the coalition against him, and, on the outbreak of war, evacuated Palestine. In Cyprus he fought the partisans of Antigonus and reconquered the island (313). A revolt of Cyrene was crushed in the same year. In 312 Ptolemy, with Seleucus, the fugitive satrap of Babylonia, invaded Palestine and beat Demetrius, the son of Antigonus, in the great battle of Gaza. Again he occupied Palestine, and again a few months later, after Demetrius had won a battle over his general and Antigonus entered Syria in force, he evacuated it.

In 311 a peace was concluded between the combatants, soon after which the surviving king Alexander was murdered in Macedonia, leaving the satrap of Egypt absolutely his own master. The peace did not last long, and in 309 Ptolemy commanded a fleet in person which detached the coast towns of Lycia and Caria from Antigonus and crossed to Greece, where Ptolemy took possession of Corinth, Sicyon and Megara (308). In 306 a great fleet under Demetrius attacked Cyprus, and Ptolemy's brother, Menelaus, was defeated and captured in the decisive battle of Salamis. The complete loss of Cyprus followed. Antigonus and Demetrius now assumed the title of kings; Ptolemy, as well as Cassander, Lysimachus and Seleucus, answered this challenge by doing the same. In the winter (306–5) Antigonus tried to follow up the victory of Cyprus by invading Egypt, but here Ptolemy was strong, and held the frontier successfully against him. Ptolemy led no further expedition against Antigonus overseas. To the Rhodians, besieged by Demetrius (305–4), he sent such help as won him divine honours in Rhodes and the surname of *Sotēr* ("saviour"). When the coalition was renewed against Antigonus in 302, Ptolemy joined it, and invaded Palestine a third time, whilst Antigonus was engaged with Lysimachus in Asia Minor. On a report that Antigonus had won a decisive victory, for a third time he evacuated the country. But when news came that Antigonus had been defeated and slain at Ipsus (301) by Lysimachus and Seleucus, Ptolemy occupied Palestine for the fourth time. The other members of the coalition had assigned Palestine to Seleucus after what they regarded as Ptolemy's desertion, and for the next hundred years the question of its ownership becomes the standing ground of enmity between the Seleucid and Ptolemaïc dynasties. Henceforth, Ptolemy seems to have mingled as little as possible in the broils of Asia Minor and Greece; his possessions in Greece he did not retain, but Cyprus he reconquered in 295–4. Cyrene, after a series of rebellions, was finally subjugated about 300 and placed under his stepson Magas (Beloch, *Griech. Gesch.* III. [ii.], p. 134 *seq.*).

In 285 he abdicated in favour of one of his younger sons by Berenice (*q.v.*), who bore his father's name of Ptolemy; his eldest (legitimate) son, Ptolemy Ceraunus, whose mother, Eurydice, the daughter of Antipater, had been repudiated, fled to the court of Lysimachus. Ptolemy I. Soter died in 283 at the age of 84. Shrewd and cautious, he had a compact and well-ordered realm to show at the end of fifty years of wars. His name for *bonhomie* and liberality attached the floating soldier-class of Macedonians and Greeks to his service. Nor did he neglect conciliation of the natives. He was a ready patron of letters, and the great library, which was Alexandria's glory, owed to him its inception. He wrote himself a history of Alexander's campaigns, distinguished by its straightforward honesty and sobriety.

PTOLEMY II. PHILADELPHUS (309–246) was of a delicate constitution, no Macedonian warrior-chief of the old style. His brother Ptolemy Ceraunus found compensation by becoming king in Macedonia in 281, and perished in the Gallic invasion of 280–79. (*See* BRENNUS.) Ptolemy II. maintained a splendid court in Alexandria. Not that Egypt held aloof from wars. Magas of Cyrene opened war on his half-brother (274), and Antiochus I., the son of Seleucus, desiring Palestine, attacked soon after. Two or three years of war left Egypt the dominant naval power of the eastern Mediterranean; the Ptolemaïc sphere of power extended over the Cyclades to Samothrace, and the harbours and coast towns of Cilicia Trachea ("Rough Cilicia"), Pamphylia, Lycia and Caria were largely in Ptolemy's hands (Theoc. *Idyll.* xvii. 86 *seq.*). The victory won by Antigonus, king of Macedonia, over his fleet at Cos (between 258–56; *see* Beloch, III. [ii.], p. 428 *seq.*) did not long interrupt his command of the Aegean. In a second war with the Seleucid kingdom, under Antiochus II. (after 260), Ptolemy sustained losses on the seaboard of Asia Minor and agreed to a peace by which Antiochus married his daughter Berenice (250?). Ptolemy's first wife, Arsinoë (I.), daughter of Lysimachus, was the mother of his legitimate children. After her repudiation he married, probably for political reasons, his full-sister Arsinoë (II.), the widow of Lysimachus, by an Egyptian custom abhorrent to Greek morality. The material and literary splendour of the Alexandrian court was at its height under Ptolemy II. Pomps and gay religions flourished. Ptolemy deified his parents as the *θεοὶ ἀδελφοί* and his sister-wife, after her death (270), as *Philadelphus*. This surname was used in later generations to distinguish Ptolemy II. himself, but properly it belongs to Arsinoë only, not to the king. Callimachus, made keeper of the library, Theocritus, and a host of lesser poets, glorified the Ptolemaïc family. Ptolemy himself was eager to increase the library and to patronize scientific research. He had the strange beasts of far-off lands sent to Alexandria. But, an enthusiast for Hellenic culture, he seems to have shown but little interest in the native religion. The tradition which connects the Septuagint translation of the Old Testament into Greek with his name is not historical. Ptolemy had many brilliant mistresses, and his court, magnificent and dissolute, intellectual and artificial, has been justly compared with the Versailles of Louis XIV.

PTOLEMY III. EUERGETES I. (reigned 246–221), son of Ptolemy II. and Arsinoë I. At the beginning of his reign he reunited the Cyrenaïca to Egypt by marrying Berenice the daughter and successor of Magas (who had died about 250). At the same time he was obliged to open war on the Seleucid kingdom, where Antiochus II. was dead and his sister Berenice had been murdered, together with her infant son, by Antiochus's former wife, Laodice, who claimed the kingdom for her son Seleucus II. Ptolemy marched triumphantly into the heart of the Seleucid realm, as far at any rate as Babylonia, and received the formal submission of the provinces of Iran, while his fleets in the Aegean recovered what his father had lost upon the seaboard, and made fresh conquests as far as Thrace. This moment marks the zenith of the Ptolemaïc power. After Ptolemy returned home, indeed, Seleucus regained northern Syria and the eastern provinces, but the naval predominance of Egypt in the Aegean remained, although there are traces of its being replaced locally, towards the end of Euergetes' reign, by that of Macedonia—in Amorgos, Naxos, Syros, Nisyros, Cos and parts of Crete. (*See* Beloch, III. [ii.], p. 463.) After his final peace with Seleucus, Ptolemy no longer engaged actively in war.

PTOLEMY IV. PHILOPATOR (reigned 221–204), son of the preceding, was a wretched debauchee under whom the decline of the Ptolemaïc kingdom began. His reign was inaugurated by the murder of his mother, and he was always under the dominion of

favourites, male and female, who indulged his vices and conducted the government as they pleased. Self-interest led his ministers to make serious preparations to meet the attacks of Antiochus III. (the Great) on Palestine, and the great Egyptian victory of Raphia (217), at which Ptolemy himself was present, secured the province till the next reign. The arming of Egyptians in this campaign had a disturbing effect upon the native population of Egypt, so that rebellions were continuous for the next thirty years. Philopator was devoted to orgiastic forms of religion and literary dilettantism. He built a temple to Homer and composed a tragedy, to which his vile favourite Agathocles added a commentary. He married (about 215) his sister Arsinoë (III.), but continued to be ruled by his mistress Agathoclea, sister of Agathocles.

Ptolemy V. Epiphanes (reigned 204–181), son of Philopator and Arsinoë, was not more than five years old when he came to the throne, and under a series of regents the kingdom was paralysed. Antiochus III. and Philip V. of Macedonia made a compact to divide the Ptolemaïc possessions overseas. Philip seized several islands and places in Caria and Thrace, whilst the battle of Panium (198) definitely transferred Palestine from the Ptolemies to the Seleucids. Antiochus after this concluded peace, giving his own daughter Cleopatra to Epiphanes to wife (193–192). Nevertheless, when war broke out between Antiochus and Rome Egypt ranged itself with the latter power. Epiphanes in manhood was chiefly remarkable as a passionate sportsman; he excelled in athletic exercises and the chase.

Ptolemy VI. Philometor (181–145), the elder of his two sons, succeeded as an infant under the regency of his mother Cleopatra. Her death was followed by a rupture between the Ptolemaïc and Seleucid courts, on the old question of Palestine. Antiochus IV. Epiphanes invaded Egypt (170) and captured Philometor.

The Alexandrians then put his younger brother Ptolemy VII. Euergetes II. (afterwards nicknamed *Physkon*, on account of his bloated appearance) upon the throne. Antiochus professed to support Philometor, but, when he withdrew, the brothers agreed to be joint-kings with their sister Cleopatra as queen and wife of Philometor. Antiochus again invaded Egypt (168), but was compelled by the Roman intervention to retire. The double kingship led to quarrels between the two brothers in which fresh appeals were continually made to Rome. In 163 the Cyrenaïca was assigned under Roman arbitration to Euergetes as a separate kingdom. As he coveted Cyprus as well, the feud still went on, Rome continuing to interfere diplomatically but not effectively. In 154 Euergetes invaded Cyprus but was defeated and captured by Philometor. He found his brother, however, willing to pardon and was allowed to return as king to Cyrene. In 152 Philometor joined the coalition against the Seleucid king Demetrius I. and was the main agent in his destruction. The protégé of the coalition, Alexander Balas, married Philometor's daughter Cleopatra (Thea), and reigned in Syria in practical subservience to him. But in 147 Philometor broke with him and transferred his support, together with the person of Cleopatra, to Demetrius II., the young son of Demetrius I. He himself at Antioch was entreated by the people to assume the Seleucid diadem, but he declined and installed Demetrius as king. In 145 in the battle on the Oenoparas near Antioch, in which Alexander Balas was finally defeated, Philometor received a mortal wound. Philometor was perhaps the best of the Ptolemies. Kindly and reasonable, his good nature seems sometimes to have verged on indolence, but he at any rate took personal part, and that bravely and successfully, in war. Philometor's infant son, Ptolemy Philopator Neos (?)[1], was proclaimed king in Alexandria under the regency of his mother Cleopatra. Euergetes however, swooping from Cyrene, seized the throne and married Cleopatra, making away with his nephew. He has left an odious picture of himself in the historians—a man untouched by benefits or natural affection, delighting in deeds of blood, his body as loathsome in its blown corpulence as his soul. Something must be allowed for the rhetorical habit of our authorities, but that Euergetes was ready enough to shed blood when policy required seems true. He soon found a more agreeable wife than Cleopatra in her daughter Cleopatra, and thenceforth antagonism between the two queens, the "sister" and the "wife," was chronic. In 130–1 Cleopatra succeeded in driving Euergetes for a time to Cyprus, when he revenged himself by murdering the son whom she had borne him (surnamed *Memphites*). Massacres inflicted upon the Alexandrians and the expulsion of the representatives of Hellenic culture are laid to his charge. On the other hand, the monument and papyri show him a liberal patron of the native religion and a considerable administrator. In fact, while hated by the Greeks, he seems to have had the steady support of the native population. But there are also records which show him, not as an enemy, but a friend, like his ancestors, to Greek culture. He himself published the fruit of his studies and travels in a voluminous collection of notebooks, in which he showed a lively eye for the oddities of his fellow kings. The old Ptolemaïc realm was never again a unity after the death of Euergetes II. By his will he left the Cyrenaïca as a separate kingdom to his illegitimate son Ptolemy Apion (116–96), whilst Egypt and Cyprus were bequeathed to Cleopatra (Kokke) and whichever of his two sons by her, Ptolemy VIII. Soter II. (nicknamed *Lathyros*) and Ptolemy IX. Alexander I., she might choose as her associate. The result was, of course, a long period of domestic strife. From 116 to 108 Soter reigned with his mother, and at enmity with her, in Egypt, whilst her favourite son, Alexander, ruled Cyprus. Cleopatra compelled Soter to divorce his sister-wife Cleopatra and marry another sister, Selene. Cleopatra plunged into the broils of the Seleucid house in Syria and perished. In 108 Cleopatra Kokke called Alexander to Egypt, and Soter flying to Cyprus took his brother's place and held the island against his mother's forces. The attempts which Soter and Cleopatra respectively made in 104–3 to obtain a predominance in Palestine came to nothing. Alexander now shook off his mother's yoke and married Soter's daughter Berenice. Cleopatra Kokke died in 101 and from then till 89 Alexander reigned alone in Egypt. In 89 he was expelled by a popular uprising and perished the following year in a sea-fight with the Alexandrian ships off Cyprus. Soter was recalled (88) and reigned over Egypt and Cyprus, now reunited, in association with his daughter Berenice. This, his second, reign in Egypt (88–80), was marked by a native rebellion which issued in the destruction of Thebes.

Ptolemy X. Alexander II.—On his death Berenice assumed the government, but the son of Alexander I., Ptolemy X., entering Alexandria under Roman patronage, married, and within 20 days assassinated, his elderly cousin and stepmother. He was at once killed by the enraged people and with him the Ptolemaïc family in the legitimate male line became extinct. Ptolemy Apion meanwhile, dying in 96, had bequeathed the Cyrenaïca to Rome.

The Alexandrian people now chose an illegitimate son of Soter II. to be their king, Ptolemy XI. Philopator Philadelphus Neos Dionysus (80–51), nicknamed *Auletes*, the flute-player, setting his brother as king in Cyprus. The rights of these kings were doubtful, not only because of their illegitimate birth, but because it was claimed in Rome that Alexander II. had bequeathed his kingdom to the Roman people. Two Seleucid princes, children of Soter's sister Selene, appeared in Rome in 73 to urge their claim to the Ptolemaïc throne. Ptolemy Auletes was thus obliged to spend his reign in buying the support of the men in power in Rome. Cyprus was annexed by Rome in 58, its king committing suicide. From 58 to 55 Auletes was in exile, driven out by popular hatred, and worked by bribery and murder in Rome to get himself restored to Roman power. His daughter Berenice meanwhile reigned in Alexandria, a husband being found for her in the Pontic prince Archelaus. In 55 Auletes was restored by the proconsul of Syria, Aulus Gabinius. He killed Berenice and, dying in 51, bequeathed the kingdom to his eldest son, aged ten years, who was to take as wife his sister Cleopatra, aged seventeen.

In the reign of Ptolemy XII. Philopator (51–47) and Cleopatra Philopator, Egyptian history coalesces with the general

[1] Or according to another view, Eupator. On the obscure questions raised by these two surnames, *see* L. Pareti, *Ricerche sui Tolemei Eupatore e Neo Filopatore* (Turin, 1908).

history of the Roman world, owing to the murder of Pompey off Pelusium in 48 and the Alexandrine War of Julius Caesar (48–47).

In that war the young king perished and a still younger brother, PTOLEMY XIII. Philopator, was associated with Cleopatra till 44, when he died, probably by Cleopatra's contriving. From then till her death in 30, her son, born in 47, and asserted by Cleopatra to be the child of Julius Caesar, was associated officially with her as PTOLEMY XIV. Philopator Philometor Caesar; he was known popularly as Caesarion. (For the incidents of Cleopatra's reign *see* CLEOPATRA, ARSINOË.) After her death in 30 and Caesarion's murder Egypt was made a Roman province. Cleopatra's daughter by Antony (Cleopatra Selene) was married in 25 to Juba II. of Mauretania. Their son Ptolemy, who succeeded his father (A.D. 23–40), left no issue[1].

See Mahaffy, *The Empire of the Ptolemies* (1895) and *Egypt under the Ptolemaïc Dynasty* (1899); Strack, *Die Dynastie der Ptolemäer* (1897); Bouché-Leclercq, *Histoire des Lagides* (1904, 1907); Meyer, *Das Heerwesen der Ptolemäer und Römer* (Leipzig, 1900).

(E. R. B.)

PTOLEMY (CLAUDIUS PTOLEMAEUS), of Alexandria, the celebrated mathematician, astronomer and geographer, was, according to the Byzantine Theodorus Meliteniota (*c.* 1361), born at Ptolemais Hermii, a Grecian city of the Thebaid. All that is known for certain about him is that he observed at Alexandria during the reigns of Hadrian and Antoninus Pius, between the years A.D. 127 and 141 or 151. Olympiodorus, a philosopher of the Neoplatonic school, who lived in the reign of the emperor Justinian, relates in his scholia on the *Phaedo* of Plato that Ptolemy devoted his life to astronomy and lived for 40 years in the so-called Περὶ τοῦ Κανώβου, probably elevated terraces of the temple of Serapis at Canopus, near Alexandria, where they raised pillars with the results of his astronomical discoveries engraved upon them. Arabian traditions say that Ptolemy lived to the age of 78 years, and give some details about his personal appearance, to which too much weight must not be attached.

His Work as a Mathematician.—Ptolemy's work as a geographer is discussed below, and an account of the discoveries in astronomy of Hipparchus and Ptolemy is given in the article ASTRONOMY: *History*. Their contributions to pure mathematics, however, require to be noticed here. Of these the chief is the foundation of trigonometry, plane and spherical, including the formation of a table of chords, which served the same purpose as our table of sines. This branch of mathematics was created by Hipparchus for the use of astronomers, and its exposition was given by Ptolemy in a form so perfect that for 1,400 years it was not surpassed. The doctrine as to the motion of the heavenly bodies known as the Ptolemaic system, was paramount for about the same period of time. The astronomical and trigonometrical systems are contained in the great work of Ptolemy, Ἡ μαθηματικὴ σύνταξις or *The Mathematical Collection*. Later it came to be known as the μεγάλη σύνταξις or alternatively as Ὁ μέγας ἀστρονόμος, *the Great Astronomer*, to distinguish it from another collection called Ὁ μικρὸς ἀστρονόμος or ἀστρονομούμενος, *the Little Astronomer*, comprising some works of Autolycus, Euclid, Aristarchus, Theodosius, Hypsicles and Menelaus. To designate the great work of Ptolemy, the Arabs used the superlative μεγίστη from which, the article *al* being prefixed, the hybrid name *Almagest*, by which it has ever since been known, is derived.

We proceed now to consider the trigonometrical work of Hipparchus and Ptolemy. In the ninth and tenth chapters of the first book of the *Almagest* Ptolemy shows how to form a table of chords. He supposes the circumference divided into 360 equal parts (τμήματα or degrees). Further, he divides the diameter into 120 equal parts. Then, for the subdivision both of the degrees and of the parts of the diameter, he uses sexagesimal fractions or, as we say, "minutes," "seconds," etc. It must not be supposed, however, that these sexagesimal divisions are due to Ptolemy; Babylonian in origin, they must already have been used by Hipparchus. Nor did the formation of the table of chords originate with Ptolemy; indeed, we know that Hipparchus wrote a treatise in 12 books on straight lines (chords) in a circle, while Menelaus (*c.* A.D. 100) wrote another in six books. Ptolemy shows how the calculation of chords is based on a few simple theorems in geometry (including the well-known "Ptolemy's theorem" relating to a quadrilateral inscribed in a circle), and these he gives in a form which for conciseness and elegance could not be surpassed; Hipparchus' method was no doubt the same, though his exposition would run to greater length.

As starting-point the values of certain chords in terms of the diameter were already known, or could be easily found by means of the *Elements* of Euclid. Thus the side of the hexagon, or the chord of 60°, is equal to the radius, and therefore contains 60 parts. The sides of the regular pentagon and decagon inscribed in a circle, which are the chords subtending arcs of 72° and 36° respectively, are found by means of propositions in Euclid's Book xiii.; expressed in terms of the "parts" of the diameter, they are found to be (nearly) $70^p\ 32'\ 3''$ and $37^p\ 4'\ 55''$ respectively. (It should be noted that the ratio of the chord subtending any angle to the diameter of the circle is the same as the ratio of half the chord to the radius; hence, expressed on this system, the chord of any angle is equivalent to the trigonometrical *sine* of half the angle.)

Now "Ptolemy's Theorem" enables us to deduce from the chords of two angles the chord of their sum or difference; the theorem is equivalent to the formulae $\mathrm{Sin}(A+B)=\mathrm{Sin}A\ \mathrm{Cos}\ B+\mathrm{Cos}\ A\mathrm{Sin}B$. Another proposition which Ptolemy gives, shows how to deduce from the chord of any angle the chord of half the angle; it is equivalent to the formula $\mathrm{Sin}^2\ \frac{1}{2}\theta=\frac{1}{2}(1-\mathrm{Cos}\theta)$. Yet another proposition gives the equivalent of $\mathrm{Sin}^2\theta+\mathrm{Cos}^2\theta=1$. As we know the lengths of (crd. 72°) and (crd. 60°), we deduce (crd. 12°); from this we deduce successively the chords of 6°, 3°, $1\frac{1}{2}$° and $\frac{3}{4}$°, and again from these (by "Ptolemy's Theorem") the chords of $4\frac{1}{2}$°, $7\frac{1}{2}$°, 9°, $10\frac{1}{2}$° etc.; we have therefore a table of chords going by gradations of $1\frac{1}{2}$°. It remains to find the chord of 1°, and thence the chord of $\frac{1}{2}$°, in order to obtain a table going by gradations of $\frac{1}{2}$°. To find (crd. 1°) Ptolemy uses a clever method of "interpolation" based on a proposition already assumed as known by Aristarchus of Samos (*fl.* 280 B.C.) and equivalent to the trigonometrical formula $\mathrm{Sin}\alpha/\mathrm{Sin}\beta<\alpha/\beta$ (where $\frac{1}{2}\pi>\alpha>\beta$). It follows from the proposition in question that (crd. 1°) : (crd. $\frac{3}{4}$°) < 1 : $\frac{3}{4}$ and (crd. $1\frac{1}{2}$°) : (crd. 1°) < $1\frac{1}{2}$: 1, whence $\frac{4}{3}$(crd. $\frac{3}{4}$°) > (crd. 1°) > $\frac{2}{3}$ (crd. $1\frac{1}{2}$°). Now Ptolemy has found (crd. $\frac{3}{4}$°) to be $0^p\ 47'\ 8''$ and (crd. $1\frac{1}{2}$°) to be $1^p\ 34'\ 15''$. Thus $\frac{4}{3}$ of the former is $1^p\ 2'\ 50''$ nearly (actually $1^p\ 2'\ 50\frac{2}{3}''$) and $\frac{2}{3}$ of the latter is $1^p\ 2'\ 50''$. Thus (crd. 1°), being both greater and less than $1^p\ 2'\ 50''$, may be taken to be $1^p\ 2'\ 50''$ as nearly as possible. Ptolemy deduces that (crd. $\frac{1}{2}$°) is very nearly $0^p\ 31'\ 25''$; and he is therefore in a position to complete his table going by gradations of $\frac{1}{2}$ a degree. No wonder that De Morgan called this exposition "one of the most beautiful in the Greek writers." Ptolemy further uses the same method of proportional increase ("interpolation") to find the chords of angles containing a number of odd minutes between 0′ and 30′, inserting in the table opposite each chord, in a third column, $\frac{1}{30}$ of the excess of that chord over the one before. One particular result is worth quoting. Since (crd. 1°) is found to be $1^p\ 2'\ 50''$, the whole circumference $=360\times(1^p\ 2'\ 50'')$ nearly, and, the length of the diameter being 120^p it follows that $\pi=3\times(1+\frac{2}{60}+\frac{50}{3600})$ or $(3+\frac{8}{60}+\frac{30}{3600})$, which is equivalent to $\pi=3{\cdot}14166$.

Trigonometry, as we have seen, was created by Hipparchus for the use of astronomers. Now, since spherical trigonometry is directly applicable to astronomy, it is not surprising that its development was prior to that of plane trigonometry.

Ptolemy obtains all that he wants in the shape of spherical trigonometry from the one fundamental proposition known as "Menelaus' Theorem" applied to the sphere, a theorem concerning the segments into which the sides of a spherical triangle are cut by a transversal. Menelaus gave the proof in his *Sphaerica*, iii. 1. Ptolemy gives it with two simple propositions on which it depends in the *Syntaxis* i. 13; the proof assumes as known the corre-

[1] The Ptolemies were not in antiquity distinguished by the ordinal numbers affixed to their names by modern scholars and represented according to the usual convention by Roman figures. This is merely done for our convenience. In the case of the later Ptolemies different systems of notation prevail according as the problematic Eupator and Philopator Neos are reckoned in or not.

sponding proposition for a plane triangle. The theorem for the sphere, though called by the name of Menelaus, must certainly have been known to Hipparchus, while the theorem for the plane triangle at least was probably known to Euclid. When Ptolemy requires the equivalent of one of our formulae in the solution of spherical triangles, he does not quote such propositions but proves them afresh each time by means of Menelaus' theorem. These various applications include the equivalent of such formulae for a right-angled spherical triangle as (1) Sin$a$ = Sin$c$ Sin$A$, (2) Tan$a$ = Sin$b$ Tan$A$, (3) Cos$c$ = Cos$a$ Cos$b$, and (4) Tan$b$ = Tan$c$ Cos$A$.

We are, above all, indebted to Ptolemy for very full particulars of observations and investigations by Hipparchus as well as of the earlier observations which Hipparchus recorded, *e.g.*, that of a lunar eclipse in 721 B.C. The work of Ptolemy is, in general, evidently based upon Hipparchus to a degree that makes it far from easy to identify Ptolemy's own contributions to the subject, except where he propounds a definite theory of the motions of the five planets, for which Hipparchus had only collected material in the shape of observations made before his time or by himself.

The "Syntaxis."—The contents of the *Syntaxis* can here be only very briefly indicated. Book i. contains the indispensable preliminaries to the study of the Ptolemaic system, treating of the earth, its spherical shape and its position in the centre of the universe, the circular movements of the heavenly bodies, the propositions required for the preparation of the Table of Chords, this table itself, the angle of obliquity of the ecliptic and Ptolemy's own method of determining it, and, lastly, so much of spherical geometry and trigonometry as is necessary for the determination of the connection between a star's right ascension, declination, latitude and longitude, and for the formulation of a table of declinations to each degree of longitude. Book ii. contains matter similar to that of Autolycus' *On the Moving Sphere, i.e.*, problems on the sphere, with special reference to the difference between various latitudes, the length of the longest day at any degree of latitude, and the like. Book iii. treats of the length of the year and the motion of the sun on the eccentric and epicycle hypothesis. Ptolemy observes that, to understand the difficulties of the question, we should read the treatises of the ancients, and especially those of Hipparchus, "that enthusiastic worker and lover of truth." He mentions here Hipparchus' discovery of the precession of the equinoxes (a subject to which he returns in viii. 2). In chapter 1, Ptolemy also lays down some general principles which are worth quoting, namely, (1) that, in seeking to explain phenomena, we should adopt the simplest possible hypothesis, provided that it is not contradicted in any important respect by the observations; (2) that in investigations depending on observations in which great delicacy is required, we should select those made at long intervals of time in order that the error due to the imperfection of our instruments may be lessened by being distributed over a large number of years. Book iv. deals with the length of the months and the motions of the moon, and Book v. with the same subject continued, the construction of the astrolabe, the diameters of the sun, the moon and the earth's shadow, the distance of the sun, and the dimensions of the sun, moon and earth. Book vi. is on the conjunctions and oppositions of the sun and moon, solar and lunar eclipses and the periods of their recurrence. Books vii. and viii. treat of the fixed stars, including precession. Book vii. ends with the catalogue (arranged under constellations) of the stars in the northern hemisphere, in which are entered the latitudes, longitudes and magnitudes; Book viii. begins with a similar catalogue for the southern hemisphere; the two catalogues include 1,022 separate stars as compared with the 850 or more included in Hipparchus' catalogue. Book viii. also describes the Milky Way and the construction of a celestial globe. Books ix. to xiii. are devoted to the planets. Book ix. begins with general remarks on the order of the planets, the difficulties in the way of framing a theory of the subject, the periods of revolution of the five planets, the different hypotheses that are possible; then (ch. 7) Ptolemy passes to the separate case of Mercury. Book x. treats of Venus; Book xi. of Jupiter and Saturn; Book xii. deals with the stationary points and retrogradations of each of the planets, and with the greatest elongations of Mercury and Venus; Book xiii. considers the motions of the planets in latitude, the inclination of their orbits and its magnitude.

The *Syntaxis* early became the subject of commentaries. For Book vi. and part of Book v. the commentary of Pappius is extant in Greek. Theon of Alexandria's commentary in 11 books was first published by Joachim Camerarius of Basle in 1538; the first two books were appended by Halma to his edition of Ptolemy. The *Syntaxis* was translated into Arabic for the Caliph al-Ma'mūn, himself an astronomer, by a translator unnamed, in 827; later it was translated by al-Hajjāj, the translator of Euclid, and again by Isḥāq b. Ḥunain (or perhaps his father Ḥunain b. Isḥāq), whose translation was revised by Thābit b. Qurra (d. 901). The first Latin translation was made from the Arabic by Gherard of Cremona; this translation, finished in 1175, was first published by P. Liechtenstein at Venice in 1515, but without the author's name. George of Trebizond made the first Latin translation from the Greek in 1451; this was revised and published by Lucas Gauricus at Venice in 1528. The *editio princeps* of the Greek text was brought out by Simon Grynaeus at Basle in 1538. The next complete edition was Halma's (1813–16). All former Greek texts are now superseded by Heiberg's edition of the astronomical works of Ptolemy (1899–1907) to which, so far as the *Syntaxis* is concerned, a German translation by Manitius has been added (1912–13).

Other Mathematical Works.—Of the other works of Ptolemy the following should be mentioned: (1) the *Analemma*, the object of which is to explain a method of representing on one plane the different points and arcs of the heavenly sphere by orthogonal projection on three planes mutually, at right angles, the meridian, the horizon and the "prime vertical." The problem is to find the position of the sun at a given hour of the day. Only a few fragments remain of the Greek text, but we have a Latin translation by William of Moerbeke from an Arabic version. This translation was edited with a valuable commentary by Commandinus (1562); and Heiberg has included it, with the Greek fragments alongside (where extant), in vol. ii. of his edition of the astronomical works. (2) The *Planisphaerium* survives in a Latin translation from the Arabic, which was edited by Commandinus in 1558 and is likewise included in Heiberg's vol. ii. The book is an explanation of a system of projection known as "stereographic," by which points on the heavenly sphere are represented in the plane of the equator by projection from one point, a pole. The pole taken by Ptolemy is the south pole. (3) Φάσεις ἀπλανῶν ἀστέρων. This is a calendar of the sort which the Greeks called *parapegma*, or a table of the risings and settings of stars in morning and evening twilight, with weather-indications (ἐπισημασίαι). (4) Ὑποθέσεις τῶν πλανωμένων, *Planetary Hypotheses*, in two books, the first of which is extant in Greek, the second in Arabic only. These works are also included in Heiberg's vol. ii.

Two separate geometrical works are mentioned by ancient commentators, (1) a single book Περὶ διαστάσεως, *On Dimension*, in which Ptolemy apparently tried to prove that there are only three dimensions in space; (2) a tract containing an attempt to prove Euclid's Parallel Postulate. The gist of the latter tract is given by Proclus in his Commentary on Euclid, Book i. (ed. Friedlein, 1873). Simplicius mentions a mechanical work Περὶ ῥοπῶν, *On Balancings*, while Suidas credits Ptolemy with three books on *Mechanics*.

The *Optics* of Ptolemy exists (save for Book i. and the end of Book v. which are lost) in a Latin translation made by a certain Admiral Eugenius Siculus from the Arabic in the 12th century. It was in five books, the last of which is interesting because it contains what is apparently the first recorded attempt at a theory of *refraction* of luminous rays through media of different densities; it deals also with astronomical refraction, of which it gives a better account than that of any astronomer before Cassini.

Lastly, Ptolemy wrote *Harmonica* in three books, a treatise on music. This was edited in Greek and Latin by John Wallis (1682); it appeared also with Porphyry's commentary, in *Johannis Wallis Opera Mathematica* (1699), vol. iii.

For further particulars the reader may refer to the article on Ptolemy in Smith's *Dictionary of Greek and Roman Biography*, vol. iii. (by De Morgan); Delambre's *Histoire de l'astronomie ancienne* (1817–21) vol. ii.; Rud-Wolf, *Geschichte der Astronomie* (1877); A. Berry, *A Short History of Astronomy* (1898); and for the mathematics to A. von Braunmühl, *Geschichte der Trigonometrie* (1900); Gino Loria, *Le scienze esatte nell' antica Grecia* (1914); and Sir T. L. Heath, *History of Greek Mathematics* (1921) vol. ii.

His Work as a Geographer.—Ptolemy is hardly less celebrated as a geographer than as an astronomer, and his Γεωγραφικὴ ὑφήγησις (or *Guide to Geography*) exercised as great an influence on geographical progress (especially during the period of the Classical Renaissance), as did his *Almagest* on astronomical. Its exceptional position was largely due to its scientific form, which rendered it convenient and easy of reference; but, apart from this, it was really the most considerable attempt of the ancient world to place the study of geography on a scientific basis. The astronomer Hipparchus had indeed pointed out, three centuries before Ptolemy, that the only way to construct a trustworthy map of the inhabited world would be by observations of the latitude and longitude of all the principal points on its surface. But the materials for such a map were almost wholly wanting, and, though Hipparchus made some approach to a correct division of the known world into zones of latitude, "climates" or *klimata*, as he termed them, trustworthy observations of latitude were then very few, while the means of determining longitudes hardly existed. Hence probably it arose that no attempt was made to follow up the suggestion of Hipparchus until Marinus of Tyre, who lived shortly before Ptolemy, and whose work is known to us only through the latter. Marinus' scientific materials being inadequate, he contented himself mostly with determinations derived from itineraries and other rough methods, such as are still employed where more accurate means of determination are not available. The greater part of Marinus' treatise was occupied with the discussion of his authorities, and it is impossible, in the absence of the original work, to decide how far his results attained a scientific form. But Ptolemy himself considered them, on the whole, so satisfactory that he made his predecessor's work the basis of his own in regard to all the Mediterranean countries, that is, in regard to almost all those regions of which he had definite knowledge. In the more remote regions of the world, Ptolemy availed himself of Marinus' information, but with reserve, and he explains the reasons that induced him sometimes to depart from his predecessor's conclusions. Among other things Ptolemy's work shows the increased knowledge of Asia and Africa acquired since Strabo and Pliny.

As an astronomer, Ptolemy was, of course, better qualified to explain the mathematical conditions of the earth and its relations to the celestial bodies than most preceding geographers. His general views had much in common with those of Eratosthenes and Strabo. He adopted from Hipparchus the division of the equatorial circle into 360 parts (our *degrees*), and supposed other circles (*meridians*) to be drawn through this, from the equator to the pole. Another set of circles was the series of parallels of latitude, and within the network of parallels of latitude and meridians of longitude it was Ptolemy's task to place the outline of the world, so far as known to him.

But at the very outset of his attempt he fell into an error vitiating all his conclusions. Eratosthenes (*c.* 276–196 B.C.) was the first who had attempted scientifically to determine the earth's circumference, and his result of 250,000 (or 252,000) stadia, *i.e.*, 25,000 (25,200) geographical miles, was generally adopted by subsequent geographers, including Strabo. Posidonius, however (*c.* 135–50 B.C.), reduced this to 180,000, and the latter computation was inexplicably adopted by Marinus and Ptolemy. This error made every degree of latitude or longitude (measured at the equator) equal to only 500 stadia (50 geographical miles), instead of its true equivalent of 600 stadia. The mistake would have been somewhat neutralized had there existed a sufficient number of points of which the position was fixed by observation; but we learn from Ptolemy himself that such observations for latitude were very few, while the means of determining longitudes were almost wholly wanting. Hence the positions laid down by him were, with few exceptions, the result of computations from itineraries and the statements of travellers, which, owing to the want of instruments, etc., were liable to much greater error in ancient times than at the present day. But, great as were the errors resulting from such imperfect means of calculation, they were increased by the permanent error arising from Ptolemy's system of graduation. Thus, if he concluded (from itineraries) that two places were 5,000 stadia distant, he would place them 10° apart, and thus in fact separate them by 6,000 stadia.

Ptolemy followed Marinus in taking, as his prime meridian from which to measure longitudes, a line drawn through the supposed position of the Fortunate islands (vaguely answering to the Canaries *plus* the Madeira group) which they placed 2½° (instead of 9° 20′) west of the Sacred promontory (*i.e.*, Cape St. Vincent, regarded by Marinus and Ptolemy, as by previous geographers, as the westernmost point of Europe). Hence all Ptolemy's longitudes, reckoned eastwards, were about 7° less than they would have been if really measured from the meridian of Ferro, which continued so long in use.

The problem that had especially attracted the attention of geographers from Dicaearchus to Ptolemy was to determine the length and breadth of the inhabited world. This question had been fully discussed by Marinus, who had arrived at conclusions widely different from his predecessors. Towards the north, indeed, there was no great difference of opinion, the latitude of Thule being generally recognized as that of the highest northern land, and this was placed both by Marinus and Ptolemy in 63° N., not far beyond the true position of the Shetland islands, which had come to be generally identified with the mysterious Thule of Pytheas. The western extremity, as already mentioned, had been in like manner determined by the prime meridian drawn through the supposed position of the outermost of the Fortunate islands. But towards the south and east Marinus gave an enormous extension to Africa and Asia, beyond what had been known to or suspected to exist by earlier geographers, and, though Ptolemy reduced Marinus' calculations, he retained an exaggerated estimate of their results.

Contents of the "Guide to Geography."—In Book i., after general explanations (cc. 1–6), Ptolemy applies himself to a correction of Marinus' results, taking account (1) of the observed (astronomical) phenomena, (2) of the various recorded itineraries of travel (*a*) by land and (*b*) by sea. Marinus had assumed as the limit of knowledge to the south a region in Africa called Agisymba, inhabited by Ethiopians and abounding in rhinoceroses, which had been reached by Julius Maternus. Modifying the data regarding this journey, Marinus placed Agisymba on the southern tropic. This made the "breadth" of the inhabited world from Thule to Agisymba 63°+24°=87°. Ptolemy, on the other hand, placed Agisymba and a certain promontory called Prason on a parallel as far south as Meroe is north of the equator; taking, then, the southern limit to be 16° 25′ S., he finds the "breadth" of the inhabited earth to be 63°+16° 25′=79° 25′, in round figures 80°, or 40,000 stades.

Marinus' estimate of the "length" of the inhabited earth overland (from west to east) may be stated in three parts, (1) from the "Fortunate islands" to Hierapolis on the Euphrates 28,800 stades, (2) from Hierapolis to the "Stone Tower" (near the Pamir?) 26,280, and (3) from the "Stone Tower" to Sera, the capital of the Serae (? inland China), 36,200 stades, making 91,280 stades in all. Ptolemy reduced the last two estimates to 24,000 and 18,100 respectively, thus arriving at a total of 70,900 stades. Reckoning 400 stades as the proper length of a degree of longitude measured at the latitude of Rhodes (36°), we have as the "length" according to Marinus 228°, which he rounded down to 225°, and as Ptolemy's estimate 177° 15′, in round figures 180°. The measurement by Marinus of the distance by sea gave 125° from the Fortunate islands to Kory, a promontory in India opposite the northern point of Ceylon, and 61° more to the "Golden Chersonese"; the distances from the Golden Chersonese eastwards to Zaba and thence nearly south to Kattigara Marinus only gave in days of sailing. Ptolemy reduced the figure

of 61° to 34° 48′, and the difference in longitude between the Golden Chersonese and Kattigara he made 17° 10′. Thus Ptolemy's total became 125° + 34° 48′ + 17° 10′ = 176° 58′ say 177°, to which he added 3° for the difference in longitude between Kattigara and the capital of the Sinae (sea-coast of China), making 180° as before.

But in thus estimating the length and breadth of the known world, Ptolemy attached a very different sense to these terms from that which they had generally borne. Most earlier Greek geographers and "cosmographers" supposed the inhabited world to be surrounded on all sides by sea, and to form a vast island in the midst of a circumfluous ocean. This notion (perhaps derived from the Homeric "ocean stream," and certainly not based upon direct observation) was nevertheless in accordance with truth, great as was the misconception involved of the continents included. But Ptolemy in this respect went back to Hipparchus, and assumed that the land extended indefinitely north in the case of eastern Europe, east, south-east and north in that of Asia, and south, south-west and south-east in that of Africa. His boundary line was in each of these cases an arbitrary limit, beyond which lay the Unknown Land, as he calls it. But in Africa he was not content with this extension southward; he also prolonged the continent eastward from its southernmost known point, so as to form a connection with south-east Asia. In Asia he took the line of coast from the Golden Chersonese as making a great bay towards the Sinae, and then proceeding *southwards* to Kattigara. The effect was to enclose the Indian ocean as one vast lake surrounded by Unknown Land. It must be noticed that Ptolemy's extension of Asia eastwards, so as to diminish by 50° of longitude the interval between easternmost Asia and westernmost Europe, fostered Columbus' belief that it was possible to reach the former from the latter by direct navigation, crossing the Atlantic.

Ptolemy proceeds (i. 19 *sq.*) to consider the question of maps and methods of constructing them. He first describes (i. 24) a method of conical projection in which the meridian circles are represented as straight lines all meeting in a certain point (a kind of north pole) and the parallels of latitude (in particular those passing through Thule, Rhodes, Meroe and Agisymba) as circles with that point as centre. (The fixed "pole," or centre of projection is as nearly as possible the vertex of the cone passing through the actual parallel circle of Thule and the equator.) A more elaborate system, in which the meridians are represented as actual arcs of circle and not straight lines, is then described (*s.* 10 *sqq.*).

Books ii. to vii. contain Ptolemy's systematic tabular location of places and features in terms of latitude and longitude for all countries. He deals in order with Europe and the Mediterranean, then Africa, then Asia, beginning with Asia Minor and passing to Palestine, Mesopotamia, Arabia, India, etc. Under Europe, the first countries dealt with are the "Britannic islands," Ireland and Albion; then comes Spain in three divisions, then Gaul in four divisions, then Germany, and so on. The arrangement of the subject-matter in tabular form, instead of being at once embodied in a map, suggests that Ptolemy's object was to enable the student to construct his maps for himself. Nevertheless, the work was from the time of its first publication accompanied by maps, which are regularly referred to in Book viii. How far the maps which are appended to the extant mss. represent the original series is a moot point. It is possible, however, that they have been transmitted by uninterrupted tradition from the time of Ptolemy.

In spite of the merits of Ptolemy's geographical work it cannot be regarded as a complete or satisfactory treatise upon the subject. It was the work of an astronomer rather than a geographer. Not only did its plan exclude all description of the countries with which it dealt, their climate, natural productions, inhabitants and peculiar features, but even its physical geography proper is treated in an irregular and perfunctory manner. While Strabo was fully alive to the importance of the rivers and mountain chains which (in his own phrase) "geographize" a country, Ptolemy deals with this part of his subject in so careless a manner as to be often worse than useless. In Gaul, for instance, the few notices he gives of the rivers that play so important a part in its geography are disfigured by some astounding errors; while he does not notice any of the great tributaries of the Rhine, though mentioning an obscure streamlet, otherwise unknown, because it happened to be the boundary between two Roman provinces.

BIBLIOGRAPHY.—Ptolemy's *Geographia* was printed for the first time in a Latin translation, accompanied with maps, in 1462(?), and numerous other editions followed in the latter part of the 15th and earlier half of the 16th centuries, but the Greek text did not make its appearance till 1533, when it was published at Basle in quarto, edited by Erasmus. All these early editions, however, swarm with textual errors, and are critically worthless. The same may be said of the edition of P. Bertius (Gr. and Lat., Leyden, 1618, typ. Elzevir), which was long the standard library edition. The first attempt at a really critical edition was made by F. G. Wilberg, and C. H. F. Grashof (Essen, 1838–45), but this only covered the first six books of the entire eight. The edition of C. F. A. Nobbe (3 vols., Leipzig, 1843), presents the best Greek text of the whole work, and has a useful index. The best edition, so far as completed, is that published in A. F. Didot's *Bibliotheca graecorum scriptorum* (*Claudii Ptolemaei geographia;* 2 vols., 1883 and 1901), originally edited by Carl Müller and continued by C. T. Fischer, with a Latin translation and a copious commentary, geographical as well as critical. *See* also H. Bradley, "Ptolemy's Geography of the British Isles," in *Archaeologia,* vol. xlviii. (1885); T. G. Rylands, *Geography of Ptolemy Elucidated* (1893); and a Polish study of Ptolemy's Germany and Sarmatia, in the Historical-Philosophical Series (2) of the Cracow University (1902), vol. xvi. (E. H. B.; C. R. B.; T. L. H.)

PTOMAINE POISONING is a popular term used to describe food-poisoning caused by toxic substances of bacterial origin. The term is misleading since the toxic substances are now known to be substances synthetized by the bacteria with or without obvious evidence of decomposition of the food rather than ptomaines, *i.e.,* organic bases, such as putrescine and cadaverine, resulting from bacterial degeneration of proteins. Examples include botulism and staphylococcus food poisoning, a violent but usually nonfatal type of poisoning, generally associated with the eating of éclairs and cream puffs. (*See* FOOD POISONING.)

(F. L. A.)

PUBLIC ADMINISTRATION is the application of a policy of a state through its government. Policy is given general legal formulation by legislative institutions in statute law; but there then remains the defining of that law for specific application. A statute is the product of a law-making agency which is not always in session, whose members are usually selected to represent general attitudes and opinions rather than to possess expert knowledge. After a statute is adopted, rules are needed for its detailed application in the enforcement of both the statute and rules to the situations it was designed to affect. Thus, a statute adopted to facilitate traffic may authorize in general terms the regulation of the movement of motor vehicles, by specifying reasonable speeds on public streets and highways with due regard to density of population, location of schools and hospitals and the existence of intersecting streets, and also will probably provide for some agency in continuous operation, and presumably with knowledge, experienced personnel and material equipment, with power to translate the general objectives into more specific regulations (*e.g.,* as to coming to a full stop at main arteries or obeying light signals) and to enforce the statute and regulations, with penalties for those who violate them.

Thus, public administration is interrelated with public opinion in that it follows upon the decision of the political leaders to undertake or abandon collective activities or to support or accept laxity in the enforcement of laws; with the legislative process in that effective administration may be rendered difficult or impossible by faulty legislation, and also because the experience and knowledge of the administrative agency are of value to the lawmaker, just as its possible corruption or ignorance may mislead or handicap him; and to the judicial process since the action of the administrator may be challenged in the ordinary or in special courts by a citizen, and the administrative agency may be required, under the terms of a particular statute, to apply to the courts for judicial action against those presumed by the agency to be violating the law. While there is a theory that administration and

policy are two separate processes of government, in fact they are constantly merging and interfused. This is because policy-making is inadequate if there is no consideration of the means for making the law effective, and administration of a general objective raises questions of choice, and hence policy, in any specific situation. It is a policeman who arrests a traffic violator, and not a statute, which remains within the covers of a book.

Administration and Policy.—The problems of public administration reflect, therefore, these interrelations with opinion, legislation and adjudication. They also reflect the stage of civilization, the time, place and environment generally of the particular political unit. Thus, at the top of the administrative structure is an official who can speak for, and to, the dominant political power of the society. This need for making the administrative agency subservient to the original intent for which the activity was authorized and the political forces, party or factional or personal, which took the responsibility for the legislation authorizing the program explains why the headship of an administrative agency, at least of national agencies, is generally a politician and nonexpert. He is chosen because he must interpret to the experts what the judgment of those in political power is, and to the politicians and the lay public what the more technical considerations that will affect their political objectives are. The greatest quantity of public administration is in the substantive functions of government such as those of public safety and order, public health, public works, education, the development of natural resources, the facilitation of transportation, the care of the handicapped and the facilitation and regulation of finance, business and industry. Roads and harbours are built. Social insurance payments are made. Forests are guarded from fire or disease. Each field of activity has its accumulated technical knowledge, personnel, forms of organization and procedure, vocational and professional ties, associations and corporate interests, loyalties and issues. For any particular jurisdiction in which a number of these functions are administered, the problem of allocating available revenue to each, of determining priorities and of co-ordinating the application by each agency of policies in which account should be taken of what other agencies are doing is one of the most important responsibilities of the highest administrative authority. At this point in the structure and process of government there is a meeting and mingling of political policy, general management and the conduct of the particular functional departments.

MANAGEMENT

Direction and General Staff.—The heads of the administration in any jurisdiction have a double responsibility of helping to formulate legislation on the one hand, and of directing and co-ordinating the administrative agencies to carry out the authorized policies on the other. This latter task becomes difficult in those stages of civilization in which many functions are undertaken through government since it includes the proper assignment of activity to organization units and the co-ordination of several organization units, each of which has some necessary share in the activity but each of which is also likely to develop its own personality, attitudes and jealousies. Hence, the top administrative policy group, in modern times often called a "cabinet" from the meeting place in the king's quarters (hence his "cabinet council"), and its chairman or chief—prime (*i.e.*, "first") minister, premier or president—need to have the problems presented to them analyzed by persons of integrity, competence and experience. This has come to be called "general staff service" from the influential and famous Prussian general staff. Elements of this important step in the administrative process are to be found wherever government has been effectively used. Thus, planning, inherent in the process of formulating policy, becomes essential also in its wise application, whether in the conduct of war, the prevention of epidemics, the facilitation of transportation or the relief of destitution.

Auxiliary Services.—The responsible political chiefs of administration have been found by widespread experience to need other aids to ensure economical and efficient application of policy. These are agents for obtaining and facilitating the best use of personnel, physical materials and equipment, architectural and engineering services and finances. Since such tools are aids both to general direction and to the operating officials (who are on the front lines in the field, building highways, waging war or constructing irrigation projects), they are frequently called the auxiliary services.

Characteristic auxiliary services are those which recruit and examine applicants for government employment, budget offices which prepare estimates and supervise expenditures authorized by the appropriating and taxing authority, purchasing agencies which prepare specifications describing needed materials, purchase them and inspect, store and deliver them and printing, architectural and construction agencies. They are also frequently known as the "housekeeping services" since they perform them for the various operating agencies. Their justification lies in their ability to perform for all the operating departments these specialized tasks more effectively and economically, and to maintain general standards of salaries, prices and procedures.

There is inevitably some clash between such auxiliary agencies with their responsibility to the administrative chiefs for over-all policy, and the particular operating agency with its enthusiasm for and special knowledge of its own field, and hence resentful of controls that are often called "red tape" (used historically to tie up documents for filing). To the operating official, there looms the threat of what is termed in the British civil service the "treasury mind"; its cousin is found in all large organizations in all times and places. To the official zealous in pressing forward his project, the scrutiny of some part of it by another agency which has no immediate apparent responsibility for the success or failure of the project or its initiator, is irksome. The auxiliary or general staff official, however, is equally impressed with the necessity of relating the single project to the other activities of the government, of bringing the enthusiasm of the official within the bounds and standards which the accumulated experience indicates as effective norms and economical expenditures.

Personnel and budget policies illustrate the fact that auxiliary and general staff services (which intermingle through day-to-day activities) are more than narrow technical matters. They are of central importance in the operation of any political system.

Personnel.—Long and varied experience in all parts of the world demonstrated the necessity, for effective administration, of a reservoir of accumulated knowledge of the administration of a function—a knowledge that can be obtained only from persons of ability and integrity who have been given an opportunity for a career, within the appropriate general political, legislative and judicial controls, in administration. That is not the only reason why spoils systems, wherever they exist, have been disastrous (except in situations in which they may have served as alternatives to more costly revolutions). Their primary evil is that they undermine any use of parties and legislatures as reasonably accurate instruments of recording political sentiment and ideas, since they replace the relationship of agency for the public by agency for the chief spoilsman and turn responsible public affairs into irresponsible private rackets. Their administrative evil is that they prevent the accumulation of knowledge that only experience can give. No person of ability and integrity would be willing under spoils conditions to seek a satisfying career, and inevitably the agency sinks in effectiveness and in public confidence and any public objective is lost. Even in revolutionary conditions a new government is generally reluctantly forced to rely upon such officials of experience and knowledge as it can find for carrying on those services necessary for the safety and welfare of populations—especially in a society partly urban. The knowledge referred to here is not only the knowledge of a substantive problem, such as preventive medicine, for example, or highway construction, but the more subtle knowledge for which long experience inside the working of human institutions is required. This is the knowledge of who knows what, of how to use procedures and codes to hasten or delay business, of how to avoid arousing group and individual jealousies, of "moving through the correct channels" and of winning the agreed consent of all those necessary to a policy. The term "bureaucracy" is sometimes given, often in

disparagement, to governments in which the "permanent" or "career" officials exercise or condition power. Such a dependence on officials, however, is inevitable and necessary in governments exercising many and interrelated functions.

The selection and training of civil servants has therefore been an important problem of government since early times. The system of widespread recruitment on the basis of examinations in the classics was a feature of the government of China for hundreds of years. The training of officials for the administrative posts in the mediaeval papacy and empire included courses in such universities as Bologna and Naples. The palace school of the Ottoman empire was the nursery of the civil, military and naval officer classes. The ruling families of the German principalities founded universities in which their civil servants (often jealously opposed by the feudal nobility) were educated. In both 19th-century Germany and France, the rise of a larger and more varied civil service was accompanied by the development of opportunities for secondary, university and specialized education that reflected also the enlargement of the middle class. The École Libre des Sciences Politiques in Paris and the development of careers in municipal administration in Germany illustrate these tendencies. The Trevelyan-Northcote report on the civil service in Great Britain in 1853 was influenced by such educators as Benjamin Jowett of Balliol and John Stuart Mill. The expansion in the functions of government in the United States prior to World War I created an interest in the education of administrators which revived strongly with another expansion in the decade 1930–40.

In general, educational qualifications for administration reflect the general social conditions of the time and place and the classification of the positions to be filled. A more fluid and democratic society opens its opportunities for secondary and higher education widely and this tends to prevent the formation of a special official caste sheltered by inherited privileges. The "single-party" system of government tends to create a new form of special privilege dependent upon party allegiance. But in all systems, a job analysis will reveal the need for continuous education after entrance if there is to be an adequate supply of recruits for the higher directive and technical positions. Hence, the questions of "in-service" training, of educational leave and the recruitment through promotion and from outside the service are as much the subject of discussion and experiment as the older question of "pre-entry" training. At this point the interest of students of public administration turns to developments in education and psychology generally as well as to experience in industry and commerce.

The Budget.—The outstanding instrument whereby the total program of a government for a given period of time is set forth by organization unit, types of expenditure and in other detail is the budget. In most states (notably Great Britain, which contributed most to its development as an important tool of government) the budget originates in the executive departments in the form of estimates of proposed expenditures and the revenues to cover them, is submitted to the legislature for investigation, amendment and legal authorization and is then administered by the budget and other finance agencies. The budget process ends with an audit to determine whether expenditures have been properly based upon the legal authorization—an audit frequently made by an agency of the legislature, or otherwise independent of the administrative chiefs. The budget as authorized by the lawmaking process is thus inevitably the total plan for all the activities of the government for the next fiscal period (generally a year), including the provision for personnel and materials. The long evolution of representative government has centred largely in the development of a good budget system, including "the control of the purse strings" by the elected representatives of the people; that is, the submission to them by the executive (usually in name, at least, by the king) of the proposals for expenditure, taxation and loans and the scrutiny and amendment, acceptance or rejection of these by the representatives, sometimes with the aim and result of forcing the king's administrative chiefs and policy advisers from office. The cabinet system, whereby the chief executive officials must possess the support of the majority of the legislature, thus had its origins; while the importance of legislative control over expenditure, and of the appropriation process, is illustrated also by provisions concerning them in the constitution of the United States and in the development of government everywhere.

The Planning Process.—The function of cabinets and chief executives as well as the heads of large departments in the preparation of policy for submission to the legislative authority became complex and difficult with the widening and interdependence of the functions of government. Thus, in a metropolitan area the design of streets and highways, water supply, parks and schools is dependent upon population, industrial, commercial and technological trends as well as changes in the ideas held by citizens as to standards of living. As a result, the usual budget processes are sometimes supplemented by special staff agencies for investigation and analysis, or by regular and continuing agencies to which the term planning is applied. Planning as an inherent need in the structure and process of administration was diagnosed and recommended by Frederick W. Taylor in his pioneer work in scientific management, although, as noted above, it has been called into existence in some form, as in military affairs, wherever thought has been applied to the problem of the improved preparation of programs.

The "mercantilist" and "cameralist" policies of the early modern state caused the rise of career civil services and methods of training for them. A similar increase in collective services, whether in the U.S.S.R. with its elaborate central, regional and local programs of state action, or a cut-over region of sparse population requiring long-time land policies in the United States, or a great urban agglomeration such as London, Bombay or New York, made desirable and necessary the establishing of planning agencies. Their function is to gather and analyze data concerning the problems of the political organisms they serve and to submit reports on their studies to the political chiefs, the legislatures and the electorate. Sometimes these agencies are also given some operating responsibility and power. Thus, they may be given the enforcement of controls over land use or authority to determine priorities in the allocation of resources to projects. Whether such planning agencies should be exclusively research and advisory in their functions or should have in addition operating functions and powers is a subject of controversy among students of administration. It is agreed, however, that there should be close and sympathetic working relations and an interchange of personnel between them and the budget and other general staff and auxiliary services and the substantive departments.

It may again be stressed that the budget should reflect, as the most comprehensive record of operations proposed for the next fiscal period, the result of the planning process as registered in the working and financial program which the chief executive and his associates are responsibly proposing to the highest lawmaking body of the jurisdiction. Thus, the estimates which are proposed will presumably be supported and justified by the analyzed data. Viewed in this light the planning process in administration is not, as sometimes argued, in opposition to legislative authority but essential to it. A legislature, in fact, may rightly demand that such preliminary collection and analysis of data be undertaken by the executive to ensure a better preparation of proposals placed before it. The use of the fiscal policy of a government to affect general economic conditions by its influence on investment and employment increases the need for careful planning of the estimates.

Internal Operation.—The directive, general staff and auxiliary agencies exist to serve the substantive or operating departments, and it is through them that the functions of a political system are applied. In these basic substantive departments there is a division of labour reflected in an organization of units whose heads are related in some line of responsibility and power. The system may be recorded on organization charts and in standard specifications for every position whereby the duties, qualifications, rates of payment and official titles are set forth. The relation of the different levels, the flow of correspondence, reports, memoranda and dockets of official business and the arrangements for conference between units (bureaus, divisions, sections, branches, regional offices, etc.) may also be guided by written and official codes of procedure. The procedure to be followed in relations

with the public generally by correspondence, interview, investigation or inspection, or hearings of an informal or formal type, tends to become standardized and codified. This results in a standardizing of practice that leads to charges of red tape, bureaucracy and the stultifying of initiative. A failure to regularize procedures, however, leads to criticisms of unfairness, capriciousness and abuse of power and an invitation to corruption. The interests affected by the function administered are generally organized in economic or professional associations. Sometimes representatives of these interests are brought into official participation in the administrative process through committees advisory to the agency or committees given some power of administering the program for which the agency is ultimately responsible. At its extreme, such a system might be termed "the corporative state" so much discussed in political theory in recent decades, although never actually embodied in any completeness.

Among the groups involved in the administrative process with some special interest or emphasis of their own are various organizations of the civil servants. Since the number of civil servants in a modern state may be great, collective action in the effort to affect rates of pay and conditions of employment generally developed despite opposition. In some systems, a regular procedure was established (as notably in the "Whitley councils" in the British civil service) for consultation between the directive and personnel officials and the representatives of the civil service organizations.

Thus, the maintenance of some balance in modern administration between the interests and attitudes of legislatures, parties, executive leaders, auxiliary service agencies, interest groups affected and the civil servants themselves is no easy task. The systems appear sprawling, cumbersome and unwieldy and too far removed from the situation from which the call for governmental action originated. Internal operation is complicated further by the relating of decisions taken at the centre to the varied conditions in the field.

The problem of clarifying and explaining the complex task of a department led to increased interest in methods of reporting. Experiments in the use not only of printed and illustrated reports but of the motion picture, the radio, television and direct face-to-face discussion and conference were undertaken. Legislatures are inclined to oppose these on grounds that they may become an alternative to the party system as a means of consulting public opinion and may stimulate public pressure for legislation favourable to the agency employing them.

The problems of internal operation in public administration are in many ways akin to or identical with those in other social institutions, including industry and commerce. The comparative study of institutions, including the relation of individuals in the smaller face-to-face groups, brought scholars and administrators together from many fields to share experience and plan and conduct research. Psychologists, personnel managers, anthropologists, sociologists and many other workers find a common field in what is given various names, such as social relations, human relations or the study of the human group. A special challenge was raised by growth of international programs and agencies in which the problems of a substantive field such as health are complicated by the need for co-operation by peoples of different cultures. The training of administrative personnel for such programs began to reflect the new emphasis on human relations, and also the area or regional studies whose origins may be found long ago in the policies of missionary societies and colonial offices, as well as in World Wars I and II.

DECENTRALIZATION AND DEVOLUTION

Whenever the size in area and population of the jurisdiction served by an administrative system is large, the adjustment of general policies and standards to varied local or otherwise specialized circumstances constitutes a major problem. If too great freedom is given to officials to adjust standards to the particular instance, effective general legislation becomes difficult or impossible, and programs may get distorted and special interests may injure the general good. Partisan, sectional, factional or other special favours and corruption may follow. And yet the particular knowledge of the persons whose life work is in an industry, or is concerned with a commodity or profession, or with a particular region or locality, should be employed if a policy is to be wisely administered. The states of the world have in all times, from ancient China or the Roman empire to the present, attempted to meet this problem either by leaving or giving some measure of local self-government to local areas, or by creating regional units in their central administrative agencies to which some discretionary powers for making decisions within the general rule for problems arising within the area are given.

A variant of the same principle is the assigning of powers for the administration of a statute or general policy of the state to a professional, commercial or industrial association or representatives of such interests. Thus, we may find, as in the Germany of the Weimar republic, not only *Länder* or member states within the Reich but local units within them and also an economic council. Similarly, in Great Britain, which we ordinarily think of as a unitary or relatively centralized state, there are county councils, rural district councils, boroughs and also boards possessing statutory powers in the steel industry or dealing with a commodity such as milk or bacon. In the United States the same problem of relating general policies to the particular situation confronted the constitution makers in 1787, resulting in a federal system, but persists to the present and indeed becomes more complicated as new units such as soil-conservation districts or local housing authorities are created with direct relations with national agencies.

The grant or taking of power by economic groups was advocated perhaps more strongly at about the time of World War I, and a political theory designated "pluralism" or "functionalism" had a period of success. It was indeed supposed to have been reflected in the doctrines of the Russian bolshevists and the fascists in Italy, as well as in the creation of economic councils in France and Germany. Probably local circumstances and situations in the latter two states, just as in the establishment of the National Recovery administration in the United States, with its industrial codes, had a much greater importance, while the Russian and Italian systems quickly revealed themselves as highly centralized single-party controlled governments struggling to secure and retain power and therefore in no position to yield power to regional or commodity or other groups except as forced by circumstances to do so.

The point is, however, that circumstances (*i.e.*, the increasingly complex nature of the activities that go to make up modern economy, the strong pull of neighbourhood and region and all kinds of provincialisms and the necessity to achieve political as well as administrative success for policies) do press for the adjustment of general policies to particular situations and do require the consultation at least by administrators with persons and organizations affected by those policies. It is characteristic of modern legislation affecting industry in some states, for example, that councils on which employers and employees, or members of a profession, are represented, participate in drafting rules and regulations under the act.

Relations of a national or central authority with provincial and local governments are made more complicated by the rise of metropolitan cities that spread over several separate political jurisdictions, the inequality of tax resources of local units, the pressure for national minimum standards of public services and the interdependence of economies. A partial answer to these conditions is found in the grants distributed from national funds to local units on condition of meeting certain required standards, with resulting inspection from the centre, generally entitled "grants-in-aid," and in the employment of officials of one level of government for enforcing the laws of another. The relation of levels of government remains, however, as one of the most difficult and perplexing problems of public administration.

CONTROLS AND STANDARDS

Obviously public administration is certain to be subjected to criticism in part because the objectives sought are disliked or the methods employed are viewed as unjust or inefficient or corrupt.

Over the centuries various devices for its control have evolved. These efforts are designed to confine it to the political objectives for which a particular administration is established, which we may call political control; or to ensure most economical and efficient methods, which we may call executive control; or to ensure observance of the accepted rules of fair conduct as understood by the particular society to apply to the relation of officials with the public, which we may call judicial control; but they necessarily intermingle, and broadly speaking, with the rise of representative government, a somewhat stronger emphasis inevitably was placed in most states upon political control. This is exercised through making the chiefs of administration politically responsible either to the legislature or to the electorate by some form of popular election.

Probably the most famous example of the evolution of political control is the wresting of power from the king and its allocation to a committee of party leaders representing a majority of the house of commons in Great Britain. This system, called "cabinet" or "parliamentary" government, was a model for most states to follow (with varying success). The U.S. "presidential" or "congressional" system makes the chief executive, except in city manager-council government cities, responsible to the electorate. Both systems, however, operate through parties; and at times the British prime minister takes on presidential attributes, and the U.S. president similarly at times plays a role in relation to congress somewhat akin to that of the prime minister in relation to the house of commons.

The more detailed devices of party and legislative control vary greatly; but most legislatures employ committee investigations of administration, scrutiny of budget estimates, the control over expenditure and audit and frequently the questioning of executive chiefs on the floor as well as in committee. These matters are usually topics of discussion at meetings of the Interparliamentary union, the conference of delegates from the legislative bodies of the states of the world.

Executive control is exercised through general staff and auxiliary services as described, and in modern complicated and large structures necessarily employs the techniques of the formulating of general standards, as of personnel, enforced by special auxiliary agencies. Probably the most important control is wielded through the analysis of budget estimates by the central financial control agency of the chief executive and his colleagues.

The struggle of legislatures first for independence of the monarchy and later for supremacy is paralleled historically in many states by a similar effort of the courts for independence; and in some states, notably the United States, the system of written constitutions and a federal distribution of powers has been the basis upon which has been constructed the exercise of judicial review not only of the acts of officials but of the constitutionality of the statutes whereby the officials may have justified their actions.

In many states, notably those influenced strongly by the traditions and precedents of the Roman law, a series of special courts evolved in which controversies involving official acts of civil servants are adjudicated, and the resulting case law, as in France, constitutes an important part of the public law. Administrative law is thus everywhere a branch of public and constitutional law that grows in importance as the extent and complexity of the functions of government increase. Questions of the competence of the authority, the adequacy and justice of the procedure, the extent of the grant of discretionary power, the adequacy of the evidence in support of the administrator's action and the finality of the administrative decision are typical issues. The study of comparative government, and in particular of comparative jurisprudence and administration, is resulting in a greater familiarity on the part of scholars and of some practitioners with the similarities between different systems and a tendency to discover devices in one system that may usefully be adopted in another. Many precedents and theories framed long ago during the struggles with monarchy are being reappraised in the light of the contemporary complexities of administration.

While legislative, executive and judicial controls are of basic importance, it should not be forgotten that in the daily life of the administrator his own knowledge, character and sense of personal and professional responsibility, constituting a series of inner standards and checks, are probably more immediately and intimately influential. Hence, the rise of professional organizations, of research, of in-service training, of journals devoted to administrative questions have increasing importance and constitute a professional control which has operated, indeed, at times in all societies.

The increasing association of citizens through advisory committees with administration, and their sharing in fact with the exercise of some of the discretionary power in rule making, and the necessity for many types of administration of winning the understanding if not the active support of the citizen, characteristic increasingly of many types of administration, is another less recognized but important control over public administration. Many statutes and programs involve matters touching intimately the lives of great numbers of citizens; it is impossible to enforce them (as, for example, systems of social insurance or of highway safety or disease prevention) without extensive efforts to acquaint citizens concerning them. But in that process, the official is often educated himself as to attitudes, habits, capacities and problems of those whom he is supposed to serve; he is probably less concerned with possible legislative, judicial or even higher executive action regarding his work than with the people and problems immediately at hand. In this sense, we may consider administration as moving into a stage in which a two-way educative process is discernible; and while it may seem a far cry from the edicts of ancient rulers, one suspects that even they, too, had sometimes to consider how far they could go with subjects unaware of or opposed to their aims and measures.

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PUBLICAN: *see* LICENSED VICTUALLER.

PUBLICANI, the name given in ancient Rome to a body of men who either hired state property or monopolies to farm for their own profit or bought for a fixed sum the right to farm the taxes due to the treasury from the public land in Italy, or the land held by Roman subjects in the provinces. In early times the senate entrusted to officials the control of the sale of salt (Livy iii, 9), and it was a development from this that the state, instead of appointing officials to manage its monopolies, let out those monopolies to individuals. A regular system was established by which the censors who held office every fifth year placed the sources of public revenue in the hands of individuals or companies, who on payment of a fixed sum into the treasury, or on giving adequate security for such payment, received the right to make what profit they could out of the revenues during the five years elapsing before the next censorship. The assignment was made to the highest bidder at a public auction. The same system was applied to the public works, the *publicanus* in this case being paid a certain sum, in return for which he took entire charge of a certain department of the public works. That this system was well established at the time of the Second Punic War is assumed in Livy's account of the various offers made by the wealthier class of citizens to relieve the exhausted treasury after the battle of Cannae (216 B.C.). On the one hand we have companies offering for branches of the revenue a price which was calculated rather to meet the needs of the state than to ensure any profit for themselves (Livy xxiii, 49). On the other hand individuals are represented as undertaking the management of public works on the understanding that they would expect no payment until the conclusion of the war (*ibid.* xxiv, 18).

Since wealth was a necessary qualification for the post, and wealth at Rome became more and more confined to the commercial class, the *publicani* became identical with the class of capitalists and traders. This was distinct at Rome from the senatorial class, which was excluded from it by definite enactment (*see* SENATE), and, except in face of common danger, was often hostile to it. It was in their capacity of *publicani* in the wealthiest provinces that the capitalist or equestrian *iudices* (*see* EQUITES) became a menace to the provincial governors who represented the senatorial power. When the demands of the equestrian party determined the policy of the state we can trace the interests of the *publicani* as

the motive of its action. Thus the fate of the Roman business men in Cirta led to the Jugurthine War in 112 B.C.; the disorganization of Asiatic commerce by the pirates led the *equites* to support the proposal to confer extraordinary powers on Pompey in 67 B.C.; and the quarrel over the contracts for the taxes of Asia in 60 B.C. led to the downfall of the senatorial party.

Under the empire the *publicani* were subject to close supervision. The name appears as "publicans" in the New Testament.

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PUBLIC AUTHORITIES PROTECTION ACT. This British statute was enacted in 1893 and represents, to some extent, a consolidation of previous statutes limiting the time within which actions may be brought against "public authorities," including thereunder local government authorities, justices of the peace and, it has recently been held, Crown servants also. It goes, however, far beyond the particular statutes which it proposed to "generalize and amend" in that it imposes new and most invidious restrictions on any plaintiff who seeks to sue a "public authority" for a wrongful act. These are dealt with in the article *Petition of Right*. The statute which requires all such actions to be brought within six months does not, however, extend to actions for breach of contract, as distinct from tort by public authorities. Such actions are subject to the ordinary period of limitation prevailing in actions between subject and subject, *i.e.*, private persons, namely six years. The Act has been described as "intended to protect public bodies from expense when they are unsuccessfully sued in respect of acts done or omitted to be done in the exercise of statutory powers or duties" (Lindley M.R. in *Fielding* v. *Morley Corporation*, 1899, 1 Ch. at. p. 4). The description is inadequate, however. As is shown elsewhere (*see* PETITION OF RIGHT), the statute operates in practice to deter persons wronged from suing at all, and penalizes them on technical grounds with special costs for suing even where they would have had an undoubted cause of action had the action been brought within the prescribed period of time. The "protection" afforded by the statute extends not only to any wrongful acts done "in pursuance or execution or intended execution" of a statutory duty but also in pursuance of any "public" duty or authority. All these terms, as also the question whether the act complained of arises out of a constructual relation or not, whether it occurred in the execution of a "duty" or merely in the exercise of a "power," as also the relation between a "continuing" act and "continuous" damage, have been the subject of endless litigation. The "protection," in other words the privilege, conferred by the statute extends not only to a public authority but also to all officers and servants acting under its orders. (J. H. Mo.)

PUBLIC HEALTH. The term as used in Great Britain connotes in the broad sense principles and measures which aim at promoting and safeguarding the health of the community in contra-distinction to those which are concerned in the main with the treatment of declared disease in the individual. For public health in the United States *see* Section II.

I. GREAT BRITAIN

The original conception of public health requirements in Great Britain was fairly simple—the improvement of drainage and sewerage, the provision of adequate and satisfactory water supplies, scavenging, the isolation of cases of infectious disease. Then came the supervision of housing conditions, the clearance of slum areas, the provision of open spaces and the efforts to provide a cleaner atmosphere. More attention is now paid to food supply as in provision for the analysis of food-stuffs, in the supervision of the production and distribution of milk, the elimination of tuberculosis from dairy cattle, the control of slaughtering and inspection of meat, the inspection of premises used for the preparation or storage of food. Action regarding infectious disease has passed beyond isolation of the individual attacked and disinfection of premises to the supervision of contacts and careful investigation of possible sources of infection, and the system of port sanitary control has been placed on a scientific basis and all these matters, as they develop, are referred to and accepted as public health measures. The present century has witnessed public health development in other directions. There has been the growth of activities which aim at the conservation of young life, the early treatment of physical defects, and the inculcation of healthy nurture with the object of ensuring healthy citizens. These have found expression in the Maternity and Infant Welfare and the School Medical services. Public provision has been made for the treatment of certain diseases which, from their economic or social importance, can best be countered by organization on a communal rather than an individual basis, such as tuberculosis, venereal disease, and the crippling effects of infantile paralysis. (*See* also MATERNAL AND CHILD HEALTH.)

The statutory authority for this work is furnished by various Acts of Parliament. The charter of public health administration is the Public Health Act of 1875 which has been amended by the Acts of 1890, 1904, 1907 and 1925. Other important health enactments are the Public Health (Water) Act, 1878, the Infectious Disease (Notification) Act, 1889, the Infectious Disease (Prevention) Act, 1890, the Open Spaces Act, 1906, the Milk and Dairies (Consolidation) Act, 1915, the Public Health (Smoke Abatement) Act, 1926, and various provisions in the Housing Acts. The later developments of public health have their basis among other enactments, in the Education (Administrative Provisions) Act, 1907, the Education Act 1921, the National Insurance Act 1911, the Venereal Disease Act, 1917, the Maternity and Child Welfare Act, 1918, the Public Health (Tuberculosis) Act, 1921, and in various regulations framed by the Ministry of Health.

The foregoing refers to legislation for England and Wales. The Scottish and Irish Acts, though similar in objects and results are usually different in form and adjusted to the national conditions of those countries.

Central Authorities.—The authorities concerned in the administration of public health are central and local. In England and Wales the chief central authority is the Ministry of Health. This department had its origin in certain movements which can be traced back to the beginning of the 19th century. Interest of the State in the physical health of its citizens is a comparatively modern development, and may be traced broadly to four chief causes; first, to reaction against the anarchy of the Industrial Revolution; secondly, to the gradual development in the latter part of the 18th century of a humanitarian spirit, as evidenced by the work of John Howard in the reform of prison life, the movement for the abolition of the slave trade, and the efforts of Sir Samuel Romilly and others to infuse a spirit of humanity and common-sense into our penal laws; thirdly, and probably the most important, to the appearance for the first time of Asiatic cholera in Europe and the threat of its invasion of England; and fourthly, to the establishment of the central Poor Law Commission in 1834.

The first Secretary of this Commission was Mr. Edwin Chadwick, one of the great public health pioneers of the 19th century. He forced upon public notice the importance of sickness and ill-health in the production of poverty, and insisted that the prevention of disease was one of the first duties of the State. Largely as a result of his efforts the first Central Health Department, the General Board of Health, was established, prematurely as it afterwards proved, in 1848. Ten years later this board was dissolved and its duties distributed amongst other offices, but in 1871 they were gathered together again and, with those of the Poor Law Commission, transferred by Act of Parliament to a newly-created department, the Local Government Board. This board remained for nearly 50 years the principal central authority for public health, until in 1919 its functions, together with other health functions, such as health insurance and the medical inspection of school children, which had come to be entrusted to separate central authorities, were transferred to the Ministry of Health. The Ministry of Health Act, 1919, by which the Ministry of Health was established, had as its purpose the prevention of overlapping and competition between certain of the central departments by bringing the health services which they administered into a single department under a Minister of Health.

Among other central authorities concerned with questions of

public health are the Medical Research Council, a Committee of the Privy Council, which co-ordinates research on medical subjects, the Board of Trade, which is responsible for the health services of the mercantile marine under the Merchant Shipping Acts, the Ministry of Agriculture and Fisheries which has certain powers and duties relating to the production of food and milk, the Ministry of Pensions which has the care of disabled officers and men after they have left the naval, military and air services, and the Home Office, in respect of industrial hygiene control under the Dangerous Drugs Acts, etc.

Local Authorities.—The local authorities charged with the administration of public health services are the Rural and Urban District Councils, the latter including the Metropolitan, Municipal and County Borough Councils. These bodies are assisted in the discharge of their duties by a technical staff consisting of the Medical Officer of Health and the chief Sanitary Inspector, whom they are required by law to appoint, together with what additional assistance may be necessary. In the smaller districts the duties are sometimes performed by a part-time Medical Officer of Health who is also engaged in general practice, and by a whole-time Sanitary Inspector. In the larger cities the staff of the Public Health Department may number several hundred persons. The Poor Law Guardians have important health functions in relation to the medical care of the poor, and are also responsible for the administration of the Vaccination Acts.

County Councils other than County Borough Councils are not health authorities within the meaning of the Public Health Acts, but they have been given important duties under the Isolation Hospitals Act, under the Tuberculosis Regulations, the Maternity and Child Welfare Act, the Venereal Diseases Regulations, and also in regard to school medical inspection, and the tendency of present-day policy is gradually to shift much of the responsibility for these and similar personal health services from the smaller urban and rural authorities to the County Councils, and thus, by increasing the strength and efficiency of local administration, to diminish the need for detailed control and interference by the central departments.

Public Health Personnel.—The first local authority to appoint a salaried Medical Officer of Health in Great Britain was Liverpool in 1847. In 1848 the Corporation of the City of London appointed Dr. (afterwards Sir) John Simon to be its Medical Officer of Health. The larger cities followed and in 1872 the practice had become so general that the Public Health Act of that year made it obligatory on every urban sanitary authority to appoint a Medical Officer of Health. The Public Health Act of 1875 extended this obligation to all local authorities, both urban and rural.

At first no special qualification was prescribed, but in the Local Government Act of 1888 a clause was inserted requiring that after the 1st of January 1892 every Medical Officer of Health of a County or of a district containing a population of 50,000 or more inhabitants should be not only legally qualified in medicine, but also be the registered holder of a Diploma in Sanitary Science, Public Health or State Medicine. By an Order issued by the Ministry of Health in 1922, this requirement was extended to all Medical Officers of Health, so that to-day no candidate is eligible for such an appointment unless he holds a Diploma in Public Health, except by special dispensation of the Minister of Health. The Sanitary Officers Order of 1922 also laid it down that every Sanitary Inspector appointed by a local authority should possess a recognized qualification in Sanitary Science.

In the brief survey which follows reference is made to some of the more important matters dealt with by local public health authorities.

Vital Statistics.—Vital statistics furnish a measure of the influence of various conditions and occupations on the health of the population and a means by which the value and efficacy of the ameliorative and preventive action taken by local health authorities can be assessed. Every Medical Officer of Health is required to furnish each week to the Registrar General a return of all cases of infectious disease notified in his district. These returns, together with those supplied by the local registrars of births and deaths, are the material on which the Registrar General bases his Weekly Report, and also his Quarterly and Annual Statistical Surveys. This information is supplemented by Annual and special reports of Medical Officers of Health and from the results of investigations by Medical Officers of the Ministry of Health and by other departments and voluntary bodies interested in the physical, industrial and social welfare of the people.

Environmental Hygiene.—Long before the discovery of bacteria and their relation to disease, sanitarians recognized the close association of dirt and pestilence and the importance of cleanliness in the prevention of infection. It is difficult to believe that elementary health services such as the provision of a public water supply, drainage, sewerage and sewage disposal, the regular removal of house refuse and the cleansing of streets, which are to-day accepted as indispensable to civilized life, were practically unknown through the greater part of England and Wales less than a century ago. These services are now regularly undertaken by all local sanitary authorities. Control is exercised over building to ensure freedom from dampness, adequate lighting, ventilation, drainage, closet accommodation in houses intended for human habitation. Many of the larger towns have long since reached out beyond these elementary objectives, undertaking other services which have, directly or indirectly, a beneficial effect on the welfare of the community—the provision of cheap transport which has helped to overcome the housing difficulty, the provision of gas and electricity which has lessened labour in the homes and contributed to a cleaner and more wholesome atmosphere, the provision of parks and pleasure grounds where the people may recruit from their labour and the children play in safety.

Infectious Disease.—Local health authorities have been entrusted with important duties in regard to the prevention and control of infectious disease and have developed elaborate machinery for this purpose. The Infectious Diseases Notification Acts of 1889 and 1899 made certain of the commoner infectious diseases notifiable to the Medical Officer of Health and gave local authorities power to add to their number where it seemed necessary and expedient to do so. Since then other diseases have appeared in epidemic form, such as cerebrospinal fever, anterior poliomyelitis (infantile paralysis), encephalitis lethargica (sleepy sickness), and the central department, acting under authority of the Public Health Act 1875, has made these diseases notifiable by regulation and prescribed the measures which should be taken for their prevention and control.

The measures adopted by a local authority to control the spread of an epidemic disease are briefly,—isolation of the patient, either in the home or, where this is not practicable, in hospital, search for the source of infection; observation of the contacts; disinfection; and, where an efficacious vaccine is available, vaccination.

Under the authority either of the Public Health Act 1875 or of the Isolation Hospitals Act 1893, most local authorities have provided hospital accommodation for cases of infectious disease occurring in their districts.

Diphtheria, Tuberculosis, etc.—It is obvious that infectious diseases which are indirectly transmitted through the agency of some medium such as water, milk, food, flies, etc. are more easily prevented than those which are spread directly from person to person, and the measures that are applicable to the one do not always prove successful in the case of the other. For this reason typhoid, cholera, and other intestinal infections which formerly exacted such a heavy toll of life, no longer cause health authorities serious anxiety. In the same category one may place malaria, typhus and other insect-borne diseases. The diseases which are conveyed by personal infection, such as scarlet fever, diphtheria and the various epidemic nervous diseases, are much more difficult to control. The infection of many of these maladies is very widely spread throughout the community and many persons contract the disease in what may be called a sub-clinical form without being conscious of it. The occasional clinical cases are often merely the apex of a considerable pyramid of infection, the greater part of which is submerged and unrecognized. One of the great problems of preventive medicine is to elicit the factors which

determine these periodic clinical or epidemic manifestations of an infectious disease. Various theories have been propounded, but none of them is entirely satisfactory. Other diseases, such as tuberculosis, have a dual character, *i.e.*, they may be transmitted directly from person to person or may be conveyed through the medium of some food such as milk or infected meat. Tuberculosis is a disease of great economic importance because the chief burden of mortality falls on the middle or productive years of life. It is for this reason that special measures have been taken to combat it in the form of notification, dispensaries, sanatoria and the other machinery established under the Tuberculosis Regulations. Somewhat similar measures, suitably modified, have been devised for the prevention and treatment of venereal diseases.

Food Inspection.—The most important measures dealing with food inspection are the various Sale of Food and Drugs Acts 1875–1907, the Public Health (Regulations as to Food) Act 1907 and the Milk and Dairies (Consolidation) Act 1915. Under these powers regulations have been made by the Central Authority dealing with such subjects as milk and cream, meat, shellfish, imported food, preservatives and the prevention of tuberculosis. To a country which imports a large proportion of its meat from abroad it is very important to have some means of supervising production at the source. Agreements have been entered into with the chief producing countries by which these countries undertake to inspect and stamp all meat intended for export to England. This reduces the inspection necessary on arrival. A certain amount of inspection is carried on both at the ports and at the chief distribution centres in order to ensure that the producing country fulfils its undertaking. The results of this method of control have been extremely satisfactory and every opportunity is taken to extend the system.

The local sanitary authority exercises supervision over the quality of the food distributed in its district and the conditions under which it is stored and sold to the public. For this purpose officers are appointed for the inspection of slaughterhouses and dairies, and samples of food are regularly submitted for analysis.

School Medical Service.—The introduction of compulsory education made it apparent that many children were unable, through ill-health, to benefit from the education facilities provided. This led to the establishment of the medical inspection of school children in 1907 and the gradual evolution of the present School Medical Service. The most important statute dealing with this subject is the Education Act of 1921 which re-enacts and amplifies previous powers and imposes on local education authorities the duty of making adequate and suitable arrangements for the medical inspection and treatment of children attending public elementary schools and also the medical inspection of scholars attending secondary schools. Education authorities are also required to make special provision for blind, deaf, defective or epileptic children.

This systematic inspection has revealed a vast amount of unsuspected disease and minor defects which, if left uncorrected, lead in time to serious crippling. It is estimated that out of a total school population of some 7 millions, over a million children require medical treatment, apart from uncleanliness and dental diseases. The seeds of much of this ill-health are sown before the children enter school, a fact which emphasizes the importance of the pre-school welfare work which has already been referred to. On the other hand, the full fruition of school medical inspection can only be assured by continuation of the supervision during the critical transition years of early industrial life. Here the advantages secured by the National Health Insurance Acts of 1911–1924 are becoming apparent. With certain exceptions these provided for compulsory insurance against sickness of all employed persons between the ages of 16 and 70. (For further industrial welfare measures *see* INDUSTRIAL WELFARE AND MEDICINE and LABOUR LAW.)

Port Sanitary Administration.—Port sanitary authorities are constituted by order of the Ministry of Health. They carry out duties imposed by the regulations relating to cholera, plague and yellow fever and other "quarantine" work according to the system of International Sanitary Conventions to which this country is party; the Aliens Order 1920, the Port Sanitary Authorities (Infectious Diseases) Regulations 1920, and the Public Health (Imported Food) Regulations 1925. The sanitary staff of a port sanitary authority consists of the Port Medical Officer of Health and such assistants as the volume of work demands. In recognition of the national importance of this work, half the approved expenditure of a port sanitary authority is defrayed out of Central Governments funds.

International Health.—Many public health problems are international in character and there is evident need for some organization which will enable the nations to pool their experience and, where necessary, to co-operate in the application of such measures as are practicable for the prevention and control of disease. The first attempt to secure international uniformity in matters of quarantine was made in Paris in 1851 when a Convention embodying the precautions against infectious diseases which were then regarded as appropriate was signed by the participating countries. Modifications have been introduced into this Convention from time to time and in the Rome Agreement of 1907 an office or bureau called the International Office of Public Health was established in Paris to consider how best the convention could be amended and kept abreast with medical science. England, by reason of its vast international traffic, has been very directly interested in these conventions and has long been at pains to introduce a spirit of reasonableness into their requirements. The last convention, which was signed in Paris in 1926 by the representatives of 70 different nations, embodies most of the views that have long been held and practised in this country. This convention aims at securing what is necessary for the prevention of the introduction of disease with the minimum of interference to commerce and travel.

In the Peace Covenant a clause was introduced providing for the establishment of a health organisation at Geneva under the aegis of the League of Nations. The functions of this organisation cover practically the whole field of preventive medicine wherever co-operation between the nations is desirable or essential. By arrangements with the international office in Paris it undertakes the collection and dissemination of current information on epidemic disease: it gives assistance in times of national emergency as during the great epidemic of typhus in Russia in 1919, during the epidemic of malaria in Southern Russia, in Greece during the influx of refugees from Asia Minor and other parts of Turkey, and during the recent outbreak of dengue in Athens. It has done much to secure the standardization of various medical preparations, such as insulin, pituitrin and certain of the antitoxins. It has promoted inquiry into cancer, certain aspects of maternity and child welfare and tuberculosis.

Public Health Finance.—The expenses of the public health services are defrayed for the most part out of local rates (general district rate or special rate), but assistance is given by the Central Government in respect of what are known as the "grant aided services." Thus half the approved expenditure on school medical inspection, maternity and child welfare work, tuberculosis and port sanitary services, and three-quarters of the expenditure on venereal diseases is defrayed from funds provided by the Treasury. With the exception of certain of the larger boroughs, half the salaries of the medical officers of health and of the sanitary inspectors is refunded out of Exchequer contribution grant.

The question of the substitution of a block grant covering all health services for these special grants-in-aid is at present under consideration by Parliament. (G. BUC.)

II. THE UNITED STATES

A definition which expresses admirably the social and scientific conception of public health in America is that of Winslow, "Public health is the science and art of preventing disease and promoting physical health and efficiency through organized community efforts for the sanitation of the environment, the control of community infections, the education of the individual in principles of personal hygiene, the organization of medical and nursing services for the early diagnosis and preventive treatment of disease, and the development of social machinery which will ensure to every individual a standard of living adequate for the maintenance of

Mortality Trends in the United States. Death Rates per 100,000 Population, 1900–37 (United States Registration Area)*

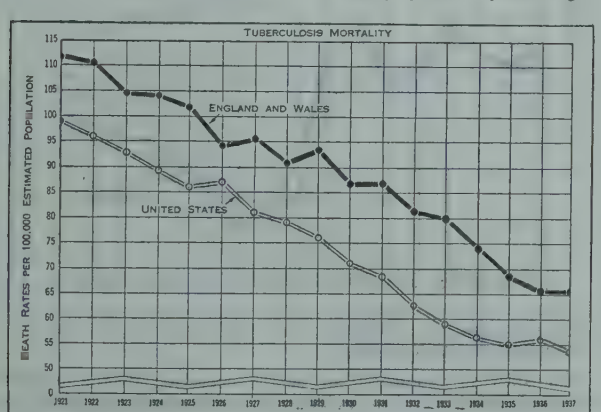
Year[1]	Increasing						Decreasing								
	Heart diseases[1]	Cancer[2]	Accidents[3]	Appendicitis	Diabetes mellitus	Cerebral haemorrhage[4]	Typhoid fever	Diphtheria	Diarrhoea, enteritis[5]	Influenza, pneumonia[6]	Tuberculosis[7]	Nephritis	Congenital malformations and diseases of early infancy	Other causes[8]	Total all causes
1900	132·1	63·0	70·0	9·7	9·7	71·5	35·9	43·3	133·2	203·4	201·9	89·0	91·8	591·5	1,755·0
1901	132·6	64·3	88·1	10·0	10·2	72·2	32·3	34·0	113·5	193·6	196·9	89·3	80·7	534·2	1,651·9
1902	137·7	65·1	78·1	10·0	10·3	72·0	34·3	30·8	105·0	165·8	184·5	90·9	82·9	520·6	1,588·0
1903	143·0	68·3	87·2	11·0	11·3	72·0	34·1	31·7	101·0	173·6	188·5	97·3	86·2	498·5	1,603·7
1904	153·4	70·2	86·7	11·8	12·8	75·2	31·7	28·3	110·6	191·6	200·7	103·1	90·8	486·6	1,653·5
1905	152·2	71·4	84·0	11·9	12·9	74·7	27·8	23·6	115·7	167·7	192·3	103·4	89·3	475·1	1,602·0
1906	148·4	69·1	93·4	11·7	12·7	73·1	31·3	25·7	120·0	155·8	180·2	97·5	91·7	457·5	1,567·5
1907	159·7	70·9	94·4	10·9	13·5	76·1	29·5	23·6	113·3	179·9	178·5	102·4	92·7	451·7	1,597·1
1908	148·8	71·5	82·0	11·3	13·4	71·7	24·3	21·5	111·6	152·2	167·6	93·7	90·4	418·0	1,478·0
1909	151·4	73·8	81·4	11·3	13·8	73·9	21·1	20·4	103·2	150·7	161·1	95·2	87·5	395·2	1,440·0
1910	158·8	76·2	84·4	11·4	14·9	75·7	23·5	21·4	117·4	162·1	160·3	99·1	88·1	402·9	1,496·2
1911	157·1	74·4	84·6	11·7	14·9	76·5	21·0	18·9	91·2	149·6	159·2	97·7	93·2	368·1	1,418·1
1912	159·9	77·1	82·4	11·6	15·0	77·5	16·5	18·2	84·1	142·7	149·7	103·2	95·4	355·5	1,388·8
1913	155·8	79·0	85·5	11·1	15·3	76·5	17·9	18·9	90·3	144·8	147·8	103·0	98·5	364·2	1,409·6
1914	159·7	79·6	78·7	12·3	16·2	79·6	15·5	17·9	79·6	130·4	147·2	102·6	95·5	343·8	1,364·6
1915	165·7	81·4	76·6	12·8	17·3	81·2	12·4	15·7	72·1	149·1	146·3	105·1	92·1	327·3	1,355·0
1916	168·7	82·1	84·2	12·8	17·1	82·9	13·3	14·5	79·5	164·3	142·1	105·6	94·0	343·2	1,404·3
1917	171·7	82·0	88·2	12·6	17·0	84·5	13·5	16·6	79·3	167·8	147·1	107·9	91·9	345·4	1,425·5
1918	170·1	80·3	82·3	12·2	15·9	81·2	12·6	13·9	72·7	587·0	150·0	97·6	92·3	341·0	1,809·1
1919	146·7	80·5	71·9	11·8	14·9	78·6	9·2	14·7	55·2	222·3	125·6	88·1	79·9	288·0	1,287·4
1920	159·1	83·2	71·3	13·4	16·0	81·7	7·8	15·3	54·3	208·0	114·0	89·2	84·7	305·8	1,303·8
1921	156·3	85·6	68·3	14·4	16·8	80·6	9·0	17·6	51·4	99·3	98·9	85·0	83·9	291·1	1,158·2
1922	164·6	86·2	69·5	14·1	18·3	82·9	7·4	14·6	39·3	132·6	96·4	87·9	77·7	282·4	1,173·9
1923	173·8	88·7	75·8	14·7	17·7	86·9	6·8	12·0	39·6	152·4	92·8	89·3	77·3	291·9	1,219·7
1924	176·5	91·1	75·7	14·8	16·4	88·9	6·7	9·3	34·5	116·7	89·7	88·8	77·6	286·3	1,173·0
1925	185·7	92·8	78·5	15·2	16·9	81·0	8·0	7·8	39·4	123·4	86·7	96·5	74·0	278·2	1,184·1
1926	199·5	95·1	78·8	15·0	18·0	82·8	6·5	7·5	33·6	143·5	87·3	98·5	71·7	287·6	1,225·4
1927	196·0	95·7	78·5	15·0	17·5	80·4	5·5	7·8	27·6	103·2	80·9	92·6	67·8	274·9	1,143·4
1928	208·2	96·1	79·4	15·3	19·0	83·4	4·9	7·2	26·9	143·5	79·3	95·2	65·8	282·4	1,206·6
1929	210·8	95·9	80·9	15·2	18·8	82·1	4·2	6·6	23·5	147·2	76·0	91·2	62·4	277·1	1,101·9
1930	205·7	97·3	80·6	15·3	19·0	81·0	4·8	4·9	26·3	102·7	71·5	90·8	61·0	273·0	1,133·9
1931	201·8	98·9	78·5	15·2	20·4	79·0	4·8	4·8	20·7	107·7	68·1	87·1	56·4	263·9	1,107·0
1932	208·9	102·8	71·4	14·2	21·9	79·3	3·7	4·5	16·3	107·7	62·8	87·1	53·1	254·9	1,087·8
1933	205·8	102·2	72·4	14·1	21·3	75·8	3·6	3·9	17·2	95·5	59·5	82·9	50·5	262·4	1,067·1
1934	212·9	106·2	70·9	14·3	22·1	77·3	3·3	3·3	18·3	96·7	56·6	84·2	52·9	275·2	1,103·2
1935	213·1	107·9	78·3	12·7	22·2	76·6	2·8	3·1	14·1	104·0	55·0	81·2	49·4	271·8	1,092·2
1936	227·9	111·0	85·8	12·8	23·7	81·2	2·5	2·4	16·3	119·3	55·6	83·2	49·7	280·4	1,151·8
1937	222·3	112·0	81·4	11·9	23·7	77·0	2·1	2·0	14·6	114·5	53·6	79·6	49·0	278·4	1,122·1

*Vital Statistics, Special Reports, Jan. 16, 1939, Vol. 7, No. 14, pages 43–47, Department of Commerce, Bureau of the Census.

[1]Excludes diseases of the coronary arteries.
[2]Includes all malignant tumours.
[3]All external causes including automobile accidents of all types.
[4]Includes softening.
[5]From 1900–20 includes ulcer of the duodenum.
[6]Includes capillary bronchitis.
[7]All forms.
[8]Includes deaths from all causes not otherwise indicated.

health." Progress in public health is shown by the following facts.

Increase in the Average Length of Life.—The health of the people of the United States has been improving consistently for the past 50 years as is revealed by the official morbidity and mortality rates and estimates of life expectancy. Even as late as 1880 the average length of life in the New England States and New York city probably did not exceed 40 years. By the beginning of the present century this had increased to 49 years for the original Registration States and in 1920 to 56 years for at least the 85% of the population in the registration area. Latest studies (1940) show the average duration of life for the white population is beyond 60 years. It is entirely possible, without any additions to the present knowledge of the causes and means of prevention of disease, that an average duration of life of 70 years may be attained by 1970.

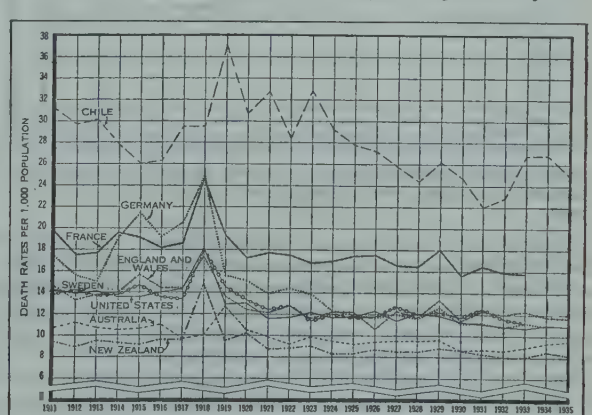


BY COURTESY OF BUREAU OF MEDICAL ECONOMICS OF AMERICAN MEDICAL ASSOCIATION

FROM ANNUAL REPORT, CHIEF MEDICAL OFFICER, MINISTRY OF HEALTH, 1937; BUREAU OF THE CENSUS AND U.S.P.H.S. REPORTS, 1938

Decrease in Death Rate.—In 1870 there were 30 deaths from all causes for each 1,000 of the total population of New York city; in 1937 there were 11·4. Similar changes have occurred in other large cities and in the rural populations, although the city rates were higher in the beginning and have fallen at a more rapid rate than have those of rural communities. In some instances the city rates have been, for recent years, lower than the rural. Since 1900 the general death rate for the registration area of the United States has fallen from 17 to 11·4 per 1,000 of the population.

The past quarter century—1910–35—during which an increasing shift of the population took place from rural to urban residence (55% urban in 1927), was characterized by a greater improvement in general health conditions in both city and rural regions than in any previous similar period of time.



BY COURTESY OF BUREAU OF MEDICAL ECONOMICS OF AMERICAN MEDICAL ASSOCIATION

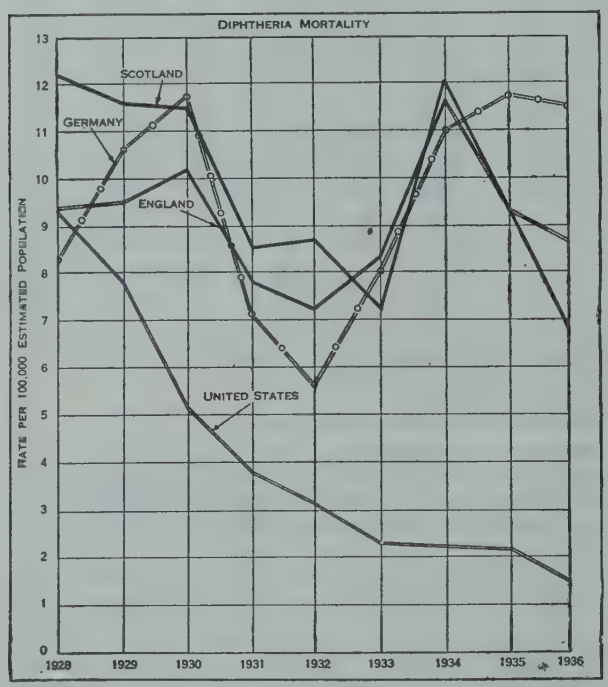
GENERAL DEATH RATES OF THE UNITED STATES REGISTRATION AREA AND CERTAIN FOREIGN COUNTRIES FOR EACH OF THE YEARS FROM 1911 TO 1935—FROM MORTALITY STATISTICS, U.S. BUREAU OF THE CENSUS

The advantage of the rural dweller over the city dweller is found in each decade of life, at least up to the age of 50, and this applies to both sexes.

Changes in Specific Death Rates.—More indicative than are general death rates, of the success of sanitation, personal hygiene and the application of administrative government and social resources for disease prevention, are the changes in the death rates from tuberculosis, typhoid fever, diarrhoea and enteritis among children, diphtheria and the infant mortality. All of these have fallen without exception in those States and cities where reliable records are available.

Typical experience is expressed in the following:

The greatest reduction in the death rate from tuberculosis has been in children under ten. The highest tuberculosis death rates for the country as a whole are those of women from 20 to 30 years of age and for men from 45 to 60.



BY COURTESY OF BUREAU OF MEDICAL ECONOMICS OF AMERICAN MEDICAL ASSOCIATION

FROM ANNUAL EPIDEMIOLOGICAL REPORTS, HEALTH ORGANIZATION, LEAGUE OF NATIONS, 1931-36: SPECIAL ARTICLE, *J.A.M.A.*, JUNE 26, 1937

Typhoid fever, from being an endemic disease of cities, chiefly due to polluted water, is now characterized by its epidemic character resulting from carriers, milk products, oysters and accidental occasional failures of water purification. The endemic typhoid areas are now the small towns and villages of rural States where unprotected water and unpasteurized milk are used.

Diarrhoea and enteritis, from being the leading cause of death in children under five, and particularly among city children and especially in the summer months, now plays a minor rôle, is less prevalent in cities than in rural areas and is hardly more frequent in summer than in winter.

Diphtheria. Now that means of permanent and universal protection of children against diphtheria by active immunization are available, in addition to the resources for specific therapy and determination of susceptibility, the practical disappearance of diphtheria as a frequent cause of death in children under five years of age is within sight.

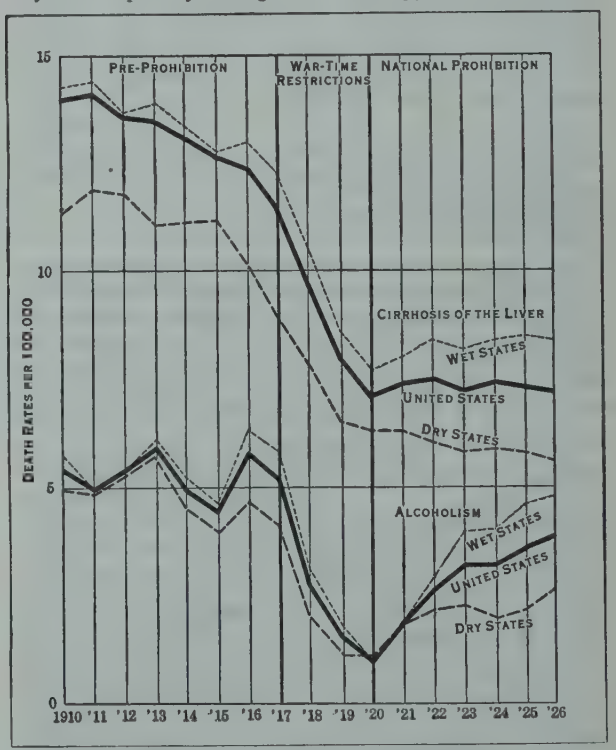
Infant Mortality. While 50 years ago one out of every four babies born alive died within the first year of life, now only one in 20 is so sacrificed. This saving in child life has occurred wherever education of the mother has been provided by doctors and nurses, and water and milk supplies have been safeguarded. It is common to find infant mortality rates lower in the cities than in rural communities, a reversal of the conditions 50 or even 25 years ago.

Increasing Death Rates.—The saving of life in the early years of childhood, particularly from diseases peculiar to infancy and from communicable diseases affecting chiefly children under five, and from tuberculosis in persons from 15 to 30 years of age, since about 1900, has, together with the limitation of immigration altered the age composition of the population to a degree affecting the rates from such causes of death as affect persons over 45 years of age. Of these the most important are heart diseases, cancer and diabetes.

The increases in the death rates from heart diseases, cancer and diabetes are in part due to the higher age grouping of the population as a whole, but in addition to this, the death rates for each decade over 45 show increases for each of these diseases.

Deaths from violence and accidents, particularly those due to automobiles, and from appendicitis have increased sharply in recent years. Deaths from causes connected with childbirth have not declined greatly, and those in the United States are above those of other countries with reliable records.

While in 1866 in New York city one death out of every 2,400 was due to diabetes, now (1940) one in 40 is from this cause. The increase, while greater in the cities, is found also in rural populations and among the coloured as among the white races, but everywhere especially among women over 35 years of age.



MORTALITY DUE TO ALCOHOLISM AND CIRRHOSIS OF THE LIVER IN THE UNITED STATES (1910-1926)

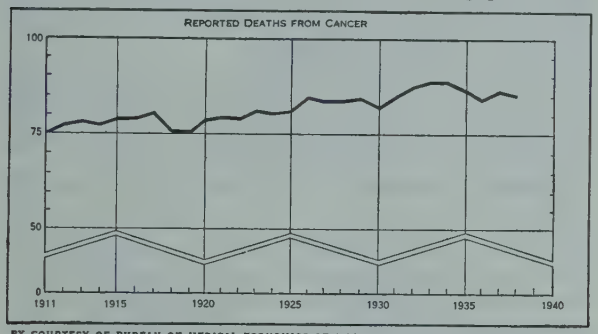
The shift in proportion of deaths occurring in the various decades of life is a striking evidence of the effective control of the communicable diseases of childhood and early maturity.

Drop in the Birth Rate.—With the reduction in loss of infant life has come a lowering of the birth rate in the United States as a whole and for each State and racial group. Within the past 50 years the birth rate has dropped from approximately 40 per 1,000 population per annum to 16·7. From 1921–25 the birth rate was 22·5 in the birth registration area and in 1936 it was 16·7.

The Three Eras of Public Health.—For the first 125 years of the life of the nation, public health work was limited to control or improvement of man's physical environment and enforcement of quarantine by the exercise of the authority of the official health agencies, the boards and departments of health acting

under the police powers which are reserved to the States under the federal constitution. This may be called the era of sanitation, the great accomplishment of which was the reduction of communicable diseases transmitted largely, if not exclusively, through drinking water polluted by human wastes. Sanitary disposal of sewage, the protection and purification of water supplies, the control of nuisances and the improvement of housing constituted the first effective attack on environmental hygiene and saved the cities from destruction. At the beginning of this era death rates in the large cities equalled or exceeded the birth rates. The health officer relied upon legal rather than scientific authority, upon the force of police powers rather than the power of education and authority, upon his individual or departmental services rather than upon the technical assistance and popular influence of volunteer co-operating agencies and associate professional groups.

Not until Lemuel Shattuck in Massachusetts in 1848 and Dr. Stephen Smith and his associates in New York city in 1865 had disclosed by careful surveys of the health of the population the



BY COURTESY OF BUREAU OF MEDICAL ECONOMICS OF AMERICAN MEDICAL ASSOCIATION

STANDARDIZED DEATH RATE PER 100,000 INDUSTRIAL POLICY-HOLDERS, AGES 1-74 YEARS. THE 1938 RATE IS PROVISIONAL.—SOURCE: "TWENTY-FIVE YEARS OF LIFE CONSERVATION," AND STATISTICAL BULLETINS, METROPOLITAN LIFE INSURANCE COMPANY

true extent of preventable disease and death, and the fact that the death rates in the cities were higher than the birth rates did the public demand something approaching qualified direction and consistent scientific operation of a well-organized department of health. The first State department of health was organized in Louisiana in 1853.

In 1900 there began the movement for public education in health which has been a factor of tremendous importance ever since, not only in the widespread dissemination of popular information about preventable disease, but in bringing to the support of the official health department or health officer interest, knowledge, financial assistance and public opinion through the influence of volunteer or unofficial health agencies.

The initial movement of this educational or public informational era of public health was that of the tuberculosis committees and societies and national, State, and local associations, now operating with undiminished vigour and sustained interest and financial strength as the National Tuberculosis Association. The three simple facts with which the public was approached were the communicability, curability and preventability of tuberculosis. Once accepted, it was inevitable that knowledge of these facts should lead to appropriate communal action. The National Tuberculosis Association, its 48 State societies and 1,300 other local societies have been the exciting, if not the driving, force which has brought 600 tuberculosis clinics, 60,000 sanatorium beds for tuberculous patients (1922), a tuberculosis division in all important State and local health departments and a scientific program of prevention uniformly accepted as an essential part of the work of the public health officer and department of every community.

The most important features of the program of the National, State and local tuberculosis associations since the beginning of the movement in 1904, have been those measures which have brought about "notification and supervision of persons afflicted with tuberculosis; the construction and maintenance by cities, counties and States, of institutions for the care and treatment of tuberculous patients of all types; institutions for the prevention of tuberculosis, such as preventoria, open-air schools and camps; the instruction of the public in the methods of avoiding and curing tuberculosis; and finally the intensive scientific study of methods to be used in the prevention and treatment of tuberculosis."

Following the leadership and example of the tuberculosis associations, there were developed similar private health agencies first as local societies and later on a national scale to carry a lesson of prevention and of health on the subject of infant mortality and child hygiene, on pre-natal care of the expectant mother, on social hygiene, a synonym in the United States for venereal disease control, on mental hygiene, cancer, blindness, heart diseases, etc., until the country was swept with successive waves of specialist health propaganda to stimulate appropriate public and official action. It is not unusual to find that twice as much money is spent for public health through the private agencies as is invested by the taxpayers in their official health department.

The third era of public health which was just emerging in 1928 as a definite new phase, out of that of public information or health education, had its inception in the World War experience from which the conviction developed that only by the systematic use of the periodic health examination could all the potential benefits of preventive medicine be made effective for the individual.

With the common action of the American Medical Association and the unofficial and official health agencies through the National Health Council in 1922 an agreement was reached which has been followed with much success. The objective of the present era of public health is to obtain from the prenatal stage until old age for each individual the benefits of personal medical guidance in a healthy way of life, in addition to medical services for the care of sickness. The supervision of the expectant mother, the guidance of the infant's growth, the supervision of the development of the runabout child of two to five, the protection of the health of young people and adults of middle age until their years of work are over in old age all depend for their effectiveness upon individual application of the principles of personal hygiene according to the requirements of age, sex, work, personality and the limitations of inheritance and of economic and social status.

The policy has been to inform the public through official and volunteer health agencies of the benefits to be obtained from a periodic medical examination and to train physicians to carry out the technical service required. Personal interest in and responsibility for individual health is essential if the present knowledge is to be effectively applied through the mechanism of medical examinations and health conferences.

In all health matters pertaining to interstate and foreign commerce the responsibility rests with the Federal Government through the U.S. Public Health Service of the Federal Security agency. In addition to large functions in medical relief, particularly for merchant seamen, the Public Health Service maintains active consulting and co-operative relations with State and local health authorities, carries on widespread attack upon the venereal diseases through a variety of channels, supervises and controls the standards and production of biological products used for diagnosis and treatment of disease, maintains an effective information and education service of national scope, and carries on researches in sanitation, preventable diseases and vital statistics.

Health activities of various kinds are carried out under six other Cabinet departments and many more independent establishments of the executive branch of the Government.

Local health organizations may not set up standards or enforce local ordinances inconsistent with those established by the competent State authority.

Not only cities, towns and incorporated villages, but counties and rural districts to an increasing degree maintain self-contained health departments adequately performing the essential functions.

A minimum provision for any unit of population of 50,000

persons or over as conceived by the professional public health workers of the United States is as follows: a full-time health officer, qualified by training and experience, free from partisan political interference in tenure of office, and paid a salary in proportion to the responsibility of the position; a board of health or advisory health council; trained personnel, including public health nurses to the number of one to every 3,000 of the population, capable of carrying on the seven functions previously described, and a budget based upon an appropriation from public funds of $1.00 to $2.00 per capita for health purposes.

Adequate provision for the organized care of sickness in any community of 50,000 persons or more includes at least:

A general hospital with a capacity of five beds for each 1,000 of the population for the use of general medical and surgical patients, and for maternity cases, and space for the cubicle isolation of acute communicable diseases (one bed for each 2,000 of the population). Beds for diagnosis and observation of tuberculosis, venereal disease and mental patients should be included.

A tuberculosis sanatorium with accommodations for one patient for every 1,000 of the population.

Hospital facilities for three mental patients for each 1,000 of the population. Institutional provision for chronic invalids and convalescent patients according to the social, economic and industrial status of the people.

While all local health departments do not have direct responsibility for the care of the indigent and other sick of the community, the hospital care of the acute communicable diseases and often of tuberculosis and venereal diseases is commonly under the health officer.

Interest in treatment and prevention of all sickness is within the proper province of the health officer and unless the institutional and private physician facilities for the diagnosis and care of sickness are adequate, a community cannot have a wholly satisfactory service for health.

ORGANIZED HEALTH WORK

In the United States the problem of the proper or desirable division of public health authority between Federal, State, and local agencies is one as yet unsettled. By the Federal Constitution, the State is the ultimate authority and each State jealously guards its autonomy in matters pertaining to public health.

In the same way the local authorities demand ultimate power in relationship to certain health functions which relate wholly to the health problems of the local community. The development of many nongovernmental health agencies is also to be considered in the evaluation of public health work in the United States.

The chief questions of recent years have related to the inequality of the distribution of the benefits of modern public health and medical science. Thus recent years have seen the conduct of a National Health Survey to determine the amount of chronic disabling illness and the extent of medical service available for its care. Innumerable surveys have also been made of local, State, and national health services. As a result there has been proposed a National Health program, involving the appropriation of vast funds to be distributed to the individual States as grants-in-aid for specific health purposes. Moreover, under the Social Security Act of 1934 extensive funds have been appropriated to the United States Public Health Service and the Bureau of Maternal and Child Welfare in the Department of Labor to carry on extensive preventive, medical, and educational services in the individual States. Under this system, the States must match the appropriation of the national Government and must submit plans for the approval of national bureaus before grants are made.

There is also widespread agitation for compulsory sickness insurance in some of the individual States and by certain agencies which would ask the Federal Government to provide funds for establishing such systems in the individual States. (*See* also HEALTH VISITOR.)

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PUBLIC HOUSE, in its general English acceptation, a house in respect of which a licence has been obtained for the consumption of intoxicating liquors. Public houses are frequently distinguished as "tied" and "free." A tied house is one rented from a person or firm from whom the tenant is compelled to purchase liquors or other commodities to be consumed therein. A free house has no such covenant. (*See* LIQUOR LAWS AND LIQUOR CONTROL; TEMPERANCE; PROHIBITION.)

PUBLIC OPINION SURVEYS. The public opinion survey, based on sampling a representative cross-section of the population, was first established as a periodical service in the United States in 1935. The antecedents of the representative sample survey were the market survey and the straw poll.

History.—The *market survey* was originated in 1912 by Roy O. Eastman, then advertising manager for a manufacturer of breakfast food, to determine the readership of various magazines in which his advertisements appeared. In 1919 Eastman set up the first survey department within an advertising agency, and in the same year Percival White established an independent surveying organization, serving agencies and advertisers. From that time on the practice of market surveying, with a crew of interviewers calling on consumers to ask a series of questions about their use of the advertiser's product, spread rapidly through the advertising world. One of the principal practitioners was the J. Walter Thompson Co., an advertising agency with offices in many parts of the world. In nearly all of these places surveys were conducted from 1922 on. The market survey usually was restricted to facts about the uses of products, and paid only incidental attention to opinion. Moreover, the market survey seldom attempted to report on a full cross-section of the population, but confined itself to those who were the most likely market.

The *straw poll* began as an intermittent practice of U.S. journalism in 1824. In that year the *Harrisburg Pennsylvanian* sent out reporters to inquire among the citizens of Wilmington, Del. whether they were going to vote for Henry Clay, Andrew Jackson, John Quincy Adams or William H. Crawford for president. Similar polls were conducted in 1883 by the *Boston Globe;* in 1904 by the *New York Herald;* in 1908, 1912, 1916 by the *New York Herald* in collaboration with the *Cincinnati Enquirer,* the *Chicago Record-Herald,* the *St. Louis Republic* and others; in 1916, 1924 and 1928 by the Hearst newspapers. The most celebrated of the straw polls was that conducted by the *Literary Digest* between 1916 and 1936, after which time it was discontinued because its results compared unfavourably with those of the newer representative sample surveys. The *Literary Digest* straw polls consisted of large numbers of ballots mailed to voters in all parts of the U.S. In a single poll as many as 20,000,000 ballots were mailed, and 3,000,000 were returned filled out by the recipients. The average state-by-state error of the *Digest* polls in predicting election results in 1924 and 1928 was 12% of the plurality forecast, and the extreme error was 39%. The straw polls were unreliable because they did not secure a true cross-section of the voting population. The failure arose from two causes: (1) available mailing lists represented chiefly the upper income strata of the voting population—automobile owners, telephone subscribers, etc.; (2) returned ballots came in larger proportions from those in the upper economic and educational levels of the lists used. These two factors compounded to make the straw poll results a reflec-

tion of the upper income and educational groups. Straw polls were used mainly to forecast election results, but in 1922, 1930 and again in 1932 the *Digest* asked questions about the law prohibiting the sale of alcoholic beverages, and in 1922 questions about granting a bonus to veterans of World War I.

The *representative sample survey* of public opinion was first presented in the July 1935 issue of the magazine *Fortune*. The editors reported and discussed a survey made for them by the market research firm of Cherington, Roper & Wood. Later the successor firm of Elmo Roper, conducting periodical surveys under the editorial direction of *Fortune*, charted large areas of U.S. opinion and recorded major changes in the U.S. view of the world and of governmental policies. In Oct. 1935, Dr. George Gallup, as director of the American Institute of Public Opinion, released a public opinion survey to a group of Sunday newspapers. Subsequently he released the findings of the institute's interviewers, first weekly and later several times a week, to a list of daily and Sunday newspapers throughout the U.S. Similar institutes were started in other countries, usually with Dr. Gallup's advice.

In 1937 a somewhat different type of organization, using questionnaire surveys as well as other surveying methods, was set up in Great Britain by Tom Harrisson and Charles Madge under the title of *Mass Observation*. Starting in 1943, a number of regional surveys were set up within the U.S. Even earlier, regular surveys of certain "interest groups"—farmers, housewives, students, etc.—were established by publishers serving those groups. The principal opinion surveys regularly publishing in 1945 were as follows:

Year Founded	Name	Principals and Home Offices
	National Surveys	
1935	*Fortune* Survey of Public Opinion	*Fortune*, New York, and Elmo Roper, New York, N.Y., U.S.A.
1935	American Institute of Public Opinion	Dr. George Gallup, Princeton, N.J., U.S.A.
1936	British Institute of Public Opinion	*News Chronicle*, London, England, Dr. Henry Durant, director
1937	Mass Observation	Advertising Service Guild, London, England
1939	Twohey Analysis of Newspaper Opinion*	James S. Twohey Associates, Washington, D.C., U.S.A.
1939	Institut français d'opinion publique	*Liberation*, Paris, France
1941	National Opinion Research Center	Marshall Field Foundation, Inc., in association with the University of Denver, Denver, Colo., U.S.A.
1941	Canadian Institute of Public Opinion	Toronto, Canada, Wilfrid Sanders, director
1941	Australian Public Opinion Polls	Melbourne, Australia, Roy Morgan, director
1942	Svenska Gallup Institutet	Stockholm, Sweden, Sven O. Blomquist and Tord Palender, dir.
1942	Instituto Científico de la Opinion Publica Mexicana	Dr. Laszlo Radvanyi, Mexico City, Mexico
1945	Danish Gallup Institut	Wahl Asmussen, Copenhagen, Denmark
1945	Suomen Gallup Oy	Artturi Raula, Helsinki, Finland
	Regional Surveys	
1943	Iowa Poll	*Des Moines Register & Tribune*, Des Moines, Iowa, U.S.A.
1944	Minnesota Poll	*Minneapolis Star Journal & Tribune*, Minneapolis, Minn., U.S.A.
1944	The Bulletin Poll	*The Evening Bulletin*, Philadelphia, Pa., U.S.A.
	Interest Group Surveys	
1935	The Companion Poll	*Woman's Home Companion*, New York, N.Y., U.S.A.
1938	The Farmer Speaks	*Successful Farming*, Des Moines, Iowa, U.S.A.
1938	Wallace-Homestead Poll	*Wallace's Farmer and Iowa Homestead*, Des Moines, Iowa, U.S.A.
1940	*Fortune* Forum of Executive Opinion	*Fortune*, New York, N.Y., U.S.A.
1943	Institute of Student Opinion	*Scholastic Magazines*, New York, N.Y., U.S.A.
1943	Wage Earner Forum	Macfadden Publications, Inc., New York, N.Y., U.S.A.

*Not a "poll"—*see* description under Press and Radio Analysis below.

METHODS OF SURVEYING PUBLIC OPINION

Sampling.—Except in those rare instances when all or substantially all of the people whose opinions are sought can readily be reached, opinion surveys of all types depend upon a sampling of the group being examined. The effort in sampling is to select people from the group in such a way that the completed sample will be in all significant respects a small scale model of the population it is designed to represent. If men and women occur in equal numbers in the population, then men and women are represented in equal numbers in the sample. If a third of the population are 50 years of age or older, then a third of those in the sample will be selected because they are 50 or older. If 5% of a certain population live in a certain city, then 5% of the sample will be drawn from that city. This principle of correspondence of sample to the population is usually applied in national samples to the following categories: sex, age, geographical region, community size, socio-economic level. Refinements and extensions of these controls are often used, and in special samples, where less than a national total is sought, special controls are also needed. For instance, a proper sample of wage earners would have to parallel the actual distribution of wage earners by types of industry. Samples on which reports are published customarily range in size from 500 to 5,000 cases, the most common number for a national sample being 3,000. A margin of 3% is normally allowed in such a sample to cover both statistical and sampling error.

Questionnaires.—The commonest type of public opinion survey relies on a fixed questionnaire uniformly administered to all members of the sample. The character and wording of the questionnaire has much to do with the impression gained from the final results and is a far greater factor in over-all accuracy than are the more easily adjusted statistical controls of the sample. The problems of questionnaire wording and interpretation have to do with the meaning of words and the prevalence of the concepts conveyed, and so cannot be dealt with adequately here. But certain common question forms are worth noting. They are:

1. the direct question, calling for a yes-or-no or no-opinion answer;
2. the multiple choice or list question, calling for the choice of one or more items in a list presented;
3. the open question, calling for a wide variety of volunteered answers which are recorded as given and later classified;
4. the attitude scale, usually calling for response to one of five verbalized attitudes offered on a given subject, the attitudes arranged to reflect unqualified approval, qualified approval, neutral feeling, qualified disapproval, unqualified disapproval (the neutral position is sometimes omitted);
5. the loaded question, which tends to force a certain kind of answer and which, therefore, often reveals the degree of uncertainty of the public when its answers are compared with those to a similar question loaded in a contrary sense;
6. the information question, usually of the direct or list types, but revealing knowledge or ignorance rather than opinion, and of use in opinion work chiefly for its correlation with expressed opinion.

Interviews and Mail Ballots.—Questionnaires are administered either by interviewers calling upon people at their homes or places of business or by mailing to selected lists. Mailing does not produce satisfactory results from a national cross-section for the reasons given above in the discussion of straw polls. But mail ballots sent to lists of fairly homogeneous people often produce results of a reliability higher than that achieved with interviewers. Within a homogeneous group the sampling error is minimal—*i.e.*, those who return ballots do not differ significantly from those who do not. But a person filling out a questionnaire by himself seems to be more likely to tell the truth on matters that affect his social prestige than is a person faced by an interviewer.

Observation.—The questionnaire supplies a uniform stimulus to call forth a varying response from a sample of the public. But public opinion is formed in actuality not so much by questions and answers as by a process of reading, listening, reflection, and spontaneous discussion. Therefore, if the things people choose to read and listen to, and the things people choose to discuss among themselves can be properly observed and intelligibly recorded, another approach can be made to public opinion.

Mass observation, as applied by the British organization already referred to, attempts the approach to spontaneous discus-

sion. The method is to have a large number of observers note in diaries what has been said in their hearing on topics of national interest. The diaries are periodically turned in and summarized. The method leaves much to be desired in exactness and runs many risks of subjective interpretation, but often succeeds in conveying the "feel" of opinion far better than a questionnaire can. The method is also used with more exactness in the observation of public behaviour as an index to public opinion. It was noted, for instance, that there was a close correlation between war news and the number of people carrying gas masks on the streets of London in 1939, 1940 and 1941. When the news was bad the proportion carrying gas masks went up, until by 1941 the news stimulus had apparently worn out. Similarly in the U.S. a correlation was noted in 1944 between the war news and the numbers volunteering as blood donors. When the news was good the number of volunteers dropped off.

Press and Radio Analysis does not report public opinion directly, but, by discovering what people read and listen to and what topics editors bring up, it throws a great deal of light on public opinion formation and change, as well as upon the operations of propagandists (*see* PROPAGANDA). Much of the early work in press analysis was done by Harold Lasswell, formerly associate professor of political science at the University of Chicago, from 1927 on. The first of the regular surveys of editorial opinion was published by James S. Twohey for a limited list of subscribers in business and government offices. The first press analysis prepared for a general readership was published in *Fortune* for Sept. 1944, and reported on the content of 50 labour papers taken as a sample of the some 928 labour papers published in the U.S. The radio popularity ratings published by Archibald Crossley after 1930 gave the approximate audiences of the news commentators and hence furnished a clue to the popularity of certain opinions. The Office of Radio Research under Dr. Paul Lazarsfeld at Columbia university, by itself and also in collaboration with Dr. Frank Stanton of the Columbia Broadcasting System, published a number of studies of radio coverage and of the reactions of listeners to programs.

FINDINGS OF SURVEYS

Elections.—The most publicized, though probably the least useful, of all the findings made through public opinion surveying is the election forecast. It is undertaken by serious surveyors of opinion because it provides dramatic validation for a method that can be of general public service only if it is widely accepted as valid. The record in U.S. national elections is as follows:

Error in Predicted Majority in Percentage Points

	American Institute of Public Opinion (Gallup) *less than*	*Fortune* Survey of Public Opinion (Roper) *less than*	Crossley *less than*
1936	7	1	7
1940	3	1	—
1944	2	1	2

In all, the American Institute through 1944 predicted 116 national, state and local elections with an average error of less than 3%.

Political Opinion.—The chief use to which public opinion surveying had been put in the U.S. regularly by 1945 was the reporting of popular sentiment on the large questions of policy currently before the people. Opinions were sought on U.S. entry into war, on drafting men for the army and for work, on peace terms, on tariffs, on taxes and on most of the matters that make up the agenda of a government. In Great Britain in 1934–35 surveying was put to a dramatic use when the opinions of 12,000,000 people were recorded on the League of Nations, with especial reference to armaments and the application of sanctions to aggressors. This survey was an unofficial plebiscite rather than a sample survey, but its very scope gave weight to the finding that a clear majority of the people of Great Britain favoured a rigorous application of sanctions. In the U.S., surveys traced the path of thought that the people followed between 1939 and 1941 in making up their minds about U.S. participation in World War II. In 1944 and 1945 surveys in various countries allied against the axis powers followed sentiment concerning treatment of the enemy.

Civic and Social Problems.—In addition to their use on matters of current national policy, surveys have been widely used to determine general public or special group attitudes toward proposals and practices in the fields of education, medicine, race relations and labour relations. Surveying on a local scale has been useful in getting the views of the community on such purely local concerns as street repairs, street lighting, water supply and curfew regulations. Contributions have been made to public health work by surveys reporting the incidence of common colds throughout the population at certain times.

Administrative Uses.—After 1939, increasing use of public opinion surveys was made by administrators in government and in business both in Great Britain and the U.S. Surveys in Great Britain provided clear clues to the effectiveness or ineffectiveness of various domestic propaganda drives sponsored by the government. Surveys conducted by the U.S. army gave valuable information on morale of the troops and on demobilization plans. Surveys of a variety of types were used to check on the rationing and price control programs. Large corporations "affected with a public interest," began to make regular checks of public attitudes toward them.

RECORDS

Published Material.—Little of the public opinion material gathered for journalistic use was available in book form in 1945, but nearly all of it was accessible in some form. The *Public Opinion Quarterly* carried and indexed summaries of Gallup findings from 1935 on; of *Fortune* findings from Sept. 1939 on and added certain other surveys afterward. At Princeton university, the Office of Public Opinion Research, directed by Dr. Hadley Cantril, filed the tabulating cards of its own and of the U.S. and British Gallup surveys. At Denver university, the National Opinion Research Center, directed by Dr. Harry Field, began publishing in Sept. 1943 a fortnightly summary of outstanding surveys in the U.S. and abroad. After 1943 *Fortune* maintained a file of all published surveys, indexed by subject. At all three of these centres the archives were opened to qualified inquirers.

Unpublished Material.—The great bulk of public opinion surveying done for administrative purposes has remained unpublished and inaccessible. Much of the governmental material has been marked for release at some later date. A small part of the corporation material has been similarly marked.

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PUBLIC RELATIONS, the activities connected with interpreting and improving the relationships of an organization or an individual with the public. The persons in charge of these activities are usually known as public relations directors, public relations consultants, etc.

Professional associations in the public relations field have maintained that the use of titles of this kind is justified only in the case of those who operate on a policy-making level, so that they have a voice not only in securing publicity for the activities of their employers, but also in making those activities conform to the public interest. However, the term has been widely used by publicity men without regard to this distinction.

The first industries to make general use of the term public relations were U.S. railways and public utilities. For example, the *Electric Railway Journal* for Dec. 13, 1913, said in an editorial that "the subject of the public relations of public utility companies occupied almost exclusively the attention of three important conferences this week in New York." Earlier uses of the term include an address by Dorman B. Eaton on "The Public Relations and Duties of the Legal Profession" to the graduating class of the Yale Law school in 1882. Thomas Jefferson used the term in his address to the 10th congress in 1807, but in the sense of foreign relations.

Forerunners of Public Relations.—While the term public relations did not come into general use until after World War I, many of its basic activities are as old as history. Primitive priests and medicine men performed public relations functions on behalf of their tribes when, in order to eliminate customs that were found to endanger the health or safety of the tribe, they built bodies of legend to give sanctions to their prohibitions.

In the 5th century B.C., the Greek poet Simonides put his muse at the service of publicity, selling songs of praise. This practice seems to have been generally considered in bad taste. However, even the fastidious Pindar accepted money from those he glorified in his odes. Among his patrons were the great merchant princes of Aegina. Plato in his *Republic* attacked poets as special pleaders, and advocated the suppression of all except those hired by the state to serve its welfare.

The Rosetta stone is an example of the governmental public relations work of the priests of ancient Egypt. The inscription, made in accordance with a decree passed by a general synod of priests in 196 B.C., informs the reader that the boy king Ptolemy V has been generous and just, and his policies conducive to prosperity.

In 60 B.C., shortly after he had become consul, Julius Caesar decreed that the acts of the Roman senate should be publicized. A bulletin, the *Acta Diurna,* was posted, and also issued in manuscript form. This publication announced that Caesar had been

offered the crown, and had refused it.

Augustus Caesar, foreshadowing a feature of Benito Mussolini's policy, ordered publicity given in the *Acta Diurna* to citizens who were rearing large families.

Gaius Maecenas, friend and adviser of Augustus, helped direct the genius of Virgil and Horace into channels that greatly enhanced the public prestige of the emperor. John Buchan, in his biography *Augustus* (Houghton Mifflin Co., 1937), sums up the role of Maecenas: "It was his task to feel the pulse of public opinion and to advise the blunter intelligence of the Princeps, and not less to create opinion for his day and for all time."

Under the influence of his friend and patron Maecenas, Horace portrayed Augustus as a symbol of enlightenment and peace. Similarly, Virgil in the *Aeneid* bolstered the pride of citizens by telling that the greatness of Rome had been foretold from the earliest days. In this feat of retroactive prophesy, he included the statement that Rome's ultimate grandeur was to be achieved by the men of the Julian house—the family of Augustus.

In the dark ages, wandering minstrels were made welcome at great castles largely because of the influence on public opinion they were able to exert on behalf of their patrons. The Anglo-Saxon scop or bard had become a respected personage by the 5th century.

The mediaeval guilds performed a public relations function for their members by maintaining the standards and dignity of their crafts. However, in contrast to modern trade associations, which publicize their methods, the guilds emphasized the "mysteries" of their vocations. Thus business became wrapped in a tradition of secrecy which tended to leave it defenseless against its critics.

A powerful handicap to the mediaeval businessman was the doctrine of St. John Chrysostom that "whoever buys a thing in order to make a profit selling it, whole and unchanged, is the trader who is cast out of God's temple." St. Thomas Aquinas amended this doctrine to permit a profit, but at a "just price" which involved a small margin.

In Augsburg, Ger., the house of Fugger, extending its banking and trading interests internationally on a large scale in the early 16th century, was hampered by restrictive laws and adverse public opinion. Jakob Fugger took his problem to Konrad Peutinger, a humanist scholar and an adviser to Emperor Charles V. Peutinger, a great forerunner of the modern public relations man, wrote a series of essays on the moral and legal aspects of trade. He pointed out that merchants were frequently forced to sell their goods at a loss, and maintained that accordingly every trader should be free to get as high a price for his wares as they could command. He argued also against restrictions on monopolies and cartels. Largely because of Peutinger's activities, the Augsburg council voted to do away with restraints on business.

In England, up to the middle of the 18th century, when it became possible for writers to look to the public for their livelihood, it was not unusual for authors who lacked private patrons to be in the pay of political groups. Swift put his talent at the disposal of the Tories, Prior and Addison of the Whigs. From 1731 to 1741, Walpole used nearly £50,000 of secret service funds for the pay of writers and printers.

In France, Racine and Molière were among the distinguished writers who supplemented their incomes by writing eulogies of royalty.

Napoleon Bonaparte made adroit use of opinion-moulding techniques throughout his career. In 1793, when there was a general revolt by Southern federalists or counter-revolutionaries against the new constitution, Napoleon's regiment was among the units engaged in suppressing the uprising. Sent on a mission to Beaucaire, he wrote a pamphlet, *Souper de Beaucaire,* to prove that the rigours of the revolutionary government were mild compared to the vengeance that the *ancien régime* would exact if disunion opened the way for its return. The pamphlet brought the young officer to the approving notice of the Convention.

In 1796, placed in charge of the army of Italy, Napoleon drafted a proclamation to his unpaid, badly equipped soldiers that gave a dramatic lift to their morale. William Milligan Sloane, in *The Life of Napoleon Bonaparte,* says of the French entry into Milan: "No scene in the history of warfare was more theatrical. The pageant was arranged on the lines of a Roman triumph, and the distances so calculated that Bonaparte was the one impressive figure." [1]

Having used pomp as an effective publicity instrument, Napoleon now showed that he could do likewise with simplicity. On his return to France he dressed plainly, visited minor officials who would normally have been expected to make the overtures—and saw to it that the modesty of his conduct was reported in the official journal, *Le Moniteur universel.*

In colonial America the talent of Samuel Adams for wooing public opinion proved a great asset to the Revolutionary cause. Typical of his practical approach to such questions is the letter he drafted for the Committee of Correspondence on Dec. 16, 1773. "We inform you in great haste that every chest of tea on board the three ships in this town was destroyed the last evening," the letter begins, and continues: "without the least injury to the vessels or any other property."

Developments in 19th and 20th Centuries.—In the early 19th century, U.S. newspapers frequently granted the hospitality of their news columns to publicity stories in return for paid advertisements. Other papers, inadequately staffed, accepted contributions without too close a scrutiny as to the motives of the writers. Shortly after the Civil War, land promoters, railroads, politicians and financial groups were making systematic use of such opportunities.

In 1869 James McHenry, press representative of the Fisk-Gould financial group, obtained wide publication of material in their interest. Shortly after this, a number of business and political organizations installed publicity departments, under the name of "literary bureaus."

Promotion-minded businessmen realized that it was possible to create news events that the newspapers would report as a matter of course. An outstanding instance of this occurred in 1892 when the manufacturers of "Sapolio" sent a 14-ft. sloop to Spain to participate in the 4th centennial of Columbus' voyage to America.

The technique of creating news events had already been brought to England by Thomas J. Lipton, who in 1881 arranged to have the world's biggest cheese manufactured in the United States, and created an effective fanfare of publicity when it reached his main store in Glasgow, Scot.

In the last decade of the 19th century and the first of the 20th, publicity men were multiplying in New York city. Almost all of them were former newspaper reporters. Knowing the ingredients of a lively newspaper story, some of them—particularly theatrical press agents—drew freely on their imaginations.

In 1909 the American Newspaper Publishers association, alarmed at the spread of press agentry, appointed a Committee on Free Publicity. One bulletin issued by it listed 757 "space grabbers."

However, most newspapers continued to use a substantial amount of material from publicity sources. A parallel situation occurred later in Britain. *Report on the British Press,* published by Political and Economic Planning in 1938, stated: "Some newspapers are very much opposed to accepting material from press agencies, and not long ago the Home and Southern Counties Newspaper Federation, representing nearly 300 newspapers, made a concerted attempt to eliminate it. Nevertheless, many of these newspapers continued to print such material, the news-value in them proving too strong a bait."

In both instances the attempted boycotts resulted in a more objective attitude toward publicity. In an article entitled "The Press Agent, His Rise and Decline," published in *Collier's* in 1911 (Crowell-Collier Publishing Co., New York, N.Y.), Will Irwin said: "No more may such as Channing Pollock trick the newspapers by having a popular actress develop a case of aphasia on the steps of the Eden Musee; no more may Toxen Worm draw column after column of space by strewing tanbark before the theatre to 'save the nerves' of an overstrung English star."

Irwin's epitaph for trickery was premature; many years later some of the old press agent devices were still in use, together with

[1] From *The Life of Napoleon Bonaparte,* vol. 1. Copyright, 1939, D. Appleton-Century Company, Inc. Reprinted by permission of Appleton-Century-Crofts, Inc.

such new ones as obtaining mention of clients in syndicated columns by attributing to them witty remarks invented or borrowed for the occasion. However, the article included a defense of the better type of press agent that might well stand as a vindication of his successor, the public relations man:

"A press agent, a special pleader it is true, but perhaps a fair one, helps wonderfully to mutual understanding. . . . The corporation head, associating only with his kind, may be as foolish as any man in misunderstanding the public. The press agent is always a graduate newspaperman. As such, he is an expert on public opinion. He can counsel against these unsympathetic follies; and often he does."

Leaders of business and finance had already begun to think along these lines. Until recently they had been opposed to any publicity except commercial puffs, and had strongly rebuffed newspapermen. The prominent banker George F. Baker told a reporter: "It's none of the public's business what I do." J. P. Morgan said to another "I owe the public nothing." William H. Vanderbilt, when pressed for a statement about reduction of train schedules on his railroad by a reporter who talked insistently of the public interest, exclaimed: "The public be damned!" Associated Press editor Melville E. Stone said in his memoirs that Vanderbilt's ire had been directed at the reporter rather than the public. However, great damage had been done.

The businessman's belief in his right to secrecy was an honest one, rooted in a tradition dating back to the mediaeval guilds. But it was dangerous to rest on real or supposed rights, in view of popular antagonism toward big business. This attitude was equally traditional; in fact, one of the motivations of the Boston Tea Party had been the fear that the British East India company would crush small merchants by selling directly to consumers.

A clash between the two traditions was forestalled for a long time by the availability of homestead lands in the west, which tended to mitigate causes of discontent. The drying up of this source of opportunity was accompanied by an epidemic of attacks on big business.

In 1886 there was a series of strikes, some marked by violence. Edward Bellamy's *Looking Backward,* 2000–1887, published in 1888, held out to a million readers the promise of a future utopia without the debasing effects of trade. In 1894 Henry D. Lloyd attacked the trusts in *Wealth Against Commonwealth.* In 1902 *McClure's Magazine* launched a series of articles indicting municipal politics and big business. Theodore Roosevelt gave the name of "muckraking" to this type of journalism. However, he had given encouragement to it by his rebuke to "malefactors of great wealth."

A series of harrying congressional investigations of big business accompanied the attacks. "We are passing through a reform —yea, a revolutionary period in business affairs," Henry Clews wrote in the *Annals* of the American Academy of Political and Social Science for July 1906. He called on banking and insurance interests to drop their policy of secrecy, which, he said, was "obviously in defiance of public sentiment."

Another development of 1906 was the appointment of Ivy L. Lee, a former newspaperman, as publicity adviser to a group of anthracite operators. The mine owners had stirred the anger of the press by their haughty attitude in labour disputes. Soon after Lee's appointment it was announced that they would supply the press with all possible information.

Lee then sent to city editors a declaration of his policies, in which he said: "This is not a secret press bureau. All our work is done in the open. . . . If you think any of our matter ought properly to go to your business office, do not use it."

Retained by the Pennsylvania railroad the same year, Lee made information concerning accidents available to the press for the first time. In 1921 his firm issued its bulletin, previously called *Notes and Clippings,* under the title of *Public Relations.*

In 1923 Edward L. Bernays published *Crystallizing Public Opinion.* This book, describing publicity functions and techniques with an emphasis on social responsibility, did much to popularize the term public relations and to gain recognition for specialists in the field.

Meanwhile, men were being hired in the service of the federal government under such titles as "director of information," "editor" and "supervisor of information research." These provided a loop-hole in a congressional act of 1913, which forbade the spending for "publicity experts" of any funds not specifically designated by congress for that purpose.

In Britain, the Empire Marketing board began using large-scale publicity for the promotion of trade in 1924. *Report on the British Press* says of the Empire Marketing board that "before its demise in 1933 it had established the archetype of Government Public Relations Departments."

In Britain, as in the United States, appointment of public relations directors by government departments during World War II was the prelude to increased postwar emphasis on public relations. The British public relations journal *Persuasion* pointed out in its issue for the winter of 1949: "The war made a great difference to the relation between a local authority and its people. . . . When peace came, the climate for formalized public relations was good."

One indication of the greatly heightened interest in the United States was the fact that many colleges were adding courses in public relations to their curriculums. Boston university established the first school of public relations in 1947.

Philosophy of Public Relations.—A realistic view of the public relations field avoids over-idealization on the one hand, or a cynical view on the other.

The basic purposes of a public relations department are the establishment and maintenance of good will. It is obvious that the more the organization does to merit this good will, the easier the task of the public relations director will be. When he invites public attention to his company in connection with some attractive phase of its activities, he cannot be sure of limiting the interest of the press or public to that particular area. The efficient public relations executive therefore works forcefully for the elimination of policies that he believes to be open to criticism.

A typical illustration of this point occurred at a conference in which plans for the construction of a winter resort were being discussed. Business executives associated with the project started with the assumption that it would provide only high-priced accommodations, since inexpensive ones would be unprofitable. The public relations consultant argued that low-priced rooms and meals should be offered also, in view of the fact that the project was backed by a railroad. His view was that a public service corporation would be inviting antagonism if it were associated with an appearance of exclusiveness. This opinion prevailed.

Following is another example of enlightened self-interest in public relations, cited by Glenn and Denny Griswold in *Your Public Relations* (Modern Industry Books, 1948):

"Suspicion and resentment had existed for years between neighboring small towns and agriculture on the one hand and San Francisco and its business interests on the other. . . . Mr. Lundborg" (general manager of the San Francisco Chamber of Commerce) "organized a committee of 83 leading farmers and of businessmen whose enterprises depended on agriculture. They sponsored a program of doing things to help farmers instead of boasting about the city's virtues. First they enlisted the help of newspapers, radio stations and grocery store chains to help dispose of an apple crop so abundant that it threatened ruin to many farmers. Within two weeks the surplus was lifted, prices had been maintained and farmers began to see some good in city business."

A significant sidelight on this story is the fact that it involved the public relations policy with which chain stores were combating campaigns to tax them out of existence. The method of an earlier day would have been merely to fight propaganda with propaganda. In this instance, propaganda was one of the weapons employed; but it was given powerful assistance by an intensive effort to win good will through service. Helping farmers to dispose of surplus crops was part of that program.

The public relations director or consultant frequently needs a high degree of persuasiveness in order to gain a hearing for a

long-range point of view in councils concerned with immediate commercial objectives. In order to be an efficient representative of his company he must also be a representative of the interests of its employees, of the local communities in which it has factories, of the retailers who distribute its wares, of the consumers who buy them, and of the public at large. It is not necessary for him to be an altruist in order to do this; he need only realize that it is easier to correct sources of irritation than to justify them.

Public relations consultants have stated that they could not have secured a serious hearing for some of their plans, involving immediate sacrifices for long-range objectives, if not for the respect engendered by their extremely high fees. On the other hand there have been many occasions, before as well as after the term public relations came into use, when businessmen have shown an innate talent in this area. For example, the suggestion box system, which later became a feature of thousands of public relations programs for maintaining employee morale, was used by the William Denny Shipbuilding company of Dumbarton, Scot., in 1880. Denny, after he had given many awards for ideas submitted by employees, said: "The scheme has the effect of making the workmen of all departments into active thinking and planning beings instead of mere flesh and blood machines."

Another Scotsman who showed a keen insight into some phases of public relations was Andrew Carnegie. During his boyhood, when he was an employee of the Pennsylvania railroad, Carnegie submitted to the *Pittsburgh Journal* an article on "the attitude of the city toward the Pennsylvania Railroad Co." In his memoirs Carnegie tells that this article brought him to the notice of the counsel for the railroad. Also, though he shared the weaknesses of industrialists of his era in other ways, he gave a building rent-free for the use of a co-operative store for employees.

Nevertheless, though early parallels can be found for every basic phase of public relations, as an organized activity it represents a major change in the philosophy of business—the recognition of the ultimate authority of public opinion. At the halfway mark of the 20th century, thousands of top-ranking business executives were devoting a major share of their time and planning to an activity that had been trivial or nonexistent in the programs of their companies a generation before.

Publicity as a Public Relations Tool.—When a policy has been set and the public relations representative is seeking publicity for it in news media, he must put his reliance not on techniques of persuasion but on his judgment as to what constitutes an acceptable story.

A story with intrinsic news value, simply and clearly presented, usually receives an objective hearing. A statement made in 1926 by Louis Wiley, business manager of the *New York Times,* is representative of a policy that gained wide acceptance with mass media: "If so-called publicity is legitimate news, it should be printed for the readers of the newspaper regardless of whether it benefits private interests or not. If it is not legitimate news, then it should not be printed, regardless of who may be pleased to have it appear."

In both large and small organizations, public relations departments are usually watchful for such publicity opportunities as anniversaries that may be of local or general interest, public events in which it would be logical for the president or some key official of the company to participate, incidents involving celebrities, and developments susceptible to treatment in text or photography as human-interest stories. In the handling of adverse news, such as that of accidents, experience indicates that the harm is minimized by candid answers to inquiries.

The policy on publicity expressed by Louis Wiley represented an important step forward for the public relations worker; but this did not mean that he was on an equal footing in a newspaper office with the paper's own reporters. The news value of a story had to be such as to be clearly and quickly apparent to the editor, who was constantly being flooded with copy by his own staff and the wire services.

In some cases the solution to this problem was found in the creation of news events—a practice that was not new but which was now followed with much greater respect for the judgment of editors. It became an important factor in the public relations programs of trade groups. For example, a group of soap manufacturers, anxious to combat the statement by some cosmeticians that soap was bad for the skin, turned to a public relations consultant, who advised formation of a cleanliness institute. This was not a dummy organization but one that conducted an actual cleanliness campaign, welcomed in public schools. It received widespread publicity. On another occasion a public relations counsel initiated soap sculpture contests on behalf of the industry. This type of oblique publicity was found to be of great value.

Similarly, when the National Cotton council was faced with the competition of paper bags with cotton ones as containers for feed, its public relations department sent emissaries to show farm wives how they could convert cotton feed bags into attractive dresses. Photography editors of newspapers and magazines were attracted by the novelty of the idea, which proved an effective stimulant for the sale of cotton.

The attitude of many editors toward this type of public relations was summed up by Stanley Walker in *City Editor:* "Once Irene Castle cut her hair, and her photograph was attractive. Barber shops, beauty parlors, hairnet manufacturers, the comb industry and the hat business were affected for better or worse. Businessmen are at the mercy of a million such whims. It is better for them to attempt some intelligent direction of these whims, so that they will know what to expect. Otherwise some morning they may find themselves ruined."[1]

A classic example of the unexplainable whims mentioned by Walker is chronicled by J. Henry Harper in *The House of Harper.* Discussing the publication of the novel *Lorna Doone,* Harper tells that at first this novel attracted little attention. Later, when the marriage of the marquess of Lorne (who had no connection with the book beyond the accidental similarity of his name) was headlined in the press, the novel was somehow associated in the public mind with this glamorous event, and its sales rocketed.

Publicity, which is capable of this freakish power, is a versatile instrument in the hands of a resourceful man or woman with newspaper experience. It proved a major factor in removing a once widespread prejudice against the game of billiards; it helped greatly to popularize bowling and other sports; and it has contributed to the making of fashions and literary and theatrical reputations.

Given an assignment that has a reasonable justification for its existence, a publicity man has many avenues of approach. A favourite one is to interest celebrities in the project, and use their names as a springboard. Another is to devise contrasts of a striking nature.

An illustration of a combination of the two methods occurred in New York city in the early 1920s, when a publicity man, admiring the work of an unknown artist, volunteered to bring it to public notice. A private exhibition was arranged for the artist's work, which included a series of panels depicting a boxing match. Several well-known fighters were then induced to come to a tea at which the pictures were shown. A Sunday newspaper devoted a full page to photographs of the artistic-pugilistic tea.

Publicity of this harmlessly playful type survived as an effective aid to some public relations programs. An instance of this was the formation, on behalf of doughnut manufacturers, of a mock-serious society known as the National Dunking association.

Perhaps the major significance of this type of publicity is that it permits imagination, judgment and energy to do the work of money. It is capable of putting a low-budget public relations office, representing a small business, a college, a church group, or a philanthropy, on a par with the most powerful organization.

Public Relations Advertising.—As some big corporations became increasingly aware of the importance of courting public opinion, they supplemented their publicity efforts with a new type of advertising—one that was not designed to gain business

[1]From *City Editor,* copyright 1934 by Stanley Walker. Published by J. B. Lippincott Company.

but to clarify their policies and improve their relationships with their employees, the local community and the public at large.

The Bell Telephone company was active in this field as early as 1908. After World War II Bell Telephone, unable to supply the demand for new installations, published a series of advertisements explaining why delays were unavoidable. The flood of complaints subsided to a point below the prewar average.

Several public opinion surveys revealed that the average American believed the profit margins of industry to be excessive. However, the popular idea of what constituted a fair percentage of profit proved to be substantially higher than the percentages that industry was actually earning. This was the basis for effective educational campaigns.

In public relations advertising by management in connection with labour disputes, a temperate policy, anticipating the day when the strike will be settled, has been found to be a wise one. During the strike at the General Electric plant in Bridgeport, Conn., in 1946, the company presented the view that wages must be geared to production, but avoided strident controversy. One advertisement was devoted to announcing that the strikers' insurance under the company's employee plan was being kept in force.

Industrial Relations.—Winning the good will of its employees is one of the major objectives of every industrial organization. The morale of a factory's workers affects many economic factors. Among these are the quantity and quality of production; the company's position in competing in a tight labour market for the services of skilled workers; its popularity or unpopularity in the local community, which in turn affects the treatment it receives from the municipal administration; and its reputation through the country as a whole.

No public relations technique can offset substandard wages or unsatisfactory working conditions. However, even a policy that is intended to be equitable may run into trouble if administered in impersonal, bureaucratic fashion. Accordingly, an efficient public relations director makes a strong effort to keep management sensitive to human values. Employees are informed of new developments promptly, before there has been an opportunity for these to be distorted by rumours. They are encouraged to submit complaints as well as suggestions. Advance proofs of institutional advertising are posted on factory bulletin boards. Facts on the company's earnings and prospects are made available. In some organizations, regular "job holders' meetings," similar to stockholders' meetings, are held. Issuance of publications for employees has become a standard practice.

An illustration of the scope of this work in a large organization was provided by the program of the International Harvester company. *Employee Relations,* a report by E. M. Claypool in *Public Relations Handbook,* edited by Philip Lesly, (copyright 1950 by Prentice-Hall, Inc.) states: "Organization of the Harvester employee relations program is divided into six main groups: labor relations, personnel, wage administration, salary administration, education and training, and group insurance. The activities of these groups are coordinated by a vice-president in charge of industrial relations who works in close harmony with the director of public relations. They use such industrial relations techniques as apprentice courses, student training, job training, supervisory training, vacations, collective bargaining, employees' benefit associations, group life insurance, hospital and surgical benefits, accident compensation, and scientific personnel selection and placement.

"An outstanding feature of the Harvester educational program is that any group of reasonable size may arrange for a course in any desired subject, whether the course is related to their present jobs or not. This policy encourages employees to develop hobbies and to broaden their intellectual horizons.

". . . Each plant has its own publication that acquaints employees with persons, departments, and activities removed from their immediate vicinity as well as those with whom they work."

Scope of Public Relations Departments.—Almost every form of the printed and spoken word, and of photography, is used in public relations work. At mid-20th century, many public relations departments included the following activities in their routine responsibilities: issuing news releases to newspapers, radio stations, trade journals and popular magazines; arranging press conferences; answering queries from the press and public; preparing text and illustrative matter for public relations advertising, pamphlets, employee magazines, manuals for the training of new employees, reports to stockholders and form letters; planning documentary motion pictures, recorded television programs, film strips, lantern slides, charts and recorded talks; planning and publicizing exhibitions and "open house" days at factories; and planning research surveys for gauging the opinions of employees, customers, or the general public. In addition, in cases where the product of the company is an expensive one, such as an automobile, the public relations department may have the duty of preparing a magazine for free distribution to listed customers. Some corporations issue special magazines for their stockholders. Public relations directors of trade organizations, long-established companies, and various institutions also have arranged for the publication of books, sometimes by well-known writers, telling the history of the organization or industry. These books are usually placed on sale through normal channels, but often are subsidized to assure the publisher against loss.

Some organizations employ not only a public relations director, with a staff under his supervision, but also a public relations consultant, to provide an outside point of view on questions of policy, or the public relations department of an advertising agency.

Most public relations work involves a combination of logical and psychological methods. Experience has repeatedly proved that exaggeration and distortion defeat their own purpose; but often it is possible to switch from an unpopular concept, expressed in a standardized term, to a popular, or at least an acceptable one, without doing violence to truth. Walter Lippmann, using the word stereotypes to describe these concepts of the mass mind in *Public Opinion,* influenced many public relations experts. An illustration of this type of thinking is the substitution in public relations advertising by labour unions of the term "union security" for "closed shop." Another is the use by manufacturers of "billiards" for "pool," which had taken on the connotations of shabby poolrooms.

Much specialization has developed in public relations work in areas such as banking, agriculture, education, philanthropy, etc. Also, many public relations executives specialize in the use of various media, such as audiovisual materials and stockholder reports.

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PUBLIC SCHOOLS. In the United States this term is used to describe free, tax-supported, public controlled and directed, nonsectarian schools. The term public school in England includes not only the schools of ancient foundation such as Eton, Harrow and Winchester, but also schools of comparatively recent creation such as Clifton, Cheltenham and Marlborough. As forming part of the secondary school system of England (*see* SECONDARY EDUCATION) they are included in the official statistics as non-aided schools.

PUBLIC UTILITIES,[1] a designation for a special grouping of industries. These industries should be distinguished from state services or public works, which are administered as public functions and hence supported by taxation, and from that variety of industrial, commercial and agricultural undertakings which are usually comprehended under the term "private business." Public utilities, properly so-called, need not be privately owned. In almost every country a varying number of them are owned and operated by the state. But these publicly managed enterprises, instead of looking to the state for financial support, sell their services to the general public. Both publicly and privately owned utilities sell their services at prices which are not fixed in the open market but are governmentally fixed. This is the most important aspect of the process known as public utility regulation. Although economic and technical evolution is continually changing the character of these industries besides creating new ones, public utilities may be classified according to the generalized function which they perform in economic life.

The following have been treated as and classified into groups of public utilities: (1) services of transportation (common carriers); (2) services incidental to transportation; (3) services facilitating communication; (4) facilities providing power, light, heat and refrigeration; (5) facilities providing water and sanitation in urban communities; (6) facilities regulating water-supply for agricultural purposes.

HISTORICAL SURVEY

Public utilities are closely associated with our developing civilization, supplying wants so fundamental for communal living that government has at all times subjected them to some measure of control. With the growth of trade in ancient empires facilities providing transport and communication were set up. The governmentally maintained highway system of the Roman empire and its many aqueduct systems are celebrated ancient public works. The need of some system of public communication was so great that even our letter post has its ancient parallel. In the more populous ancient cities, systems of sanitation also became a necessity. Along with this came the recognition that services used collectively should be supplied by the state. Public utilities thus began as state functions. By the middle ages most

[1]The writer is indebted to the Macmillan Company for permission to adapt from his work, *Outlines of Public Utility Economics,* certain summaries for substantial portions of this article.

of the ancient public utilities had declined or virtually disappeared. By slow stages, upon the manors and in the mediaeval cities, these public facilities again appeared. Of great importance in British and American legal history is the fact that out of the economic and legal relationships of feudalism there arose the concept of a "public calling" upon which is based the present-day policy of public utility regulation.

The modern national state gradually supplanted the elements of the feudal system of social control. The expanding domestic system of manufacture was displacing the guild and manorial system of production; foreign trade was growing. National systems of transport involving highways and canals were undertaken and the regulation of utilities became national rather than local.

Effects of the Industrial Revolution.—The greatest impetus in the expansion of public utilities came with the industrial revolution. The factory system so stimulated production that the need for ever-expanding markets became the limiting factor in economic evolution. Cities grew as never before, creating a new municipal need for systems of water-supply, sanitation, transport, communication, illumination and finally of power.

But the philosophy of *laissez faire* was not fertile ground for extending public functions. Thus, although the rapid industrial changes intensified needs, the tendency was to give greater scope to private enterprise.

However, the evils of a system which left the supply of basic economic wants to private industry insufficiently regulated by government became too flagrant to be overlooked. Beginning about 1840 the revolt against *laissez faire* doctrines caused an enlargement of the scope of governmental action. The older public utility services were continued for the most part as public enterprises, while the newer services were supplied by private initiative under some form of public supervision and assistance. Thus emerged the modern notion of a public utility, distinct from strictly governmental services and strictly private business.

Need for New Utilities.—The beginnings of the modern postal system date back to the 15th century. In the 18th century England was covered with improved roads built by public authority or by private turnpike companies. The first canal in a new era of canal building was completed in 1761. The first steam railroad was built in 1825 and the first regular steamboat began operation in 1812. The steam railway developed into the backbone of land transportation, yet canals and inland waterways continued to serve as important arteries of commerce. With the coming of the automobile, in the United States as elsewhere, highway systems were reorganized upon an unprecedented scale. The motorbus and the motor truck made use of this development and soon were rapidly cutting into the short-distance traffic of steam railroads. After 1850, systems of rapid, world-wide communication were perfected. The commercial electric telegraph and the telephone are now of tremendous importance. (*See* TELEPHONE; TELEGRAPH.) After 1900 radiotelegraphy and after 1907 radiotelephony increased the varieties of means of communication. The ancient art of irrigation underwent a rebirth.

In the field of municipal public utilities local transportation was supplied, at first, by fleets of omnibuses in the '20s of the 19th century. The horsecar came in the 1830s. Artificial gas for illumination was introduced commercially in London in 1812 and was widely in use for lighting by 1840. A new development in water-supply systems appears to have been introduced by the municipality of London in 1583, followed by Plymouth in 1585 and by Oxford in 1610. Boston in 1652 installed the first modern central water-supply system of the gravity type in America. Central water-supply systems became general in the large cities by 1820. Growing out of experiences in the cholera epidemic, British sanitary authorities put forward the trilogy of public hygiene—street paving, canalization and water supply. As a final achievement in the development of municipal sociology came a new city-planning movement, begun in Paris about 1850. (*See* TOWN AND CITY PLANNING and related articles.)

New public utilities centring in cities developed out of the industrial applications of electric power. In 1882 the first central station for electric lighting began operation in the United States. By 1885 electric power was applied to street-railways. The first hydroelectric plant began operation in 1882, the precursor of a new movement in power production.

In this historical survey it is important to note that public utilities were not definitely segregated from public functions until the *laissez faire* philosophy of the 18th century restricted the scope of governmental activity and created institutions and processes whereby the supplying of these changing public needs could be left to private initiative. Industrial interdependence now prevails. Thus public utilities, although privately owned, were subjected to governmental regulation. The term socialization has been chosen to describe this latest phase of utility development because it implies that government may actively promote these enterprises through public ownership or arrive at the same result by creating private agencies and controlling them through well-conceived policies of regulation.

ECONOMIC CHARACTERISTICS

Developments in the engineering arts bring changes in economic organization. For instance, lighting of the home was transformed first from a self-sufficient household industry (as the making of candles) to a commercial competitive industry (the supply of candles, lamps, whale oil and petroleum), and then to monopolistic industry (electric lighting), where central sources of supply satisfy all demands. Perhaps the most significant economic conclusion founded upon these changes is that the social value of public utility services is increased and the economic cost of rendering them is reduced by a consolidation of enterprises. The individual user of water in urban centres no longer had to depend for his supply upon his own well, nor did he have to buy from one of several competing sources. He resorted to a single common source of supply along with other users. This was found to be more convenient, economical and, indeed, the only practical solution. But this process of integration of supply was a long process. In some public service industries it was not completely realized. The tendency toward monopoly, however, whether the result of a competitive struggle or brought about by legislation, became a fundamental characteristic of public utility business.

Every public utility must be in possession of the natural resource upon which that industry is based. A gas or electric company must have possession of sites for the location of its works; a transportation company must have rights of way and terminal sites. These properties must have strategic locations. Limitation in the choice of this agent of production tends to make the cost of acquiring or leasing these facilities greater than it would be if the industry had a wider range of choice. Furthermore, utilities must make allowances in advance for probable increase in the required capacity. For these reasons utilities are provided with the governmental power of eminent domain which makes possible the compulsory sale of private property. Thus the law recognizes that, socially considered, these properties are being put to the highest uses of which they are capable.

Fixed Capital Characteristics.—All the varying stages of transmutation of capital can be found in constructing public utility plants. The so-called free or liquid capital is changed into durable and specialized types of buildings, structures and equipment, capable of use in only one industry. The roadway and track of a railway, for instance, is so completely specialized that only the rails and rail-fastenings can be salvaged. These characteristics of specialization, durability and immobility are included in the definition of fixed capital. It is also well to bear in mind the specialized managerial and engineering talent required in constructing and operating these enterprises.

A utility which has assembled its plant and thereby incurred heavy construction costs of a fixed character anticipates that the product can be sold at a profit. If expectations are not realized the utility will suffer a pecuniary loss because the government has not generally undertaken to secure the utility against such risks. It is therefore highly important that each enterprise take into account the economic principle of proportionality which requires that enterprises be so planned that the maximum of physical output may be secured at the lowest possible money cost and that

this maximum supply does not exceed the reasonable, long-run demand for service.

But there is another aspect of the matter. Technical improvements involving much fixed investment of capital are also more economical. A double-track railway has more than twice the efficiency of a single-track railway. Electrical generators of large capacity cost less per kilowatt than do generators of small capacity. The cost of operating large plants thus tends to be less than for small plants. Public utilities are therefore anxious to increase the volume of business. Economical operation is also secured by interconnection of power sources into so-called super-power systems. A super-power system consists of two elements: the utilization of highly economical generating stations, steam or hydro, and the interconnection of power stations by transmission lines.

Not only is the fuel consumption per unit of output reduced by using only large steam plants but the investment cost per unit of capacity is also lowered. By interconnecting such power systems the reciprocal sale of power from one system to another is made possible, and a common reserve is made to serve for a large area. Co-operative action thus ensures the utilization of surplus power, safeguards the service from interruptions and secures the advantages of long-hour use of investment by building up the diversity of use. This movement for interconnection grew particularly in the instance of natural gas and electric utilities.

Availability of Utility Services.—There are also peculiarities arising out of the time when the demand of customers comes, and these have a special influence upon cost of production. All public utilities must stand ready to supply their services when demanded, and from this point of view utilities may be divided into two classes according to the ease or difficulty with which they meet this situation.

The first class comprises the utilities which must adjust themselves to demand variations by having constantly ready a productive capacity equal to or exceeding the maximum demand for service. Thus utility plants will have spare capacity for service at other times in the shape of idle equipment and reserves of employees. This class of utilities has been called the service type and is exemplified by electric utilities, telephone and telegraph utilities, the different kinds of transportation utilities and the postal service. There the nature of the service is such as not to permit of delay if it is to be performed efficiently. Technical development has not been successful in making available for instant use surplus service which existing equipment might have produced at times of low demand. Changes in the volume of business can not be met by a policy of meeting peak requirements in part by stored supplies of the past. This has a tendency, therefore, to increase the cost of operation.

The second class consists of those utilities where the inequalities in customers' requirements may be met, at least in part, by a policy of production and storage of surplus to meet future deficiencies. This class has been called the product type. It is exemplified by water and gas utilities which may produce at a uniform rate, impounding the water and storing the gas not required to meet the immediate demands against the excess demands of the future. Storage facilities thus enable the product type to operate at a uniform output within the productive limits for which the plant was designed. Utilities of the second class need have a producing capacity equated only to meet an average demand, but they must provide storage capacity.

Therefore, it is necessary to compare the operating efficiency of the product-type utility, based upon a constant output with costs enhanced by an added investment in storage facilities, with the operating efficiency of the service-type with its lessened efficiency resulting from a variable output and with costs enhanced by standby losses and the carrying charges for idle equipment. The services of public utilities are thus conditioned by factors which tend to differentiate them from other business enterprises. They minister to wants which are regarded as basic. From a social point of view they are necessary economic functions because they are the basis for the specialization of occupations and the interdependence which exist in modern economic society.

SOCIAL CONTROL OF PUBLIC UTILITIES

Public service enterprises are regulated by governments throughout the civilized world. It is impossible in this article to trace this development or to outline the modern structure of regulation. Those desiring a detailed presentation are referred to the bibliography. In this summary is mainly given a discussion of the development of social control of public utilities in Anglo-American countries. The regulation of national systems of transportation and communication is also excluded except in so far as their prior development has influenced the course of regulation of local utilities.

Munn v. Illinois Decision.—The legal basis of public utility regulation may best be disclosed by considering the famous decision of the U.S. supreme court in *Munn* v. *Illinois* (94 U.S. 113 [1877]). In this decision is focused the common historico-legal background of public utility regulation in both the United States and Great Britain. *Munn* v. *Illinois* involved the validity of an Illinois statute fixing maximum rates for storing grain in elevators at Chicago. Munn had been engaged in the elevator business since 1862, long before the enactment of the statute, and had been in the habit of charging rates fixed by agreement among the elevator owners in Chicago and had continued to charge these rates although they were in excess of those fixed by the act. Munn was convicted and fined in the state courts but appealed to the U.S. supreme court upon the ground that the act violated the 14th amendment in that it deprived him of his property without due process of law.

Chief Justice Waite, in upholding the validity of the statute, said in substance that under the circumstances in which the elevators were being operated in Chicago (*i.e.*, standing in "the very gateway of commerce and taking toll from all who pass") they had become business "affected with a public interest and had ceased to be *juris private* only." This was not his own language but was quoted from Lord Chief Justice Hale who had penned it about 200 years before in England. This legal doctrine, he said, had been a rule of the law of property ever since; that under this rule and in exercising the police power of the state, "it had been customary in England from time immemorial and in America from its first colonization to regulate ferries, common carriers, hackmen, bakers, millers, wharfingers, innkeepers, and so forth," and to fix maximum charges. In further explanation of this "public interest" doctrine, the court said that private property is being used "in a manner to make it of public consequence, and affecting the community at large. When, therefore, one devotes his property to a use in which the public has an interest, he, in effect, grants to the public an interest in that use, and must submit to be controlled by the public for the common good, to the extent of the interest he has thus created. He may withdraw his grant by discontinuing the use; but, so long as he maintains the use, he must submit to the control."

In a later case (*Charles Wolff Packing Co.* v. *Court of Industrial Relations of the State of Kansas*, 262 U.S. 522 [1923]), Chief Justice W. H. Taft of the U.S. supreme court gave further precision to this "public interest" doctrine by saying: "In a sense, the public is concerned about all lawful business because it contributes to the prosperity and well-being of the people. The public may suffer from high prices or strikes in many trades, but the expression 'clothed with a public interest' as applied to a business means more than that the public welfare is affected by continuity or by the price at which a commodity is sold or a service rendered. The circumstances which clothe a particular kind of business with a public interest, in the sense of *Munn* v. *Illinois* and other cases, must be such as to create a peculiarly close relation between the public and those engaged in it, and raise implications of an affirmative obligation on their part to be reasonable in dealing with the public."

Between 1923 and 1934, and particularly during the depression years, a series of cases involving the constitutionality of price regulation was decided by the United States supreme court. With a dissenting minority of liberals, the court ruled against the regulation of the resale price of theatre tickets in New York city and of the fees of private employment agencies in New Jersey. With-

out dissent it forbade the regulation of the retail prices of gasoline in Tennessee. A divided court decided against the regulation of competition among artificial ice plants in Oklahoma. This negation of the extension of regulatory power was halted in 1934 when New York was upheld in its efforts to stabilize the fluid milk supply industry and rescue it from price-cutting tactics through the fixing of minimum prices by a milk control board. The seeming confusion behind these contradictory opinions can be explained by noting that the trend was in the direction of extending the use of the police power in the interests of public health, safety, morals and the general welfare, while the hard core of public utility regulation in the interests of monopoly control continued without abatement.

Obligations of Public Utilities.—The affirmative obligations upon public utilities arising out of their peculiarly close relation to the public are usually spoken of as that system of rights and duties which constitutes the law of public service undertakings. Briefly, this law places upon a public utility the extraordinary duty to render reasonably adequate service to all who apply. It is required to serve them up to the limit of its capacity, with capacity being defined as the limit of profitableness. It may not let customers' wants go unsatisfied. Nor may it attach unreasonable conditions to contracts for service so as in effect to negative its duty "to serve all comers." Furthermore, it must serve without discrimination all customers similarly circumstanced. Finally, a public utility must observe more than ordinary care in the rendition of service in view of the dependence of the public upon such service and the hazards associated therewith. On the other hand, the same law concedes a public utility the right to collect a reasonable price, to render service subject to reasonable rules and regulations and to withdraw service under prescribed conditions after giving notice to customers. While customers are given the right to demand that a public utility live up to its duties, they are, on the other hand, required to accept reciprocal obligations.

In determining whether a given industry is subject to this coercive law of public utility the courts have adopted certain practical tests of both a legal and an economic nature. The economic tests look to the presence of elements of natural monopoly in such number and strength that competition cannot work successfully. Under these conditions fair prices, in the sense of competitive prices, are not realized. The power of the state will be used either to regulate industries so as to restore equality of bargaining power by maintaining competition and controlling competitive practices, or used to promote the inherent trend toward monopolistic organization by conferring upon such industries legal monopolies and then controlling their economic relations by means of the system of rights and duties just outlined.

From an economic point of view it is clear, therefore, that the concept of a public utility is made up of two ideas: (1) the idea of monopoly; and (2) the idea of common necessity. Both must be present in order that an industry may become a public utility. Neither alone will suffice. The supply of housing facilities is a necessary economic function, and when it is furnished upon a competitive basis the customer is not coerced. But when, in emergencies such as the acute housing shortage (*see* HOUSING) during World Wars I and II, the consumer is forced to bargain for a necessity under conditions of temporary monopoly, the courts will uphold the regulation of rents. Yet the character of regulation will be such as to enable the industry to reachieve normal condition. The emergency having passed, as building operations are resumed competition again sets in and the reason for regulation disappears. The housing industry therefore represents a borderline case which, nevertheless, ought not to be classed as a public utility under normal conditions.

Legal Conception of a Utility.—When freedom of choice is seriously restricted—that is, when the coercion residing in private property makes itself felt as a monopolistic power—public interest arises in proportion as equality of opportunity to choose is restricted, provided that the wants supplied are recognized as a common necessity. Monopolization of a luxury will not call forth regulation, for public opinion is the arbiter in the selection of those common economic needs whose monopolization engenders regulation. The concept of public utility thus becomes a legal instrumentality to achieve an improvement of the standard of life. In a society which is accustomed to look to governmental initiative for the supply of common needs, the facility will be supplied as a public function. On the other hand, a society which is distrustful of the state will leave the supplying of such common needs to a private agency under a franchise privilege, not as a matter of common right, but as an agency of the state.

Since the law had long recognized the rights and duties of public utilities, this legal conception attained a certain fixity in the form of legal rules. But the number and kind of industries that may be subjected to these rules is not fixed. It may be said that the legal notion of public utility is that of a fixed concept with a changing content. The industries at any time recognized as "clothed with a public interest" are not necessarily the industries which may legally be classified as public utilities at another time. The industrial and political situation as mirrored in public opinion will determine: (1) the number and kind of industries classified as public utilities; (2) the elaboration of the system of rights and duties which make up the institution; (3) the regulating agencies and instrumentalities employed (whether the legal rules and decrees of courts or the charters, special franchises and statutes of legislatures); and (4) the subordinate administrative standards which are evolved in practice. The trend in the development and application of the institution will be a resultant of the amount of social inertia, of the pressure of the economic environment and of the influence of intellectual progress. Special attention should be directed to these dynamic factors: (1) the growth and extension of monopoly; (2) war and other conditions creating special emergencies; (3) the movement for conservation of natural resources; (4) the movement for public ownership.

Regulation in the United States has been accomplished in three distinct ways: (1) judicially by means of suits at law where the common law duties and rights of public utilities are applied in specific cases; (2) legislatively by means of corporate charters or special franchises; (3) legislatively by means of the police power of the states or its federal equivalent, the power of congress over interstate and foreign commerce. Judicial regulation is the oldest and constituted almost the only form of control during the first half of the 19th century. Legislative regulation later largely supplanted judicial regulation, but the latter remained in the background as a potential agency which might become active again if legislative regulation should disappear. The function of the judiciary by 1898 had been restricted to the review of legislative and administrative acts.

Legislative regulation by means of the charter or special franchise was the next to be tried. The special franchise is now generally conferred under constitutional or statutory authority by local governments. The method of special franchise regulation is applied to so-called local public utilities, furnishing telephone, gas, electric, water and transportation services in local communities.

The weakness of legislative regulation by charter was that the maximum rates therein provided were largely in excess of those actually charged by the companies. Competition of carriers with each other, the decreasing unit cost of operation on account of increased utilization of plant capacity, the decline in the level of prices after the Civil War, continuous improvements in technique, made necessary and possible the rendition of service at rates below those fixed in the charters. The failure to provide adequately for financial and accounting control enabled the issuance of more stock and the padding of investment accounts, thus vitiating the control based upon net income. Special franchise regulation followed the procedure applied in the case of carriers. Maximum rates were fixed in the local franchise of telephone, gas, electric and water undertakings. These maximum rates soon became obsolete because the growing business of the companies required more complex and flexible rate schedules. Moreover, the companies began to appreciate that increased earnings, both gross and net, could be secured by means of rate reductions.

When state legislatures in the case of national carriers and local councils in the case of local utilities attempted to adjust these rates downward, they were met by the objection that the change would violate a contractual obligation and confiscate the property of the companies. Only when the franchise was silent on rate questions or when the power to alter, amend or repeal the terms of franchises was reserved, could the power to regulate rates or service be exercised by state or local legislatures. Another evil that had crept into the administration of public utilities as a result of the ineffectiveness of rate control was discrimination in rates. This was also induced by the fact that competition had never been entirely eliminated. Added to this, in the case of the limited term franchises of local utilities, was the growing insecurity of tenure. Failing to obtain a renewal the properties would be worth only their scrap value. Often there were no provisions for public purchase or for purchase by some other grantee at the end of the franchise period. The inducement was too great, therefore, to manipulate operations so as to enable investors to recoup their capital out of earnings.

About 1870–80 a policy was adopted of fixing rates by direct legislation. Legislatures realized that statutory regulation should be general rather than specific; that the rate and service problems require continuous attention; that the subject matter of statutes should be the laying down of principles and standards; that the new policy of continuous regulation required an effective agency, sufficiently informed by experience to carry legislative standards and principles into effect. This agency is the modern administrative commission, acting as an agent of the legislature. All states except Delaware set up regulatory commissions with varying jurisdictions. The Interstate Commerce commission (1887), the Maritime commission (1938), the Federal Power commission (1920) and the Securities and Exchange commission (1935), were established as federal commissions to regulate the interstate operations of national utilities. The administrative commission applies the common law rule of reasonableness to the concrete facts in each case and names the particular rate or service regulation reasonable under the circumstances. Practically all states prohibited discrimination in rates for service. This legislative injunction was made operative in connection with another one calling for publicity of rates and providing that only rates and regulations on file and approved by the administrative authority are the lawful rates. In six states designated local utilities continued to be controlled by means of franchises.

Regulation of all public utilities was hampered by the insistence of the courts after 1898, when the epoch-making case of *Smythe* v. *Ames* was decided, upon defining the basis for rate-making which commissions might use. The major conflict was over the weight to be accorded reproduction costs as compared with actual original costs in the determination of the "fair value" of the investment. With the rise in the levels of prices, particularly after 1914, commissions were inclined to use the standard of actual investment costs while the utilities were contending for reproduction costs. In a series of decisions culminating in *McCardle* v. *Indianapolis Motor Co.* (272 U.S. 400, 1926) the courts upheld the position of the utilities. But the courts receded from this extreme position after the depression set in and in 1942 in *Federal Power Commission* v. *Natural Gas Pipeline Co.* (315 U.S. 575) conceded that the particular formula of rate-determination was within the discretion of commissions, so long as the result was not arbitrary or confiscatory. This decision definitely revitalized regulation by commissions.

REGULATION IN EUROPE

On the continent of Europe practically all of the telephone and telegraph systems and so many of the railroad systems became nationally owned and operated that there is little opportunity for the development of anything like the Anglo-American system of public utility control. This also holds true in a large measure of local utilities. Where local utilities are privately owned they are operated under franchise contracts with the municipalities.

Great Britain.—In Great Britain until 1948, railroads and so many of the local utilities were in private hands as to cause considerable development in policies of social control.

Regulation of public utilities in England was accomplished by the method of private bill legislation, a special act of parliament for each undertaking performing the double function of conferring a franchise and of laying down regulatory standards. Usually certain applicable general laws were by reference made a part of the special act, such as the legislation controlling the acquisition of land by condemnation as set forth in the Lands Clauses Consolidation act of 1845.

Other important general legislation was contained in the following: Railways Clauses Consol. act, 1845; Companies Clauses Consol. act, 1845; Waterworks Clauses act, 1847; Gasworks Clauses act, 1847; Harbours, Docks and Piers Clauses act, 1847; Tramways act, 1870; Electric Lighting (Clauses) act, 1899.

In certain cases of common occurrence special legislation by parliament establishing public service undertakings was made unnecessary by permitting some appropriate department of the government to issue provisional orders under general legislation after due inquiry. But full parliamentary control was retained by requiring confirmation of provisional orders, either by parliament itself or, in some cases, by an agency such as the board of trade, made effective by resolution of each house of parliament.

The English system of regulation was, accordingly, comparable to the charter or special franchise system in the United States. Legislation of this type were the Gas Regulation act of 1920, the Electricity Supply acts of 1919, 1922 and 1926 and the Railways act of 1921. The focal point of control was the regulation of rates. In the case of private gas companies the first method of control, after a brief preliminary period of competition, was the so-called "official revision system." Maximum rates and maximum dividends were fixed in special acts but the power to reduce rates was given to the court of quarter sessions.

Later another method, the system of sliding scales, was used, the adoption of which was optional. There was established a standard selling price for gas and a standard maximum rate of dividend. Then it was provided that the dividend rate might vary in inverse ratio to the rate of charge.

In order to bring about mergers and reorganizations in the electrical industry which would make possible the generation of electricity in large units and the attainment of greater economy and efficiency, the Electricity act of 1919 created a board of electricity commissioners of five members, appointed by the minister of transport with the approval of the board of trade. Most of the regulatory powers over electric undertakings vested in governmental departments were transferred to this body. On the whole the act failed to achieve its end because many public and private authorities refused to co-operate. Accordingly the Electricity act of 1926 created a central electricity board with power to carry the "scheme" prepared by the electricity commissioners into effect.

With the inauguration by the Labour government in 1945 of the policy of nationalization, the remaining segment of private ownership of utilities passed into the hands of the government. Communication facilities (postal service, telephones and telegraphs) had long been a government monopoly and operated by the central government previous to World War I. The war period added the cables and wireless services. The British Broadcasting corporation became a public agency operating all radio broadcasting.

World War I had demonstrated the need of further coordination and consolidation of railway transport. This was accomplished under the Railways act of 1921, when 123 companies were consolidated into four great regional monopolies. The period between World Wars I and II seems to have brought the realization that co-ordination of domestic water transport and highway transport with railway transport was necessary. Consequently, when all forms of domestic transportation were nationalized on Jan. 1, 1948, under a minister of transport, he was required to set up four regional railway executives, a dock and inland waterways executive, a road transport executive, a hotel executive and a London transport executive.

In electricity supply, although the Central Electricity board had succeeded in establishing the British grid and was by 1938

supplying more than 97% of the energy required by the distributing undertakings of Britain, local agencies, both public and private, were continuing to distribute this energy as formerly. Complete nationalization of all phases of electric supply was accomplished on April 1, 1948, with the establishment of a British electricity authority.

Integration of gas supply was much less extensive. When on July 30, 1948, an act nationalized the entire artificial gas industry of Britain, the properties of 1,056 gas utilities, both public and private, were transferred to gas boards set up for 12 separate areas. Some national co-ordination between them was to be achieved by requiring their operations to be co-ordinated with the National Coal board. Thus public monopoly and ownership had become the dominant policy in Britain as well as on the continent.

Continental Europe.—Similar movements to bring about the large-scale generation of electrical energy were also being pushed in Italy, France, Germany and elsewhere. In Germany public joint-stock companies were created, similar to the German Railways company, with the shares in the hands of the private companies and cities co-operating under the plan. By means of these so-called "mixed undertakings" it was planned to separate the technical administration and financial management from the political arm of the government, at the same time providing for flexibility in the economic area within which service was supplied.

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PUBLIC WELFARE LAW: *see* POOR LAW.

PUBLILIUS (less correctly PUBLIUS) **SYRUS,** a Latin writer of mimes, flourished in the 1st century B.C. He was a native of Syria and was brought as a slave to Italy, but by his wit and talent he won the favour of his master, who freed and educated him. His mimes, in which he acted himself, had a great success; he was perhaps even more famous as an improvisatore, and received from Caesar himself the prize in a contest in which he vanquished all his competitors, including the celebrated Decimus Laberius. All that remains of his works is a collection of Sentences (*Sententiae*), a series of moral maxims in iambic and trochaic verse, which has been much interpolated with later extracts.

The best texts of the *Sentences* are those of E. Wölfflin (1869), A. Spengel (1874) and W. Meyer (1880), with complete critical apparatus and index verborum; recent editions with notes by O. Friedrich (1880), R. A. H. Bickford-Smith (1895), with full bibliography; *see* also W. Meyer, *Die Sammlungen der Spruchverse des Publilius Syrus* (1877).

PUBLISHING. Publishing is the selection, reproduction and circulation of written matter. It is older than both printing and paper, though in modern times it has come to depend upon both. Printing from blocks was invented in China some time before the middle of the 9th century; printing from movable type was invented there by the middle of the 11th century. But at neither time was printing thought of or encouraged other than as an excellent device for avoiding the errors of transcription that often marked the work even of the best manuscript scribes and copyists. In Europe, printing from movable type was invented by the middle of the 15th century. But there, as in China, its major advantage over older methods of reproduction was thought to be the standardization of scripture and of official texts. Neither in Asia nor in Europe was printing viewed at first as being useful in the wide dissemination of literature, learning or political or religious discussion. As an instrument of publishing, indeed, printing had to fight its way; it became a great instrument of spiritual and intellectual development and theological and scientific discourse, but the earliest reaction, which persisted for centuries in the west as in the east, was one of opposition by church, government, university or other powerful interests, such as the Brahmin caste in India, to its use in giving wide publicity to certain ideas and information.

The Earliest Books.—Before the invention of printing and of paper, publishing was carried on by means of professional scribes or skilled slaves making numerous transcriptions of manuscripts on papyrus or parchment. Flourishing industries producing papyrus or parchment rolls for sale on which were inscribed the classics of ancient literature, religion and law were to be found in Egypt under the Ptolemies and in the major cities of Greece and republican Rome. Often under the Roman empire, as often under later western kings, princes, parliaments and presbyteries, censorship and intimidation controlled or attempted to control publishers' output, thus interrupting the continuous history of commercial publishing for long stretches. Yet these ancient enterprises were authentic prototypes of modern publishing houses. Their work consisted in selecting manuscripts for reproduction in quantity, in taking the risks of compensating authors in advance of public sale for rights to such manuscripts, in determining the size, price and format of editions of different titles, and in developing markets in which such editions could, by various means, profitably be sold. They were publishers in every modern sense of the word, even though their products were not yet books.

Books in the form with which the world has long been familiar, that is, made up of pages bound together at one side, had a long and obscure development of their own. By the 4th century the bound book had become moderately well-known, at least among the jurists of the later Roman empire. Its first real vogue, however, was in Ireland, two or three centuries later, the climax of the remarkable flowering of intellectual and religious spirit there being the Book of Kells, not infrequently mentioned, according to one authority, as "the most beautiful book in the world."

To distinguish it from the old *volumen,* or roll (from which, oddly enough, the word "volume," often used interchangeably with "book," is derived), the early bound book was called a codex. The codex became the typical book of the middle ages, and theological codices were produced in large quantities especially in the monasteries of various church orders, which were the publishing centres of the day. Codices in law, medicine, rhetoric and other fields of learning came from the rising universities which, in certain cities, early grasped control over the publishing industries from the church and the state. In such centres, the second-hand market was as well-known to mediaeval students as it became to those of the 20th century and to 20th-century textbook publishers as well. The difference was that the universities, as publishers but not commercial ones, strove (in these early efforts at price-fixing which became such a feature of publishing in the 20th century) to keep prices down for the students and thus encouraged the use of old copies. This also relieved the universities of producing large new editions every year.

The codex, of course, like the papyrus and parchment rolls that it replaced, was written entirely by hand. In the scriptorium or "writery" of the monastery, scribes more or less devoted to their work toiled during the daylight hours (fear of fire from artificial light prompted the monasteries to forbid work on books at night) copying page after page of ancient classics, thus laboriously accomplishing the great task of preserving them as well as the Bible. "After the scribe had finished his quaternion, or group of four sheets in eight leaves," writes Douglas C. McMurtrie, "his work was proofread in comparison with the original by a second person, and the sheets were then sent to the rubricator, who inserted titles, headlines, chapter and other initials, notes, and the like. If the book was to be illustrated, the sheets next went to the illuminator. After he had completed his work on the volume, it was ready to be bound." This procedure was not very different, in essence, from manuscript preparation in a modern publishing house—except that with modern printing and illustrating methods, these and related publishing tasks need be performed only once for an edition of many thousands, and not over and over again for every individual codex or book.

Printing and Publishing in Modern Europe.—Though the early history of publishing owes nothing to printing, Johann Gutenberg's invention of printing from alphabetical type gave a great boost to publishing in Europe after the middle of the 15th century. Gutenberg probably was not the first European to use movable letter type successfully. After his epochal achievement, however, Mainz, his home in Germany, became the indisputable

publishing centre of the continent, and Germany itself the source and fount of subsequent printing and publishing developments in the western world. Before 1500 about 30,000 books were printed in Europe; of these, more than two-thirds came from such great German centres of learning as Leipzig, Cologne, Basel, Nuremberg, Augsburg and Strasbourg. More important, it was Germans, trained in these cities, who introduced modern printing and publishing into Italy about 1460, where it played an important part in the spread of Renaissance culture and trade. Similarly, it was Germans, trained in turn in Italy, who carried the printing industry and modern publishing to France in the early years of the 16th century.

It was only then that a broadening of the lay market for books took place. In 1501 Aldo Manuzio designed the first books in small format, which eventually replaced the huge, elaborate and costly codex, just as the codex had replaced the awkward *volumen*. In succeeding decades, especially in France, much attention was given to typography, and names still commonly used for type faces in the 20th century became well-known, from the work, for example, of Claude Garamond and Robert Granjon. A customer of both of these typographical artists, Christophe Plantin, was the most famous of the early printers who became publishers. Born in France in 1514, Plantin fled from Paris in 1548 to escape religious persecution. He settled in Antwerp, Belg., and there made his fortune. In the end he returned to the good graces both of the church and the university, gaining from the Holy See the monopoly of publishing liturgical books for the Spanish empire, and becoming late in life, printer to the University of Leyden, itself a great publishing centre of the time.

Though many early printers remained faithful to the church and to their princes, the publishing of printed works quickly became one of the major means of organizing protestant and radical opinion in the late 15th and early 16th centuries. This naturally led to reprisals against the new publishing industry, especially in Germany, and in self-defense the publishers and printers organized into independent corporations and guilds of their own. These lasted until the 19th century in many countries. Where printing and publishing was not shut down or forced underground, as was the case in Nuremberg and Augsburg early in the 16th century, it was controlled by other means. Thus in France, as early as 1474, the new independent printers and their printed books were brought under the same licensing regulations by which the University of Paris alone had monopolized the work of the old scribes and the publication of their manuscripts. This was indeed a signal recognition of the rapid rise of the printer to publishing eminence; yet it was also an onerous burden to the new publishers who were out of sympathy with officialdom.

Between them, official controls on the one hand and guild restrictions on the other impeded the development of printing and publishing for centuries. On the continent, one result was the emigration of printers and publishers to England where, from 1476 to 1536, it is estimated two-thirds of all printers, binders and stationers were aliens. But even in England from 1534, when the Stationers company or guild was first organized into the monopoly of all English book publishing, to 1710, when the first copyright act was passed in the reign of Queen Anne, there was constant harrassment of publishers, which, in due time, was carried across the ocean to America as well. It was on an occasion during this epoch, when some freedom of publishing, bitterly won, was challenged by new efforts at control, that John Milton wrote his *Areopagitica* in 1644.

In France, control was more or less thorough until the revolutionary copyright law of 1793 freed publishing and printing from all existing monopolies. This freedom was short-lived, however, ending under Napoleon's First Empire and not restored until the declaration of the republic in 1870. French restrictions had a salutory effect on the publishing industries in the Netherlands and Belgium where, during the 17th and 18th centuries, large editions of the works of Molière, Boileau, Voltaire, Rousseau and others were issued clandestinely for the French market.

As is usual with excessively rigorous controls, they often were poorly enforced; and as is usual with official monopolies, they often bred strong, if *sub rosa*, competition. Both of these situations, whatever the prevailing atmosphere, permitted printed literature and learning to spread rapidly in Europe between the 16th and 20th centuries, and authorship and publishing to flourish because of it. The English Copyright Act of 1710 freed the individual author and enterprising publisher from monopolistic printers and recognized the right of both to negotiate for the best royalties and other terms for the publication of literary property. But this right had been recognized as early as Roman times, when publishers of the empire bid competitively for the exclusive privilege (for which they paid fees, not royalties) of duplicating literary creations. What was significantly new about the English act was its recognition of the right of the whole public to literary property after a specified term. That is the nub of modern publishing copyright; it protects authors in their rights to literary property and publishers in their acquisition of such rights; but more than that, it gives the public, increasingly eager for great published works, freer access to such property after a limited number of years—under Queen Anne's act the term was 14 years, with the author retaining the privilege of renewing for another 14 years; in the United States in the 20th century, it was 28 years, with the same privilege for another 28 years; in most other countries, the term is the remaining years of the author's life, plus 20 to 50 years.

The development of copyright practice since the early 18th century is an authentic clue to the growth of professional authorship and commercial publishing, and by the protection it affords, a stimulus to both. But it is more than that. It is also an authentic clue to the growing thirst for access to literature and learning among the populace who, with the centuries, became more and more literate. Roman usage and common law had acknowledged the author's right—if he could assert it—to his property in perpetuity. English and later continental statutes freed this property for public use after protecting the author and publisher for specified periods of time.

Toward Contemporary Publishing Practice.—Just as the monasteries gradually yielded their monopoly of publishing to the universities, and the universities to the corporations and guilds, and the guilds to the competitive printers, so the printers, under the pressure of this growing market for literary works, gradually surrendered their dominant position to the booksellers.

None of these transitions took place in a day. Even as early as the 1580s in England, the pressure of costs for printing equipment and the like forced printer-publishers to appeal to booksellers for capital and credit. Thus in 1582 Christopher Barker complained to the queen: "The booksellers being growen the greater and wealthier number have nowe many of the best Copies and keepe no printing howse, neither beare any charge of letter, or other furniture but onlie paye for workmanship . . . [with] the artifice printer growing every daye more and more unable to provide letter and other furniture, requisite for any good worke; or to gyve mayntenaunce to any such learned Correctours as are behovefull. . . ." Yet it was not until the 18th century that the bookseller had his great day as publisher. By then the reading public, especially in England, was growing much faster than before and trade in popular new books (as distinct from the earlier staples of the whole industry: Bibles, commentaries, textbooks, dictionaries and the like) was booming. To meet the new demands circulating libraries were established as early as the 1720s, and new authors were developing sufficiently large popular followings to be able to insult and dispense with their former aristocratic patrons. By the late 18th century booksellers whose names continued to adorn modern publishing houses as late as 1950—such as Constable and Longmans—had already become kingpins of the publishing industry. Only a few decades later in the new world itself, Harper, Scribner, Dutton, and Little, Brown had become well-known.

Thus, with the rise of the bookseller, contemporary publishing began, and with the more or less simultaneous rise of the novel and the novelist it flourished. Both developments reflect the ascendancy of the middle classes, and thus had their greatest vigour in England and America. They followed more deliberately

on the continent, where literacy was slower to become nation-wide and where extremes of wealth and poverty kept the middle class markets small.

The unity of bookselling and publishing, in turn, persisted far longer in England than in the United States, where the great development of new writers (after piracy of English titles was successfully abated late in the 19th century) gradually stimulated the creation of independent publishing houses which were neither printers nor booksellers. This change in turn brought with it new independent printers, binders and booksellers—the first two to produce, under contract, books arranged for by the new publishers; the second to sell those books to the ever growing public.

By the third decade of the 20th century still newer publishers appeared in numbers in England and the United States and in Germany and France on the continent, devoted almost exclusively to so-called trade books—that is, general books of fiction, popular biography and history, books of memoirs and inspirational psychology, books of sentiment and sentimental learning. Many houses among the older group and some among the newer ones as well continued to have all kinds of special departments for Bibles, other religious books, school and college textbooks, medical books and similar works that once were the foundation of the entire publishing industry. But the newer vogue was the trade publisher as such. The age of specialization had indeed set in, and nowhere more strongly than in the United States, where the industry was less encrusted with old traditions and thus afforded the most suitable soil for the new flowerings.

The Age of Specialization.—In the 20th century in the United States, as elsewhere, the number of new titles published each year grew steadily, except for dips in war years or their immediate aftermaths. At their peaks, about 35,000 new titles were published in Germany, 15,000 in Great Britain and 12,000 in the United States. These figures are not altogether commensurable; the definition of a book, almost since the time of the Romans, has always remained vague, and the categories for calculation in Germany, for example, were much broader than those used by the United States census. Even the United States census bureau has altered its definition of a book from decade to decade.

But whatever the actual figure, the relative size of the industry in the 20th century can be judged by comparing even its smallest annual volume of titles with that of earlier centuries. In the first half of the 18th century in England, for example, it has been calculated that the average annual number of new titles was about 93. The first quarter of the 19th century saw a jump to an average annual total near 600. This, as has been said, was reflected by the growth of the publishing industry itself. By comparison, the 20th-century totals make it clear why specialization in publishing could so readily be supported; indeed, they make it clear why specialization had to come.

Within trade publishing itself, moreover, again notably in the United States but not only there, the 20th century saw the development of hard cover reprinters, paper cover reprinters, specialized western story and detective story publishers, science-fiction publishers and others who profited greatly by concentrating on special books for special, but sufficiently large, markets. In distribution, moreover, the old fashioned bookseller—even the one who himself came to specialize in trade books—was supplemented by the book club, by other types of mail order houses and by the ordinary newsstand which accounted for the bulk of the sales of the paper cover reprints. How important these new avenues of distribution became is indicated by the fact that while most regular trade publishers still ordered editions ranging from 3,000 to 10,000 copies for most of their titles, for book clubs and paper cover reprinters editions often ran to more than 100,000 copies and not infrequently for the latter to more than 200,000 copies. Clearly the old middle class market had become, by the middle of the 20th century, a mass market, especially but not only in the United States. In England, where between World Wars I and II and after, the Penguin-Pelican series set such a high editorial standard, and in the United States, some of the publishers of cheap paper-covered books sought out and issued original works. In the main, however, those publishers, like the book clubs and others selling in mass markets, continued to look to the regular publishers for titles to reprint. Thus literary production in the form of books, and hence the literary health of their countries, remained such publishers' responsibility throughout.

Some bore it better than others, but virtually all sought to share it. To discover manuscripts for this publishing industry, new occupations thus became prominent after the first quarter of the 20th century. Two of these were most important: the manuscript scout, who often worked for publishers under contract by which his remuneration was a stated percentage of the retail price (usually ranging from 1% to 2%); and the literary agent, who universally worked for authors, handling all their business relations with publishers for compensation in the form of 10% of the author's royalties and other income from his literary production. The growth of the agency business reflected further specialization in the publishing industry by which the publisher, becoming more a business manager, passed over his editorial functions to others. It also reflected the broadening of the market for the work of authors, especially authors of fiction. In the 20th century to the old magazine and newspaper serial rights were added moving-picture rights, dramatization rights, radio rights, television rights, digest rights and a series of others, the sale of which required complicated negotiations and contracts and which, however much it might enrich them, most authors were themselves incompetent to handle.

In facilitating distribution of books, further specialized agencies appeared in many countries in the 20th century. These were advertising agencies, some of which merely added books to all the other products for which they sought to stimulate demand, others concentrating on books alone. Though in Germany the amount of money spent for the promotion of books remained less than 5% of the publisher's net return, and though in England it never rose much higher than that figure, in the United States 8% to 10% was a more likely figure, and for books with great sales expectations it often rose well above that amount. The spending of this money most effectively required skill and experience which the publisher often did not have; thus the development of advertising agency business in books.

Though trade books were the fastest growing part of the whole publishing industry in the 20th century, and paper cover reprints the fastest growing part of trade publishing, growth elsewhere also added measurably to the flow of books. Especially notable in the United States was the growth of the federal government as publisher—a development that reflected not only the rapidly increasing number of all kinds of government investigations, but also the growth of federal services to farmers and others not ordinarily reached by regular publishers and regular means of book distribution. Far smaller in volume was the production of the American university presses. Their work was largely in books of importance to science and learning which would, without the vigour of these presses, probably have gone unpublished and thus unknown.

All told, in 1945, according to the United States census bureau, almost 500,000,000 copies of books were printed in the United States alone. The history of the technological improvements in printing that made such production possible is a long one in itself, including the history of such familiar machinery as linotypes, cylindrical presses, rotary presses and attachments to them. Most of these came in around the turn of the 20th century; subsequent great improvements in their performance allowed them to keep up with the demand for books.

In the 20th century, moving pictures, radio entertainment, television broadcasts, the automobile, the massive illustrated magazines and other vehicles of entertainment and enlightenment occupied the attention of growing populations. All competed with the traditional book; but the book publishing industry itself enjoyed the most remarkable growth in its long and troubled history. In mid-century it was rising on the continent once again from the devastation of two wars. In the United States it remained one of the major channels of communication, one of the major forums from which were fed the spirit and the intellect,

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(WI. MR.)

Subscription Books.—One of the widest and most extensively developed methods of distributing books is by subscription: sales are assured by the canvassing and pledging of subscribers. Today reference works of all kinds—encyclopaedias, sets of children's books, some dictionaries, collections of popular novels—are distributed almost solely by this method and the value of the sales in the United States and elsewhere amounts to many millions of dollars.

Sales by subscription, it is believed, began in the 15th century when William Caxton is said to have initiated this method to finance the publication of *Mirror of the World.* The purpose was to ensure moneys for the production of this work and differed from the traditional practice, of having one sponsor or patron for the book, by enlisting the interest and money of many.

The idea proved attractive to printers and to authors but it was not until the turn of the 17th century that this form of distribution flourished. In most instances, the issue remained a single volume and the cost of production was assured by the persons who promised to buy the book. The method fell into disrepute after a time when some printers, selling a book in advance of publication, sold trash or no book at all.

In the 18th century larger sets of books were distributed by subscription. *Encyclopædia Britannica* in 1768 was one of the first. In some instances, where the cost of the initial production is excessive, prepublication offers are made and subsequent sales are continued under instalment or, as it is known in Great Britain, the hire purchase plan. Mark Twain in the United States adopted this idea for the distribution of Gen. Ulysses S. Grant's *Memoirs.* Albert Bigelow Paine says in his monumental biography of Mark Twain, that Twain was able to present General Grant, who needed it, the largest single royalty check, $20,000, ever given to an author up to that time, and, of course, before the volumes actually were made.

Perhaps the greatest recent venture in prepublication subscription was the publication of *Great Books of the Western World* in 54 volumes by Encyclopaedia Britannica, Inc., in 1952. It was the generosity of 500 founder prepublication subscribers which facilitated the general distribution of this costly work.

According to the American Textbook Publishers institute the subscription sales of reference books to homes and offices and to schools and libraries in the United States alone were estimated at more than $75,000,000 for the year 1950.

PUCCINI, GIACOMO (1858–1924), Italian operatic composer, was born at Lucca on June 22, 1858, of a family already distinguished in music: his great-great-grandfather Giacomo, great-grandfather Antonio, grandfather Domenico, and father Michele, having all been professional musicians. He was educated at the Milan conservatoire where he studied under Ponchielli. In 1889, *Edgar* was performed at La Scala, and in 1893 his *Manon Lescaut* in Turin. The former, based on *La Coupe et les lèvres* of Alfred de Musset, was a failure, but the latter, founded on the well-known story of the Abbé Prévost (which had been previously treated by three other composers, Halévy, Auber and Massenet) was favourably received, and still holds the stage. Its success was as nothing compared with that of the work which followed it, the sparkling *La Bohème* (Turin, Feb. 1, 1896). The libretto is based on Mürger's novel from which four scenes are taken, and the skill and resource and effectiveness with which they are treated leave no room for doubt as to the merits of the work. In *La Tosca* (Rome: Jan. 14, 1900), based on Sardou's tragedy, Puccini had an altogether different task, of which, however, he acquitted himself no less successfully. The work contains some of the strongest and most genuinely dramatic music which he ever wrote, and like *La Bohème* has enjoyed unlimited popularity at the hands of the general public from the first.

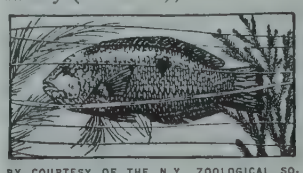
Madame Butterfly, on its first performance at La Scala on Feb. 17, 1904, was pronounced an absolute failure. Probably the libretto of the opera, with its unusual setting in Japan, had at least as much to do with this result as its music, but the Milan public's unfavourable verdict was reversed when the work was heard again at Brescia three months later, and since then its popularity has been prodigious and world-wide. If equal success did not attend its successor *La Fanciulla del West* (The Girl of the Golden West), this was accounted for by the unsatisfactory character of its "book" and by the undoubted inferiority of its music, so that the work, though favourably received when first performed in New York (Dec. 10, 1910), has never found general favour. Of the one-act operas *Il Tabarro, Suor Angelica* and *Gianni Schicchi,* which followed, all contain clever and characteristic music, but only the third, based on a most amusing libretto, has kept its place in the general repertory. As regards *Turandot,* the composer's last work, which he had not quite finished at the time of his death, and which was completed by Alfano, and produced at La Scala on April 25, 1926, critical opinion has been sharply divided. While some condemn it severely, others reckon it the composer's finest achievement. Puccini died at Brussels on Nov. 29, 1924.

See A. Weissmann, *Giacomo Puccini* (Munich, 1922); A. Fraccarroli, *La vita di G. Puccini* (Milan, 1925); and Wakeling Dry, *Giacomo Puccini* (*Living Masters of Music*) (London, 1906); V. J. Seligman, *Puccini among Friends* (1938); R. Specht, *Giacomo Puccini, the Man, His Life, His Work* (1933).

PUCHTA, GEORG FRIEDRICH (1798–1846), German jurist, was born at Kadolzburg in Bavaria on Aug. 31, 1798. His father, Wolfgang Heinrich Puchta (1769–1845), was a legal writer and district judge. From 1811 to 1816 Puchta attended the gymnasium at Nuremberg, and in 1816 he went to the University of Erlangen, Bavaria. Taking his doctor's degree, he established himself there in 1820 as *privatdozent* (teacher recognized by the university) and in 1823 was made professor extraordinary of law. In 1828 he was appointed ordinary professor of Roman law at Munich; in 1835 he took the chair of Roman and ecclesiastical law at Marburg. But he left that post for Leipzig in 1837, and in 1842 he succeeded Friedrich von Savigny at Berlin.

In 1845 Puchta was made a member of the council of state (*Staatsrat*) and the legislative commission (*Gesetzgebungskommission*). He died in Berlin on Jan. 8, 1846. His writings include *Lehrbuch der Pandekten* (Leipzig, 1838), in which he elucidated the dogmatic essence of Roman law, and the *Kursus der Institutionen* (Leipzig, 1841–47), which gave a clear picture of the organic development of law among the Romans. Other works were *Das Gewohnheitsrecht* (Erlangen, 1828–37) and *Einleitung in das Recht der Kirche* (Leipzig, 1840). Puchta's *Kleinezivilistische Schriften,* a collection of 38 essays on various branches of Roman law, was published posthumously in 1851 by A. A. F. Rudorff. The preface contained a biographical sketch of the author.

PUDDINGWIFE. A tropical American fish of the wrasse family (Labridae), called also doncella. It has a deep, compressed body, which is covered with large scales except on the head, has strong canine teeth in the front part of the jaw, and attains a length of 18 in. In colour the puddingwife is a vivid blue-green tinged with bronze or soft orange, though varying somewhat with sex and age. Spots and streaks of blue, especially on the head, fins and through the eye, add to its attractive appearance.



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THE PUDDINGWIFE (IRIDIO RADIATUS), A TROPICAL FISH

PUDSEY, a municipal borough in the Pudsey and Otley parliamentary division of the West Riding of Yorkshire, England, served by the North-Eastern Region railway. Pop. (1951) 30,276. Area, 8.3 sq.mi. It has an important woollen trade and dyeing

and fulling mills. It was incorporated in 1900 and considerably enlarged in 1937.

PUDUKKOTTAI, a former princely state of southern India, lying between Tanjore and Madura districts of Madras, with which it was merged in 1948 as part of the Trichinopoly (*q.v.*) district. The area of the state was 1,185 sq.mi. Pop. (1941) 438,348. The chief, whose title was *tondaman,* was of the Kallan or robber caste. His ancestors received a grant of territory for loyal services to the British during the wars in the Carnatic at the end of the 18th century.

The town of Pudukkottai had a population in 1951 of 44,527. It is well laid out with several fine public buildings. A college affiliated to Madras university and a training school were established there.

PUEBLA, an interior plateau state of Mexico. Pop. (1950) 1,595,920. Area, 13,122 sq.mi., with its capital at Puebla (*q.v.*). On the southeast corner of the Anáhuac plateau, Puebla varies in elevation between 5,000 ft. and 8,000 ft., with numerous fertile valleys formed by the Sierra Madre Oriental which runs through the state. Endowed with a temperate, semihumid climate, crossed by main highways running southward from the national capital, and traversed by railway lines, Puebla is one of the most densely populated and important states of Mexico. Its strategic location and natural endowments in pre-Hispanic times are attested by innumerable archaeological sites and by its many towns and villages, notably Cholula, Atlixco and Tehuacán. Coffee, sugar cane, fibres, maize and cereals are its main crops, while onyx, gold and other metals occur in its richly veined mountains. Numerous short, fast rivers provide hydroelectric power. Its Nahuatl-speaking native peoples were highly developed at the coming of the Spaniards in the 16th century, and the latter founded many estates in this region, a main focus of their religious and economic activities. In the 19th and 20th centuries Puebla developed as an agricultural-industrial area in the important corridor between Mexico City and its main seaport at Veracruz. (Hd. C.)

PUEBLA, fourth city of Mexico and capital of the state of the same name (*q.v.*). Pop. (1950 est.) 140,000. It is in the centre of an important agricultural and industrial region of central Mexico. On highways to the federal capital (80 mi. N.) and main rail routes to the south and the Gulf of Mexico, Puebla is a metropolitan area which is considered the military key to the national capital and has been a commercial hub since pre-Spanish times. The city, founded by Spaniards in 1532 and named "Puebla de los Angeles," is on a broad healthful plain at 7,050 ft. above sea level in foothills of the Sierra Madre Oriental, within view of Mexico's three highest snow-topped volcanoes, Orizaba (18,696 ft.), Popocatepetl (17,883 ft.) and Ixtaccihuatl (17,338 ft.). It is a modern city whose historic and economic significance changed but remained dominant over many centuries.

Often termed the "Rome of Mexico" Puebla's architecture is notable and characteristic. Its cathedral is one of the largest and most sumptuous in Latin America, one of innumerable churches that testify to local piety. Puebla is renowned for manufacture of Talavera tiles and ware and other glazed tiles used locally and throughout Mexico for decoration. As the second most important city of colonial Mexico, Puebla has numerous historic public edifices. Notable are its Teatro Principal (1790), one of the first permanent theatres in the hemisphere. The impressive state legislative halls, municipal offices and main buildings around the public square date from independent Mexican times.

Supplied with electric power and centrally located, Puebla is a brisk industrial centre and has a long tradition in the manufacture of cotton and woollen textiles, glass, soap, pottery, leather goods and other light articles. Its onyx working is a specialty. Numerous small shops commingle with modern factories and foundries.

As the seat of a bishopric since 1550, raised to an archbishopric in 1903, Puebla is conservative and Catholic. A school of medicine, an academy of fine arts, a national university, and the Palafox collection of more than 100,000 volumes are significant landmarks. The city was named Puebla de Zaragoza after Gen. Ignacio Zaragoza (1829–62) who defended it against the French in 1862 in one of countless battles fought over this important place. (Hd. C.)

PUEBLO. The agricultural, town-dwelling Indians of the semidesert southwestern United States. They are of four distinct linguistic groups: (1) Shoshonean, comprising the seven Hopi (*q.v.*) villages in Arizona; (2) Zuñi, one town in western New Mexico; (3) Keres, comprising Acoma (*q.v.*), Laguna, Sia, Cochiti, Santa Ana, Santo Domingo, San Felipe, all but the first two in the Rio Grande valley; (4) Tano, consisting of three divisions, all near the Rio Grande; (*a*) Tiwa, five towns, of which Taos is the most northerly and best known; (*b*) Tewa, six pueblos (including Hano among the Hopi); (*c*) Jemez. The aggregate population is not far from 10,000, stationary or slowly decreasing, and approximately equally divided between the four speech groups. At the discovery in 1540 the Hopi, Zuñi and Keres may have been twice, the Tano three or four times, as numerous as to-day; the number of towns has also decreased, though some new ones have been founded. The Pueblos live on ancestral lands and cultivate these much as in the prehistoric period, though they have added wheat to maize and acquired some sheep, cattle, horses and asses; their houses, though larger, are of the old type; their religion has been successfully maintained by the Hopi and Zuñi and partly preserved alongside Roman Catholicism by the Keres and Tano. They are peaceable, gentle, unenterprising, quietly industrious and conservative. Physically they are fairly uniform; below average in stature, generally brachycephalic, with the skull somewhat flattened occipitally from the cradle board.

Of all the tribes of the United States the Pueblos are most similar to the advanced native peoples of southern Mexico, and the bases of their culture—maize-beans-squash agriculture, cotton growing and weaving, turkey rearing, painted pottery, masonry architecture, ritualism—are no doubt derived from these Mexican civilizations. They lack, however, a number of accomplishments characteristic of the Aztec, Toltec and Maya, such as metallurgy, political organization, calendrical system, ideographic writing, temples and pyramidal substructures. Since some of these traits have an age of about 2,000 years, the main influences emanating from Mexico are likely to have reached the Pueblos perhaps as much as three millennia ago.

South-western archaeology reveals a development through several stages: (1) Basket maker, possessing maize but apparently no other cultivated plants; no pottery or stone houses; spear thrower, but no bow; the physical type was long-headed. (2) Post-basket-maker, with crude pottery, slab-lined pit houses, the bow and arrow. (3) Proto-Pueblo, with the short-headed type which has persisted to the present; masonry, painted and neck-corrugated pottery, cotton, the turkey, the essentials of historic Pueblo culture, are already present. (4) Early Pueblo, in small house clusters; black-on-white and body-corrugated pottery; this is the era of most of the cliff dwellings and of the greatest geographical extension of Pueblo culture, ruins in Nevada and well north in Utah belonging to this period. (5) Great Pueblo period, with large towns like Pueblo Bonito and Aztec, centring in the San Juan drainage; the northernmost area had been given up, but the ruins in Chihuahua, like Casas Grandes, seem to be of this epoch. (6) Late Prehistoric Pueblo, with glaze-painted pottery; the San Juan area, and Chihuahua extension had been given up, but there were still Pueblos on the middle Rio Grande near El Paso. The Spanish discovery of 1540 falls in this period, which may be assumed to have continued until the influence of the missions became strong in the early 17th century, or until the general Pueblo rebellion of 1680. (7) Historic Pueblo, after the unsettlement caused by the rebellion; pottery is again painted instead of glazed, but both black-on-white and corrugated ware are long since forgotten; domesticated mammals have been introduced and sheep's wool tends to take the place of cotton for clothing.

In general, the Pueblos did not irrigate, although they knew how to choose farmlands containing sub-soil water. They are matrilineal and matrilocal, women owning the houses; but men order all public and religious matters. On the Rio Grande the clans weaken and moieties appear, until in the extreme northern towns

clans are, to-day at least, lacking. The religious edifice is the kiva, Spanish estufa, a small semi-underground structure for the performance of esoteric rites. Temporary altars are erected in these, often with ritualistic sand or meal paintings; feathers are "planted" as offerings at outdoor shrines; and for all religious organizations, offices and clans there are fetish bundles. The mythology is characterized by tales of emergence from the lower world and long tribal wandering. Cults take three chief aspects: (1) Youths are initiated into a communal men's society performing masked dances representative of gods and ancestors—kachinas. (2) Men and women are initiated individually into "fraternal" societies whose main function is curing, although there are also war and hunt societies; masks are little used. (3) Hereditary priests fast, entreat and pray for rain for the crops and communal welfare, and ultimately direct not only all religious affairs but the civil officials. Ritual symbolism is rich, especially as regards the idea of fertilization and number-colour-direction symbol patterns.

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PUEBLO, a city of Colorado, U.S., on the Arkansas river at the mouth of Fountain creek, 112 mi. S. by E. of Denver, the county seat of Pueblo county and the second city of the state in size. It is on federal highways 50 and 85 and is served by the Colorado and Southern, the Colorado-Kansas, the Denver and Rio Grande Western, the Missouri Pacific and the Santa Fe railways. Pop. (1950) 63,685; (1940) 52,162. It lies at an altitude of 4,690 ft., near the coal fields of the state and many of the metal deposits, in an irrigated region of 50,000 ac., which produces 65% of all the cucumber seed grown in the U.S. and great quantities of red clover, cantaloupe, squash and onion seed. San Isabel National forest (600,000 ac.) is 20 mi. to the south and west. Pueblo is an important manufacturing centre. At Minnequa, on the mesa south of the city, is the plant of the Colorado Fuel and Iron corporation, Colorado's largest industry, employing 8,000 in the Pueblo mills, 5,000 men in mining and 5,000 in the manufacture of iron and steel. There are plants for meat packing, brooms, brick, tile, tents, awnings; also foundries and machine shops and a piston manufacturer. Pueblo is the seat of the state hospital for the insane (established 1879), and is the home of the Colorado state fair.

In 1806 Lieut. Zebulon Pike and his exploring party camped at the confluence of Fountain creek with the Arkansas ("The Forks," he called it), and the spot was visited by Maj. Stephen Long in 1820. A band of Mormons settled there temporarily in 1846–47 on their way to Utah. In 1850 a trading post was established. In 1858 a settlement (Fountain City) was made on the east side of Fountain creek, and the following winter (1859–60) the townsite of Pueblo was laid out and the first house was built on the site of the present city. Regular stage service to Denver began in 1862 but development was slow until the Denver and Rio Grande railroad reached the Arkansas in 1872. The two pioneer settlements were consolidated and chartered in 1870, when the population was about 500. By 1880 this had grown to 3,217. Other railroads reached the city in 1875, 1887 and 1888; the Colorado Coal and Iron company had its steelworks in operation in 1881; and in 1890 the population of the city was 24,558.

PUENTE GENIL, a town of southern Spain, in the province of Cordova; on the right bank of the river Genil or Jenil, a tributary of the Guadalquivir. Pop. (1940) 22,309 (mun., 27,552). It is on the Cordova-Malaga railway and is the starting point of the line to Linares. A bridge across the Genil, from which the name of the town is derived, joins the lower part of Puente Genil with the higher. The principal industry is the manufacture of olive oil. There are also flour mills and linen factories.

PUERPERAL FEVER, a medical term implying infection of some part of the genital passages following childbirth or abortion. The infection is most commonly of the raw surface inside the womb left after separation of the afterbirth, but pathogenic organisms may also gain entry through laceration of the mouth of the womb or other parts of the birth canal and may invade the blood stream, causing septicaemia.

History.—The disease has been recognized from the earliest days, and some of the greatest names in medicine have contributed to its study. In the 5th century B.C. Hippocrates stated, "If a woman in childbed have erysipelas of the womb she will usually die"; and this truth was manifest in the appalling mortality from the disease that persisted down to the 1930s. William Harvey (1651) was the first to describe the raw placental site as "one vast ulcer" in cases of puerperal fever. Charles White of Manchester, Eng. (1773), drew attention to the identity of puerperal and "surgical" fever; advised postural drainage of the womb in the lying-in period; and, by his vigorous insistence on cleanliness in the conduct of deliveries and on isolation of cases of puerperal fever, made a famous advance in the art of midwifery. Alexander Gordon (1795) noted that puerperal fever was a contagion, since it seized only such women as were visited or delivered by a practitioner or nurse who had previously attended patients affected by the disease. Jean Louis Baudelocque (1789) noted the greater incidence of the disease when hands or instruments had been introduced into the birth canal. I. P. Semmelweiss (*q.v.*) of Vienna (1847) rediscovered White's teaching and, noticing that the mortality from the disease among women attended by doctors and students who also practised dissection upon cadavers was far greater than among the women delivered by midwives, strenuously advocated washing of the hands in antiseptics before attending women in childbed.

During all this time, contagions were held to lurk in "humours" or miasmata which affected the air and the clothing and were thus borne from patient to patient directly or by an attendant. But in 1879 Louis Pasteur demonstrated a dotlike microorganism grouped in short chains which he had isolated from the lochial discharge of a woman with puerperal fever, and the bacteriological era of the study of disease had arrived.

These streptococci (*Streptococcus pyogenes, S. haemolyticus*) are only one, although the most deadly, of the causes of puerperal fever; others uncovered later are the anaerobic streptococci (which flourish in dead and dying tissues such as are to be found in the genital tract after long and injurious labour and difficult or injudicious instrumental delivery); the *Bacterium coli* and *Clostridium welchii,* inhabitants of the lower bowel; and various staphylococci commonly found on the skin and in skin eruptions of a pustular nature. Many of these organisms can be demonstrated in the vagina during pregnancy, and for some time the endogenous or autogenous theory of puerperal sepsis excused the neglect of rigid antiseptic precautions by the attendants of labour on the grounds that pathogenic germs were already present in the birth canal. However, in 1930 Leonard Colebrook stressed the fact that the anaerobic streptococci do not assume dangerous significance unless provided with the medium of bruised and lacerated tissues in which to grow and multiply and that such a development could be avoided by the utmost skill and gentleness in operative obstetrics.

In 1935 Rebecca Lancefield (U.S.) and Ronald Hare (England) showed that the haemolytic streptococci causing severe puerperal fever, scarlet fever, dangerous wound infections and tonsillitis were all of an easily identifiable group (A) which were not found in the normal birth passage before labour. Leonard Colebrook and his sister, Dora, then showed that in a series of cases of puerperal fever caused by the haemolytic streptococcus the infection had been conveyed by medical and nursing attendants or by other contacts who harboured the organisms in nose or throat. Thus was established overwhelming proof that puerperal fever is an easily preventable infection.

Infection and Symptoms.—The severity of the disease varies with the nature of the infective organism (that is, its powers of invasion of local tissues or the blood stream) and with the local and general resistance of the patient. In the gravest cases, the infecting organisms are commonly the pus-producing haemolytic streptococci and anaerobic streptococci and rarely staphylococci and pneumococci. Infection with the germs of gas gangrene (*Cl. welchii*) are rare but carry a very high mortality. Milder cases of puerperal fever are caused by infection with the nonhaemolytic streptococci and coliform bacilli.

The symptoms and course of the disease are similar to those of an acute wound infection. Fever with rigours usually arises on the third day after delivery, the pulse rate quickens and general prostration develops. The womb remains enlarged and tender, the discharges from it may be profuse and foul-smelling. Serious symptoms are persistent high fever and pulse rate, repeated rigours, sleeplessness, delirium and diarrhoea. Should the infection remain localized to the genital tract (as with coliform bacteria and nonhaemolytic streptococci), recovery is usual after a more or less severe illness (complicated by pelvic abscesses, etc.); but should invasion of the blood stream or peritoneum occur (as with haemolytic streptococci, anaerobic streptococci, *Cl. welchii*) the disease assumes the utmost gravity and, until about 1935, when sulfonamides were first used, accounted for about half the total maternal mortality in childbearing.

Prevention.—A main concern of those caring for women in childbirth is, therefore, to prevent infection from reaching or spreading among their charges. Until the development of antiseptic principles, the incidence and mortality of puerperal fever were horrifying, and the improvement reached by the first third of the 20th century was still unsatisfactory in comparison with that accompanying the prevention of sepsis after surgical operations. The more natural the labour and the less the interference, the lower the incidence of fever. Conversely, the more prolonged and extensive (*i.e.*, the higher up the genital canal) the interference and the greater the injury caused, the higher the risk of infection. Cleansing of the external genitals, disinfection of instruments and dressings and the wearing of sterilized gloves lessen the risk but will not wholly eliminate infection as it is impossible to render the skin surrounding the external genitals and anus absolutely germ-free. Hence the introduction of hands and instruments into the genital passage carries with it the risk of conveying organisms. Careful antenatal assessment of the size of the maternal passages by radiographic means increasingly prevented the necessity for these dangerous manoeuvres, and the discovery and use of powerful, yet safe, skin antiseptics with a prolonged action greatly lessened their risks. The local resistance of the tissues of the genital tract is lowered by bruising and injury and these can in large measure be avoided. The readiness with which infection may be conveyed by doctors and nurses harbouring organisms in the nose and throat has been clearly realized, and the wearing of an impervious mask over the nose and mouth during ministrations to childbearing women much decreased the danger. Antenatal measures directed to the general health of the pregnant woman—the treatment of coexistent disease such as diabetes, anaemia, tuberculosis or malnutrition—tend to raise the maternal powers of resistance to infection.

Treatment.—Treatment is, therefore, first of all preventive; the most stringent care is taken to adopt the same antiseptic and aseptic precautions in labour as for a major surgical operation and further by antenatal care to maintain the vitality at its best, avoiding all foreseeable complications in labour and generally securing natural delivery without interference. Loss of blood and exhaustion should be prevented or remedied by transfusion and restoratives. Complete emptying of, and free drainage from, the womb are essential, as are good nursing and attention to every detail of the mother's comfort and hygiene in the lying-in period. Until the middle of the 1930s, the curative treatment of puerperal sepsis consisted entirely of the above measures and, as has been said, they were successful in cases where the patient's good power of resistance, or the low virulence of the organisms, prevented the development of a generalized infection. Later, the sulfonamide group of drugs, first used by L. Colebrook and Meave Kenny in 1935, specific antidotes for infection by haemolytic streptococci, gonococci and pneumococci and *Bacterium coli*, caused a spectacular drop in the mortality of the disease; and, from the early 1940s, penicillin carried this victory over sepsis still further —more than three-quarters of the women who would previously have been doomed to die in this way now being saved. Before the era of chemotherapy, the haemolytic streptococcus accounted for about 75% of the total mortality from puerperal infection; the major instrument of death thereafter was the anaerobic group of organisms against which neither the sulfonamides nor penicillin had yet been shown to prevail and for which the only remedy lies in measures directed toward avoiding gross injury of the genital tract in labour. Deaths from puerperal infection by mid-century accounted for about one-sixteenth of the total maternal mortality, but the saving of a woman from death to leave her barren or an invalid is not enough. The incidence of the disease showed some reduction after 1935; but it was likely that the published figures did not present the real picture of the prevalence of the disease since, with sulfonamides and antibiotics, the patient's fever might be restrained below notifiable levels.

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PUERTO CABELLO, a city and port of Venezuela, in the state of Carabobo, 34 mi. N. by W. of Valencia, the capital of the state. Pop. (est. 1950) 34,000. Puerto Cabello has railway and motor road connections with Valencia and from there with Caracas. Puerto Cabello is one of Venezuela's principal ports of entry, and has dock and warehouse facilities to handle a considerably greater volume of trade than it normally transacts. The protected area is small but accessible to the largest vessels calling at Venezuelan ports. Products of agriculture, chiefly coffee and cacao, and of the livestock industries, are the principal exports. Of additional importance to the port was the establishment there of the national dry dock and navy yard, which has two floating docks in operation for the repair of coasting vessels and small steamers, a large machine shop and building facilities for small vessels. Some industries took root in the city and in the area between it and Maracay and Valencia. Puerto Cabello suffered much in the War of Independence, changing hands several times and remaining in the possession of Spain down to 1823.

See A. Briceño Valero, *La Traición del Castillo de Puerto Cabello en 1812* (Maracaibo, 1941). (C. E. Mc.)

PUERTO DE SANTA MARIA, a seaport of southern Spain, in the province of Cádiz, on the right bank of the river Guadalete, with a station on the railway from Cádiz to Seville. Pop. (1940), 28,262 (mun., 29,197). Puerto de Santa Maria, commonly called "El Puerto," is probably the *Menesthei Portus* of Ptolemy. Its most important industry is the wine trade; there are also glass, liqueur, alcohol, starch and soap manufactures.

PUERTO LA CRUZ, principal port and largest city of the state of Anzoátegui, Venez., terminus of oil pipe lines and site of extensive oil refineries and storage facilities. In 1936 the former fishing village had only 1,879 inhabitants; by 1950, it had 28,315. (C. E. Mc.)

PUERTOLLANO, a town of central Spain in Ciudad Real province, on the Madrid-Ciudad Real-Mérida railway and at the north-east of the Valle de la Alcúdia. Puertollano is 2,345 ft. above sea level and has mineral baths. Its population (22,099 [mun., 24,676] in 1940) more than doubled in the 20th century.

PUERTO MONTT, a city and port of Chile, capital of the province of Llanquihue, located at the northern end of the gulf of Reloncaví, about 670 mi. S.W. of Santiago. Population (1943) 21,360. It is the southern terminal of the southern section of the Chilean state railways and is served by air lines. Its chief importance lies in its geographical location, which makes it the logical point of contact between the northern and southern sections of Chile. Puerto Montt is built on a plain surrounded by wooded hills and by grazing land. Its principal industry is lumber. The city was founded in 1853 by a group of German emigrants led by Vicente Pérez Rosales, and was named for Manuel Montt (*q.v.*).

PUERTO PRINCIPE: *see* CAMAGÜEY.

PUERTO REAL, a seaport of southern Spain, on the Bay of Cádiz and on the Seville-Cádiz railway. Pop. (1940) 12,510 (mun., 14,854). It is the Roman *Portus Gaditanus* and is probably the most ancient trading station on the bay.

It owes its modern name to the fact that it was rebuilt in 1488 by Ferdinand and Isabella. The port has good quays, a

dry dock and deep water for large steamers.

PUERTO RICO: *see* PORTO RICO.

PUFENDORF, SAMUEL (1632–1694), German jurist, was born at Chemnitz, Saxony, on Jan. 8, 1632, the son of a Lutheran pastor. He was educated at Grimma and the University of Leipzig, and then at Jena. Pufendorf quitted Jena in 1657 and became a tutor in the family of Petrus Julius Coyet, one of the resident ministers of Charles Gustavus, king of Sweden, at Copenhagen. As a result of Danish resentment of Gustavus' conduct in suddenly declaring war, Pufendorf with the rest of the suite was imprisoned. He occupied himself during this time in meditating upon what he had read in the works of Grotius and Hobbes. He mentally constructed a system of universal law; and when, at the end of his captivity, he accompanied his pupils to the University of Leyden, he was enabled to publish, in 1661, the fruits of his reflections under the title of *Elementa jurisprudentiae universalis*. The work was dedicated to Charles Lôuis, elector palatine, who created for Pufendorf at Heidelberg a new chair, that of the law of nature and nations, the first of the kind in the world. In 1667 he wrote, with the assent of the elector palatine, a tract, *De statu imperii germanici, liber unus*. Published under the cover of a pseudonym at Geneva in 1667, it was supposed to be addressed by a gentleman of Verona, Severinus de Monzambano, to his brother Laelius. The pamphlet made a great sensation. It was a direct attack on the Holy Roman Empire and the house of Austria. In 1670 Pufendorf was called to the University of Lund, where he published in 1672 the *De jure naturae et gentium, libri octo*, and in 1675 a résumé of it as *De officio hominis et civis*.

In the *De jure naturae et gentium* Pufendorf took up in great measure the theories of Grotius and sought to complete them by means of the doctrines of Hobbes and of his own ideas. His first important point was that natural law does not extend beyond the limits of this life and that it confines itself to regulating external acts. He combated Hobbes's conception of the state of nature and concluded that the state of nature is not one of war but of peace. But this peace is feeble and insecure, and if something else does not come to its aid it can do very little for the preservation of mankind. As regards public law Pufendorf, while recognizing in the state (*civitas*) a moral person (*persona moralis*), teaches that the will of the state is but the sum of the individual wills that constitute it, thus showing himself a precursor of J. J. Rousseau and of the *Contrat social*. Pufendorf powerfully defends the idea that international law is not restricted to Christendom, but constitutes a common bond between all nations.

In 1677 Pufendorf was called to Stockholm as historiographer-royal. To this new period belong *Einleitung zur Historie der vornehmsten Reiche und Staaten*, also the *Commentarium de rebus suecicis*, and *De rebus a Carolo Gustavo gestis*. In his *De habitu religionis christianae ad vitam civilem* he traces the limits between ecclesiastical and civil power. This work propounded for the first time the so-called "collegial" theory of church government (*Kollegialsystem*), which, developed later by Pfaff (1686–1760), was the basis of the relations of church and state in Germany.

This theory makes a fundamental distinction between the supreme jurisdiction in ecclesiastical matters (*Kirchenhoheit* or *jus circa sacra*), which it conceives as inherent in the power of the state in respect of every religious communion, and the ecclesiastical power (*Kirchengewalt* or *jus in sacra*) inherent in the church, but in some cases vested in the state by tacit or expressed consent of the ecclesiastical body. The theory helped towards the principle of toleration.

It was put into practice to a certain extent in Prussia in the 18th century. The theory, of course, has found no acceptance in the Roman Catholic Church, but it none the less made it possible for the Protestant governments to make a working compromise with Rome.

In 1688 Pufendorf took service under Frederick William, elector of Brandenburg, but he had no sooner arrived than the elector died. His son, Frederick III, fulfilled the promises of his father; and Pufendorf, historiographer and privy councillor, was instructed to write a history of the Elector Frederick William (*De rebus gestis Frederici Wilhelmi Magni*). Pufendorf was also created baron.

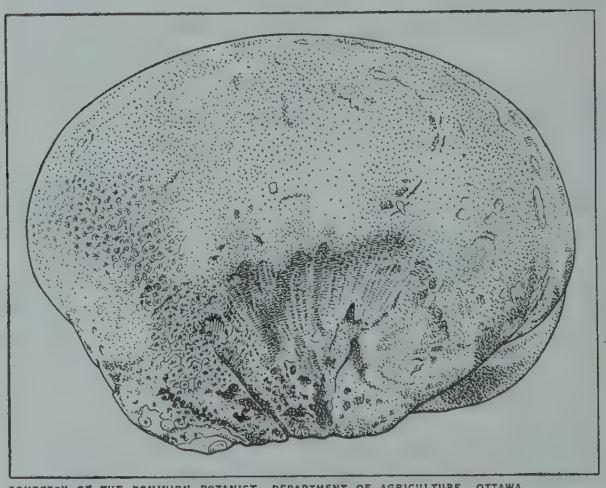
Pufendorf died at Berlin on Oct. 26, 1694.

The value of Pufendorf's work was much underestimated by posterity. Much of the responsibility for this injustice rested with Leibnitz, who would never recognize the incontestable greatness of one who was constantly his adversary, and whom he dismissed as "vir parum jurisconsultus et minime philosophus." His *Jurisprudence* is the standard one for the 17th and 18th centuries.

See H. von Treitschke, "Samuel von Pufendorf," in *Preussische Jahrbücher* (vol. xxxv., 1875, and xxxvi., 1876); J. Bluntschli, in *Deutsches Staats-Wörterbuch* (1857–70), and *Geschichte des allgemeinen Staatsrechts und der Politik* (1864); J. Lorimer, *The Institutes of the Law of Nations* (2 vols., 1883–84); J. C. Droysen, "Zur Kritik Pufendorfs" in his *Abhandlungen zur neueren Geschichte* (1876); W. Roscher, *Geschichte der National Oekonomik in Deutschland* (1892); O. Franklin, *Das deutsche Reich nach Severino von Monzambano* (1874).

PUFF ADDER: *see* ADDER; VIPERS; SNAKES.

PUFF-BALL, the popular name of a group of fungi belonging to the Basidiomycetes (*see* FUNGI), and so called because of the cloud of brown dust-like spores which is emitted when the mature plant bursts or is struck a blow. They are common in meadows and woods and on heaths or lawns, and when young



COURTESY OF THE DOMINION BOTANIST, DEPARTMENT OF AGRICULTURE, OTTAWA

Puff-ball. A medium sized specimen of the giant puff-ball (approximately 8½ in. wide)

resemble white balls, sometimes with a short stalk, and are fleshy in texture. While white and fleshy they are edible.

The giant puff-ball, *Calvatia maxima*, may sometimes attain a weight of 15 pounds or more and measure up to 4 to 5 ft. or more in circumference. It has been estimated that a specimen measuring 15.7 x 11.0 x 7.8 in. will produce approximately 7,000,000,000,000 spores.

PUFF-BIRD, the name given to a group of birds forming the family *Bucconidae*, of the order Piciformes, which also includes the woodpeckers (*q.v.*). The *Bucconidae* are confined to the neotropical region, in the middle parts of which, and especially in its sub-Andean subregion, they are, as regards species, abundant; while only two seem to reach Guatemala and but one Paraguay. *Chelidoptera* breeds in holes in banks, and lays white eggs. The *Bucconidae* are plainly coloured, and the majority have a spotted or mottled plumage suggestive of immaturity.

PUFFIN, a sea-bird (*Fratercula arctica*), known also as bottle-nose, coulterneb, pope, sea-parrot and tammy-norie. Of old time, puffins were a valuable commodity to the owners of their breeding-places, for the young were taken from the holes in which they were hatched, and were "kept salted and reputed for fish." Puffins resort in vast numbers to certain stations on the coast, reaching them in spring with remarkable punctuality. They lay their single egg (white, with a few grey markings at first, but which speedily becomes begrimed by the soil) in a shallow burrow, which they either dig for themselves or appropriate from a rabbit.

The plumage of both sexes is glossy black above—the cheeks grey, encircled by a black band—and white beneath; the feet are of a bright reddish orange. The most remarkable feature of these birds is their huge bill. In the breeding season this is very deep, laterally flattened, parti-coloured—blue, yellow and red—and curiously grooved and embossed in places. The puffin's bill undergoes an annual moult, some of its most remarkable appendages, dropping off at the end of the breeding season. The puffin, when feeding its young, manages to arrange crosswise in its bill, a number of fish at a time. In the north Pacific we find the horned (*F. corniculata*) and the crested puffin (*Lunda cirrhata*).

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TUFTED PUFFIN (LUNDA CIRRHATA)
A blackish brown bird, with a white cheek, and a yellow plume over the eye

PUGACHEV, EMEL'YAN IVANOVICH (1741?–1775), Russian pretender, the date of whose birth is uncertain, was the son of a small Cossack landowner. He married a Cossack girl Sofia Nedyuzheva, in 1758, and the same year was sent with his fellow Cossacks to Prussia, under the lead of Count Zachary Chernuishev. In the first Turkish War (1769–74) of Catherine II. Pugachev, now a Cossack ensign, served under Count Peter Panin and was present at the siege of Bender. Invalided home, he led for the next few years a wandering life; was more than once arrested and imprisoned as a deserter; and finally, after frequenting the monasteries of the "Old Believers," who exercised considerable influence over him, suddenly proclaimed himself (1773) to be Peter III. Pugachev asserted that he and his friends had escaped from Catherine, and were resolved to redress grievances, give liberty to the Cossacks and put Catherine in a monastery. He held a mimic court at which one Cossack impersonated Nikita Panin, another Zachary Chernuishev and so on. At the beginning of Oct. 1773 500 roubles was considered a sufficient reward for the head of the troublesome Cossack. At the end of November 28,000 roubles were promised. Still, Catherine, in her correspondence with Voltaire, affected to treat *"l'affaire du Marquis de Pugachev"* as a mere joke. By the beginning of 1774 the forts on the Volga and Ural were in the hands of the rebels; the Bashkirs had joined them; and the governor of Moscow reported great restlessness in central Russia. Pugachev captured Kazan, reduced most of the churches and monasteries there to ashes and massacred those who refused to join him. Panin, the conqueror of Bender, was sent against the rebels with a large army, but the innumerable and ubiquitous bands of Pugachev were victorious in nearly every engagement. Not till August 1774 did General Mikhelson inflict a crushing defeat upon the rebels near Tsaritsyn, when they lost ten thousand in killed and prisoners. Suvorov completed their discomfiture. Pugachev was delivered up by his own Cossacks on attempting to fly to the Urals (Sept. 14), and was brought in an iron cage to Moscow, where he was executed on Jan. 11, 1775.

See N. Dubrovin, *Pugachev and his Associates* (Rus.; Petersburg, 1884); *Catherine II., Political Correspondence* (Rus. Fr. Ger.; Petersburg, 1885, etc.); S. I. Gnyedich, *Emilian Pugachev* (Rus.; Petersburg, 1902); also the literature quoted *s.v.* CATHERINE II.

PUGACHEVSK (formerly NIKOLAYEVSK), a Russian town in the Samara province, in 52° 1′ N., 48° 48′ E., on the Irgiz river. Population 17,460. It is a collecting point for agricultural produce. Under the name of Mechetnoye, Nikolayevsk was founded in 1762 by the Old Believers who had fled to Poland and returned when Catherine II undertook to grant them religious freedom. In 1828 serious persecutions began, with the result that the monasteries were closed with the exception of three, which were handed over in 1829 and 1836 to the United Greek Church. In 1835 the name of the town was changed to Nikolayevsk.

PUGET, PIERRE (1622–1694), French painter, sculptor, architect and engineer, was born at Marseille, on Oct. 31, 1622. He travelled in Italy as a young man, and was employed by Pietro di Cortona on the ceilings of the Barberini palace. On his return to Marseille in 1643, he painted portraits and carved the colossal figure-heads of men-of-war; he also painted numerous pictures for Aix, Toulon, Cuers and La Ciotat; his caryatides for the hôtel de ville of Toulon were executed between 1655 and 1657. Fouquet employed him to sculpture a "Hercules" for his château in Vaux. In 1655, owing to a serious illness, he was forced to give up painting. In 1660 he was in Genoa, where he executed his French Hercules (Louvre) and the statues of St. Sebastian and of Alexandre Sauli in the church of Carignano (*c.* 1664). In 1669, at the summons of Colbert, he returned to France, and took up his old work in the dockyards of Toulon, until in 1685, disheartened by the destruction by fire of an arsenal he was constructing, he returned to Marseille. Here he continued the series of sculptures on which he had been employed by Colbert. His statues of Milo (1682), Perseus and Andromeda (1684), and the bas-relief, Alexander and Diogenes (1685) are in the Louvre. In 1688 he visited Paris, but court intrigues obliged him to abandon the project of an equestrian statue of Louis XIV., and he retired to Marseille, where he died on Dec. 2, 1694. His best work, the St. Sebastian at Genoa, shows energy and life. In the museum of Aix in Provence is the bust of a long-haired young man, believed to be Louis XIV., made by Puget in 1660.

See L. Lagrange, *Pierre Puget* (1868, with a catalogue of works); C. Ginoux, *Annales de la vie de P. Puget* (1894); P. Auquier, *Pierre Puget . . . biographie critique* (1903).

PUGILISM, the practice or sport of fighting with the fists (from Lat. *pugil,* boxer, Gr. *πύξ,* with clenched fist). The first mention of such fighting in literature is found in the 23rd book of the *Iliad;* another full description is in Virgil, *Aeneid.*

Although fist-fighting was supposed by the Greeks of the classic period to have been a feature of the mythological games at Olympia, it was not actually introduced into the historic Olympic contests until the 23rd Olympiad after the re-establishment of the famous games by Iphitus about 880 B.C. Onomastos was the first Olympic victor. Wearing no belt, or *ζῶμα,* the contestants, except for the cestus, fought entirely naked, since the custom had been introduced in the 15th Olympiad, and was copied by the contestants at the Pythian, Nemean, Isthmian and Panathenaic games (*see* GAMES, CLASSICAL). At Olympia the boxers were rubbed with oil to make them supple and limit the flow of perspiration, a precaution the more necessary as the Olympic games were held during the hottest part of the year. The cesti, of which there were several varieties, were bound on the boxers' hands and wrists by attendants or teachers acting as seconds. On account of the weight of the gloves worn, the style of boxing differed from that now in vogue (*see* BOXING), the modern straight-from-the-shoulder blow having been little used. Both Homer and Virgil speak of "falling blows," and this was the common method of attack, consisting more in swinging and hammering than in punching. The statue of a Greek boxer in the Louvre shows the right foot forward, the left hand raised as if to ward off a blow from above, and the right hand held opposite the breast, the whole attitude more resembling that of a warrior than of a modern boxer. The Greek champions trained for months before the games, but encounters between athletes armed with such terrible weapons as the loaded cestus were bound to result in very serious bruises and even disfigurement. Pluck was as highly thought of as at the present day, and it was related of a certain Eurydamas, that, when his teeth were battered in, he swallowed them rather than show that he was hurt, whereupon his antagonist, in despair at seeing his most furious blows devoid of effect, gave up the battle. As, on account of the swinging style of blows, the ears were particularly liable to injury ear-protectors (*ἀμφωτίδες*) were generally used in practice, though not in serious combats. The so-called "pancratist's ear," swollen and mis-shapen, was a characteristic feature of the Greek boxer.

The rules of Greek boxing were strict. No wrestling, grappling, kicking nor biting were allowed, and the contest ended when one combatant owned himself beaten. On this account pugilism and the *pancratium* (*see* pp. 758) were forbidden by Lycurgus, lest the Spartans should become accustomed to an acknowledgment of

defeat (Plutarch, *Lycurgus*). Moreover, it was strictly forbidden to kill an adversary, on pain of losing the prize. Rhodes, Aegina, Arcadia and Elis produced most of the Olympic victors in boxing, which was considered an excellent training for war.

The Greek athletic contest called *pancratium* (παγκράτιον, complete or all-in, contest), which was introduced into the Olympic games in the 38th Olympiad, was a combination of boxing and wrestling in which the contestants, who fought naked, not wearing even the cestus, were allowed to employ any means except biting to wring from each other the acknowledgment of defeat. Boxing, wrestling, kicking, dislocation of joints, breaking of bones, pulling of hair and strangling were freely indulged in. The fight began with sparring for openings and was continued on the ground when the contestants bit the dust. Sudden attacks were also taught, reminding one of the Japanese *jiu-jitsu*. The *pancratium* was considered by the Greeks the greatest of all athletic contests. It became popular in Rome during the empire and remained so until the time of Justinian. Diagoras of Rhodes, his three sons and many grandsons, who were sung by Pindar (*Olymp.* 7), were the most celebrated of the Olympic boxing champions. A celebrated fighter and wrestler was Milo of Crotona (520 B.C.).

Boxing was evidently in vogue in very ancient times in Italy, imported, in all probability, from Greece, for Livy (i. 35) relates that, at the first celebration of the great Roman games (*ludi, Romani magnique varie appellati*) by Tarquinius Priscus (6th century B.C.), boxers were brought from outlying provinces; and there was an old tradition that a school of pugilism flourished in Etruria in heroic times. During the republic boxing was cultivated as a gentlemanly exercise, and we find Cato the Elder giving his son instruction in the art (Plutarch, *Cato Major*). Tacitus (*Ann.* xvi. 3) says that the emperor Caligula imported the best Campanian and African pugilists for the gladiatorial games, and Strabo (iii. 3) records that the Lusitanians and also the Indians, who gave virgins as prizes, boxed. The art remained popular in Italy down to a late period of the empire.

Pugilism in England.—From the fall of the Roman empire to the beginning of the 19th century pugilism seems to have been unknown among civilized nations with the single exception of the English. The first references to boxing in England as a sport occur towards the end of the 17th century, but little mention is made of it before the time of George I., when "prize-fighters" engaged in public encounters for money, with the backsword, falchion, foil, quarter-staff and single-stick, and, to a less extent, with bare fists, the last gradually gaining in popularity with the decline of fencing. The most celebrated of these fighters and the one who is generally considered to have been the first champion of England, fighting with the bare fists, was James Figg, who was supreme from 1719 to 1730. Figg was succeeded by Pipes and Gretting, both of whom made way in 1734 for Jack Broughton, who built the amphitheatre for public displays near Tottenham Court road and who was undisputed champion until 1750. Broughton seems to have been a man of intelligence, and to him is ascribed the scientific development of the art of boxing. During his time the sport became truly national and the prize-fighter the companion of the greatest in the land. Among Broughton's successors were Slack, "Big Ben" Brain, Daniel Mendoza (a Jew who flourished about 1790 and was the proprietor of the Lyceum in the Strand), J. Jackson, Tom Cribb, Jem Belcher, Pearce (called the "Game Chicken"), and John Gully, who afterwards represented Pontefract in parliament.

To Broughton is ascribed the invention of boxing-gloves for use in practice. All prize-fights, however, took place with bare knuckles in roped-off spaces called rings, usually in the open air. Pugilists toughened their hands by "pickling" them in a powerful astringent solution. A fight ended when one of the "bruisers," as they were called, was unable to "come to the scratch," *i.e.*, the middle of the ring, at the call of the referee at the beginning of a new round. Each round ended when one fighter fell or was knocked or thrown to the ground, but a pugilist "going down to avoid punishment," *i.e.*, without being struck by the opponent, was liable to forfeit the fight. Wrestling played an important rôle in the old prize-ring, and a favourite method of weakening an adversary was to throw him heavily and then fall upon him, seemingly by accident, as the manoeuvre, if done intentionally, was foul. The fighting was of the roughest description, low tricks of all kinds being practised when the referee's attention was diverted, gouging out an adversary's eye being by no means unknown. Until 1795 pugilists wore long hair, but during a fight in that year Jackson caught Mendoza by his long locks and held him down helpless while he hit him. This was adjudged fair by the referee, with the result that prize-fighters have ever since cropped their heads. Nevertheless, there were rules which no fighter dared to overstep, such as those against kicking, hitting below the belt, and striking a man when he had fallen.

From the time of Cribb the English champions were Tom Spring (1824), Jem Ward (1825), Jem Burke (1833), W. Thompson, called "Bendigo" (1839–45), Ben Caunt (1841), W. Perry the "Tipton Slasher" (1850), Harry Broome (1851), Tom Sayers (1857–60), Jem Mace (1861–63), Tom King (1863), and again Mace, until 1872. In America boxing began to be popular about the beginning of the 19th century. The first recognized national champion was Tom Hyer (1841–48), who was followed by James Ambrose (born in Ireland), called "Yankee Sullivan"; John Morrissey (afterwards elected to the United States Congress); John C. Heenan; Tom Allen (of England); Jem Mace (of England); J. Kilrain; John L. Sullivan (1880–91). Sullivan was the last of these to fight with the bare fists. Pugilism (*i.e.*, fighting with the bare fists) was driven out in favour of boxing (*i.e.*, fighting with the glove) by public opinion and by the general adoption after 1866 of the Marquis of Queensberry rules. The last championship fight under the old prize ring rules was fought between Frank Slavin and Jem Smith in Belgium, the latter retaining the championship. The old prize ring being illegal and extinct no champion can succeed him. *See* BOXING.

See Egan, *Boxiana* (1818–1824); *Fistiana* (1868); *American Fistiana* (1876).

PUGIN, AUGUSTUS WELBY NORTHMORE (1812–1852), English architect, son of Augustus Charles Pugin (1762–1832), a Frenchman who settled in London as an architectural draughtsman, was born in Store Street, Bedford Square, on Mar. 1, 1812, and died on Sept. 14, 1852, at Ramsgate. He was educated at Christ's Hospital and in his father's office, where he helped to prepare a large series of works on the Gothic buildings of England. All through his life he made numerous drawings and sketches, in pen and ink or with sepia monochrome, perfect in their delicacy and precision of touch. After his reception into the Roman Catholic Church in 1833, he became a leader in the English Gothic revival. In 1837–43 he assisted Sir Charles Barry by working out the details of the designs for the new Houses of Parliament at Westminster; and though his exact share was the subject of bitter controversy after both he and Barry were dead, there is no doubt that the excellence of the details was partly due to him and to his training of the masons and carvers. Many of his executed works suffered from the fact that his designs were altered, both by cutting down their proportions and by introducing shams, such as plaster groining and even cast-iron carving. The cathedral of St. George at Southwark, and the church in Farm Street, Berkeley Square, London, are melancholy instances of this. The cathedral of Killarney and the chapel of the Benedictine monastery of Douai best express the original conception. Pugin was very broad in his love for the mediaeval styles, but on the whole preferred the Perpendicular of the 15th century as being best suited to modern requirements. He used this with success in his own house at Ramsgate and in the stately Adare Hall in Ireland built for Lord Dunraven.

In 1836 Pugin published his *Contrasts; or a Parallel between the Architecture of the 15th and 19th centuries; True Principles of Christian Architecture* (1841); *Glossary of Ecclesiastical Ornament* (1844); and *Treatise on Chancel Screens and Rood Lofts* (1851). He was a skilful etcher.

See B. Ferrez, *Recollections of A. W. Pugin and his Father* (1861); Paul Waterhouse, "The Life and Work of Welby Pugin" in the *Architectural Review*, iii., iv. (1898).

PUINAVIAN, a tribe of South American Indians, which appear to constitute by itself alone an independent linguistic

stock. The Puinavis live or lived on the border between Venezuela and Colombia, on the Inirida river, just south of 4° N. lat. *See* A. F. Chamberlain, *Sur quelques familles linguistiques . . . de l'Amérique du Sud* (J. Soc. Americanistes de Paris [n.s.], vol. vii., pp. 179–202).

PUISNE, a term in law meaning "inferior in rank." It is pronounced "puny" and the word, so spelt, has become an ordinary adjective meaning undersized. By the Supreme Court of Judicature act, 1877, a "puisne judge" is defined as a judge of the High Court other than the lord chancellor, the lord chief justice of England, the master of the rolls, the lord chief justice of the common pleas, and the lord chief baron, and their successors respectively; but the last two offices have since been abolished.

PUJA, Hindu "worship": whence *pujāri,* "priest." Colloquially the word is used for any rite; and "pujah of the flag" is the sepoy term for trooping the colours.

PUKET, sometimes spelled BHUKET (the Chinese name is *Tongkah*), leading Thai port on the west coast of the Malay peninsula, on Junk Ceylon island (also called Puket) in 7° 50′ N. and 98° 24′ E. The island constitutes one of the 70 changvads (districts) of Thailand; pop. (1937) 41,827, nearly half Chinese. Rich tin deposits have been worked by Chinese from ancient times. A European company commenced modern dredging operations in 1907. The 1938–39 tin ore production was 4,256 tons. Exports of ore from the Puket customs area (the Thai west coast) amounted to 31,873,287 bhat (about $14,000,000) in 1939–40. Rubber stood second among exports, followed by betel-nuts, oriental equivalent of chewing tobacco. European merchants began trading at Puket in the 16th century. It was besieged by the Burmese during the 18th century wars between Burma and Thailand, but was relieved by troops from the mainland.

PULASKI, CASIMIR, COUNT (1748–1779), Polish soldier, was born in Podolia in 1748, and took a prominent share, under his father Count Joseph Pulaski, in the formation of the confederation of Bar and in the military operations which followed, becoming ultimately commander-in-chief of the Polish patriot forces. Driven into exile about 1772, Pulaski went to America and joined the army of Washington in 1777. He distinguished himself at Brandywine, was made a brigadier-general and chief of cavalry by Congress, and fought at Germantown, and in the battles of the winter 1777–78, after which he raised a mixed corps called the Pulaski legion, with which he defended Charleston in May 1779. He was mortally wounded at Savannah, dying on Oct. 11th.

PULASKI, a town of Virginia, U.S.A., county seat of Pulaski Co.; 50 mi. S.W. of Roanoke, on federal highway 11 and Norfolk and Western Ry. Pop. (1950) 9,136. It is in a region of beautiful scenery and of coal, lead and iron mines, between the Blue Ridge and Allegheny mountains. It is a summer resort.

PULCI, LUIGI (1432–1484?), Italian poet, was born at Florence on Dec. 3, 1432, of a well-connected family. His elder brother Luca (d. 1470) was also a poet, and the share of each of the two brothers in the poems *Pistole, Driadeo d'amore,* and *Ciriffo Calvaneo* is not easily distinguishable. Luigi was patronized by Cosimo, Piero, and Lorenzo de' Medici. He used to find an object for his mockery in the long romances of chivalry recited in the streets and in public places. He chose for his semi-burlesque poem, *Morgante,* generally known as *Morgante Maggiore* (complete ed. Venice 1482; critical ed. Milan 1875), the epic of Charlemagne. The story centres in Ganelon's hatred of Roland and the Christian Paladins. Pulci's *Letters* were edited at Lucca 1886.

See L. Einstein: *L. Pulchi and the Morgante Maggiore* (Berlin 1902) A. Momigliano: *L'Indole e il Riso di Pulci* (1907); E. Walser: "Die Religion des L. Pulci" in *Die Neueren Sprachen* 10 Beiheft (1926).

PULICAT, a town of British India, in Chingleput district, Madras, 25 m. N. of Madras city. Pop. (1941), 3,781. The Dutch built a fort here as early as 1609, and it was for a long time their chief settlement on the Coromandel coast. Repeatedly captured, it did not finally become British until 1825. It gives its name to the Pulicat lake, a shallow lagoon stretching for about 37 m. along the coast. The seaward side is formed by the island of Sriharikota, which supplies firewood to Madras city.

PULITZER, JOSEPH (1847–1911), American editor and newspaper proprietor, was born in Mako, Hungary, April 10, 1847. His father, a grain-merchant, was Magyar-Jewish; his mother Austro-German. Pulitzer was educated privately in Budapest. Excluded from the army as a result of physical defects, and failing in an attempt to join the French Foreign Legion, he was induced by an American agent to emigrate to the United States as a prospective recruit for the Union army. He enrolled in Company L, 1st New York Lincoln cavalry, for a term of one year. Discharged on July 7, 1865, in New York city, he looked in vain for work there. In the autumn he started west for St. Louis, where he arrived penniless.

In St. Louis, with its large German population, Pulitzer's progress was rapid. While making his living by odd employments, he studied for the bar and was admitted in 1867. On March 6 he was naturalized, and in 1868 became a reporter on the *Westliche-Post* staff; in Dec. 1869 he was elected to the lower house of the legislature. Here he led a successful movement to reform the corrupt county government of St. Louis. When the revolt against Grant led to the Liberal Republican movement in 1871–72, Pulitzer helped to organize this party in Missouri and was one of the secretaries of the Cincinnati convention which nominated Greeley.

Pulitzer then became a newspaper proprietor. Some owners of the *Westliche-Post* sold him a share on liberal terms. This he soon resold for $30,000, using part of the proceeds for an extended tour of Europe. On his return he purchased a moribund German daily, the St. Louis *Staats-Zeitung,* for a song, and sold its Associated Press franchise to the *Globe* for $20,000. In 1876 he took an active share in the presidential campaign, breaking loose from all his Republican associates.

On June 19, 1878, he married Miss Kate Davis, a distant relative of Jefferson Davis. On Dec. 9 of the same year he laid the foundation of his fortune by purchasing at auction the worn-out St. Louis *Dispatch,* paying $2,500 cash and giving a $30,000 lien. This newspaper he merged with the *Post,* owned by John A. Dillon, as the *Post-Dispatch,* which immediately began to pay and soon dominated the St. Louis evening field. It was independent in politics and devoted to "hard money" and tariff reform. In 1880 Pulitzer became sole owner. He laboured with unremitting energy, and the profits were soon running from $40,000 to $85,000 a year. Unfortunately in Oct. 1882 his chief editorial aid, Col. John A. Cockerill, shot and killed a lawyer, Col. Alonzo W. Slayback, in a bitter quarrel of political origin. The case did not come before the courts, but public reprobation was so great that the *Post-Dispatch* lost revenue and Pulitzer thereafter felt unwelcome in St. Louis. He departed for the East in the spring of 1883, and bought the New York *World* for $346,000, taking possession on May 10.

In 1884 he was elected to Congress from the Ninth District, a position he resigned before his term expired. Under its new management the *World* won an immediate prosperity. It was aided by a quarrel in which its rival, the *Herald,* became engaged with the newsdealers, and by the *Sun's* disastrous decision in 1884 to support Benjamin F. Butler for the presidency. By 1886 the annual earnings of the *World* were more than $500,000. With these resources Pulitzer in 1887 established the *Evening World,* which lost $100,000 the first year, but by 1890 was highly profitable. William R. Hearst's purchase of the New York *Journal* in 1895 brought the *World* a powerful competitor, and it met the challenge on Feb. 10, 1896, by reducing its price from two cents to one. The daily circulation of the *World* quickly rose to 300,000 and its Sunday circulation before the end of 1896 reached 623,000 copies. To the *World,* as to the *Post-Dispatch,* Pulitzer gave a tone of aggressive editorial independence. The paper earnestly supported Cleveland in his contests for the presidency in 1884, 1888 and 1892. It was sympathetic to labour, and in 1892 took the side of the striking steel workers at Homestead, Pennsylvania. It opposed Bryan for the presidency in 1896. A year later the *World* became an advocate of war with Spain, for Pulitzer sympathized with the Cuban struggle for liberty. Meanwhile Pulitzer's health, including his eyesight, compelled him to

live the secluded existence of an invalid, but he kept in intimate touch with the *World* until within a few weeks of his death in Charleston (S.C.), Oct. 29, 1911.

During his lifetime Pulitzer had given liberally. In 1903 he endowed the School of Journalism of Columbia university, opened in 1912. In his will he established a series of prizes, known as the Pulitzer prizes, to be awarded annually, for letters, the drama, music and newspaper work.

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PULKOVO (Pulkowa), the most important meteorological observatory in Russia, 10 m. S. of Leningrad in 59° 47′ N., 30° 18′ E., altitude 248 ft. and built 1833–9. Russian longitude is usually indicated from Pulkovo, though some recent Russian atlases and maps give longitude east of Greenwich, the difference having been fixed by wireless.

War conditions (1914–21) made a considerable break in international exchanges with Pulkovo. Yudenich captured Pulkovo in his march against Leningrad in 1919, and its re-capture by Soviet troops was the beginning of the collapse of his army.

PULLEY, a wheel, either fixed to a turning axle or carried freely on a stationary one, the periphery of which is adapted to receive some form of wrapping connector. A pulley carried on a rotating shaft and connected to another pulley on a second shaft by an endless band consisting of a flat belt, rope, chain or similar connector serves for the transmission of power from the one shaft to the other and is known as a driving pulley; while combinations of pulleys or "sheaves" mounted in fixed or movable frames or "blocks" facilitate the raising of heavy weights.

Driving Pulleys.—These are usually constructed of cast iron, and are of circular form, having a central nave by which they are secured to the shaft by keys or other fastenings, and straight or curved arms connecting the nave to the rim, which latter is of a form adapted to the connector. Pulleys are usually cast in one piece, and the proportions of the various parts are designed to resist the unknown stresses due to contraction of the casting in cooling. The rim is slightly wider than the belt, and is of such a section as will suffice to resist the stress due to the pull of the belt, which is commonly taken as 80lb. per inch of width for single belting and 140lb. per inch of width for double belting. The rim is also subject to a centrifugal tension of amount wv^2/g pounds per square inch of section, where w is the weight in pounds of a length of one foot of the pulley rim one square inch in section, and v is the velocity of the rim in feet per second. This stress amounts to 1,043lb. per square inch, if the velocity is 100 ft. per second. The combination of these stresses generally limits the rim velocity of cast-iron pulleys to 80 or 100ft. per second. The arms, preferably straight, are elliptical in cross-section, diminishing from the nave to the rim, and are usually designed as equally loaded cantilevers, fixed at the nave and free at the rim. The statical experiments of C. H. Benjamin (*American Machinist,* 1898) showed that the rim is usually not sufficiently rigid to load the arms equally, and that the ends of the arms are subjected to bending movements of opposite sign, that at the nave being almost invariably the greater.

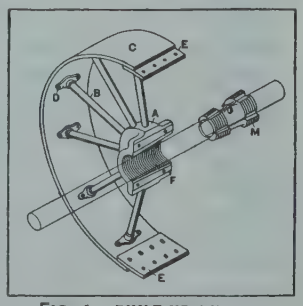

FIG. 1.—BUILT-UP PULLEY

Pulleys are also built up of wrought iron and steel, and can then be constructed entirely free from internal stress; they are thus much lighter and stronger, and are not liable to fly to pieces like cast iron if they break. Fig. 1 shows a built-up pulley having a cast-iron nave A, straight wrought-iron arms B, screwed therein and connected to a steel plate-rim C by riveted ends, and also by screwed flanges D riveted on each side to the rim. The pulley is in halves to facilitate fixing, and when in place the sections C are joined by plates E bolted or riveted to the rim. The two halves of the nave are secured by bolts or rivets passing through the flanges F, and the pulley is connected to the shaft by a sunk key or by conical keys driven in between the shaft and the boss, which latter is bored to suit. A modified form of this arrangement of cone keys is shown in the figure, in which a screwed conical bush M, divided into several parts longitudinally, is clamped round the shaft, and screwed into the corresponding part of the nave until the grip is sufficient. The parts of the bush are glued to a sheet of emery paper, so that its rough side may give a better grip on the shaft.

Pulleys are also made of paper, wood and other materials. Wooden pulleys are preferably made of maple, the rim being formed of small sections morticed, pinned and glued together, with the grain set in such directions that any warping of the material will leave the cylindrical form practically unaltered. Wooden pulleys are generally made in two halves, bolted together at the rim and nave, and are provided with wooden spokes dovetailed into the rim and secured by keys.

If the centre of gravity of a pulley is on the axis of rotation, and the whole mass is distributed so that the axis of inertia coincides with the axis of rotation, there can be no unbalanced force or unbalanced couple as the pulley revolves. The magnitude of the unbalanced force, for a mass of w pounds at a radius of r feet and a velocity of v feet per second, is expressed by wv^2/gr lb.; and, since the force varies as the square of the velocity, it is necessary carefully to balance a pulley running at a high speed to prevent injurious vibrations. This can be accomplished by attaching balance-weights to the pulley until it will remain stationary in all positions, when its shaft rests on two horizontal knife-edges in the same horizontal plane, or, preferably, the pulley and shaft may be supported on bearings resting on springs, and balanced by attached masses until there is no perceptible vibration of the springs at the highest speed of rotation.

The rims of pulleys, round which flat bands are wrapped, may be truly cylindrical, in which case the belt will run indifferently at any part of the pulley, or the rim may be swelled towards the centre, when the central line of the band will tend to run in the diametral plane of the pulley. This self-guiding property may be explained by the tendency which a flat band has, when running upon a conical pulley in a direction normal to its axis, to describe a spiral path as it wraps on to the surface because of the lateral stiffness of the material; the advancing side therefore tends to rise towards the highest part of the cone. In practice the pulley rim is curved to a radius of from three to five times its breadth.

Parallel Shafts.—Parallel shafts may be driven by flexible bands or connectors passing over pulleys, the central planes of which coincide, without any guiding arrangements for the belting. The shafts revolve in the same or opposite directions, according as the belt is open or crossed. Means of changing the relative speeds of rotation are furnished by pulleys of continuously varying diameter, or by speed cones. A common arrangement for driving a lathe spindle, in either direction at several definite speeds, is to provide a countershaft on which are mounted two fixed pulleys and two loose pulleys to accommodate two driving belts from the main shaft, one of which is open and the other crossed. The belts are moved laterally by the forks of a striking gear pressing on the advancing sides of the belts, and the pulleys are arranged so that the belts either wrap round the loose pulleys, or can be shifted so that one wraps round a fixed pulley, while the other still remains on its loose pulley. Motion in either direction is thereby obtained and a considerable variation in the speed of rotation can be obtained by providing a cone pulley on the countershaft, which drives the cone pulley secured to the lathe spindle by a separate band. The dimensions of the pulleys are generally so arranged that the return motion of the lathe spindle is faster than the forward motion.

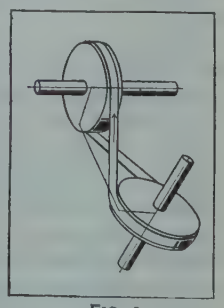
FIG. 2

When pulleys are mounted on shafts which are parallel to one another, the band will retain its position, provided that its central line advances towards each pulley in the diametral plane of this latter. This condition is fulfilled in the example shown by fig. 2, in which the central planes of each pulley pass through the points of delivery of the other pulley for the given direction of motion. If the motion is reversed the condition is no longer satisfied and the belt will leave the pulleys. In more complicated cases guide pulleys must be used. In the most general case for inclined pulleys, any two points may be chosen on the line of intersection of the diametral planes, and tangents drawn to the pitch circles of the pulleys. Guide pulleys are set with their diametrical planes in the planes containing corresponding pairs of tangents, and a continuous belt wrapped round these pulleys in due order can then be run in either direction.

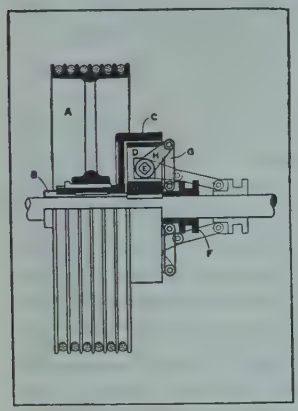

FIG. 3.—FRICTION CLUTCH FOR ROPE-PULLEY

The rims of pulleys for hemp or other ropes or cords are grooved, and the sides are usually either inclined at 45° or curved to give a sharper angle at the outside than at the bottom of the groove; in the latter case, as the rope wears it engages in a groove of greater angle and less effective grip. Wire ropes are injured by the lateral crushing of the material, and in this case the grooves are wide enough to allow the rope to rest on the rounded bottom, which is lined with leather or wood to diminish the wear and increase the friction. In English practice there are as many separate endless ropes as there are pairs of grooves in the two pulleys to be connected, but in cases of American practice the rope is continuously wound round the two pulleys, and the free end passes over a pulley mounted on a movable weighted carriage to adjust the tension.

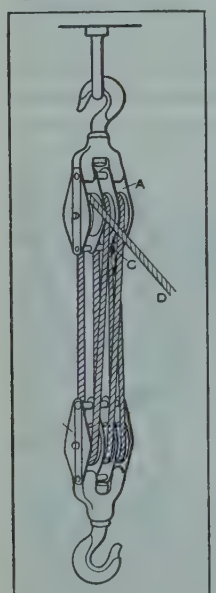

FIG. 4.—SHEAVE PULLEY BLOCK

Pulleys may be detachably connected to a shaft by friction clutches, so that they may be thrown in and out of engagement at will. The section, fig. 3, shows a clutch for a rope-driven pulley A, which runs freely on a bush B on the shaft, and is provided with an enlarged cylindrical nave or clutch box C. A split ring D, carried by the clutch and turning with it, can be thrust against the clutch box by right- and left-handed screws E, so that a sufficient grip is obtained to cause the clutch and the pulley to turn as one piece. The engagement of the pulley and clutch is determined by a hand-controlled block F sliding on the shaft, the movement of which is communicated to the right- and left-handed screw shafts by links G connected to the levers H.

Pulley Blocks.—Frames or blocks containing pulleys or sheaves are used in combination for lifting heavy weights. There are usually two blocks, of which one A (fig. 4) is fixed, and the other B is movable, and a rope or chain, with one end secured to one of the blocks at C, passes round the sheaves in a continuous coil, leaving a free end D at which the effort is applied. In the arrangement shown there are three equal sheaves in each block, and each set turns on a pin secured in the framing. The load, supported by the lower hook, is raised by hauling on the free end and, neglecting any slight obliquity of the plies of rope, the free end moves six times as fast as the lower block carrying the weight, and in the absence of friction and other resistances the mechanical advantage will be in the same ratio of the effort to the resistance. In practice the full advantage of this or any other similar combination is not realized, because of the friction of the sheaves against the pin or shaft, and more important still is the stiffness of the rope, which requires work to be done upon it to bend it round the sheave and straighten it again.

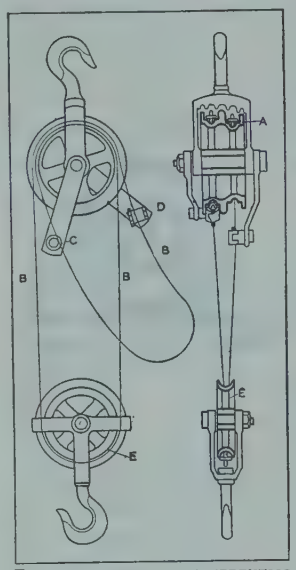

FIG. 5.—WESTON DIFFERENTIAL PULLEY BLOCK

Differential Pulley Block.—To obtain a greater ratio of resistance to effort, without using a large number of sheaves, various arrangements are used, of which the Weston differential pulley block is a typical example. The upper block carries a pair of chain pulleys A (fig. 5), strongly secured together and of slightly different effective diameters. An endless chain B, passing through guides C and D, encircles these pulleys and the single loose pulley E of the lower block, as indicated. If a greater difference of effort from resistance is required, a further mechanical advantage can be obtained by employing a separate hand-wheel and chain, or by forming the upper sheave with an annular spur-wheel gearing with a pinion driven by a hand-wheel and chain, as in the Tangye form of Weston pulley-block. The efficiency of the Weston pulley-block is less than 50%, and it does not therefore overhaul. An objection to this form of block is the great length of the endless chain, which may drag on the ground and pick up dirt and grit, and thereby interfere with the smooth working of the mechanism. Other forms, which do not require so lengthy a chain, sometimes employ an epicyclic train to obtain the reduced velocity of the load.

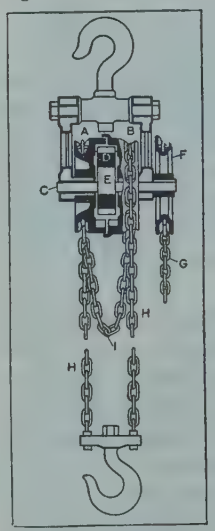

FIG. 6.—MOORE AND HEAD PULLEY BLOCK

The Moore and Head block has two equal chain-wheels A, B, fig. 6, loosely mounted on an axle C, and provided with annular toothed gear-wheels which usually differ by one tooth. A spur pinion D, gearing with both wheels, is carried loosely upon an eccentric E forming part of the central pin, so that when this latter is turned by the hand-wheel F and chain G the axis of the pinion describes a circle the diameter of which equals the throw of the eccentric, and a small relative motion of the two sheaves takes place, depending on the number of the teeth of the annular wheels. The motion obtained is divided between the two vertical parts of the chain H, which is wrapped round each sheave in opposite directions, with a free loop I between, while the ends are attached to the lifting hook. This form is self-sustaining at all loads.

Worm Gear Pulley.—To obtain a self-sustaining pulley tackle, which will have an efficiency of more than 50%, various arrangements are adopted, which during lifting automatically throw out of action a brake and cause it to come into action again when the effort is removed. A worm-gear tackle of this description is shown in fig. 7, in which a worm A, operated by a hand-wheel B and chain C, drives the worm-wheel D, thereby coiling up a chain E, one end F of which is secured to the upper

block, and the other end hangs loosely, after passing round the sprocket-wheel. The worm is of great pitch, so that if the effort were removed the weight would descend, did not the axial end thrust of the worm shaft throw into action a friction brake H, the resistance of which prevents motion downwards. In the brake shown, the cone I is pressed against a corresponding recess in the ratchet-wheel J, which latter turns loosely in the casing and is provided with a pawl not shown in the figure; this pawl allows freedom of motion when the load is being raised. The frictional grip between the two surfaces prevents return motion of the worm shaft and the load remains suspended, but it may be lowered by turning the hand-wheel so as to overcome the friction brake. Various other arrangements of friction brakes have been devised to give a resistance proportional to the load.

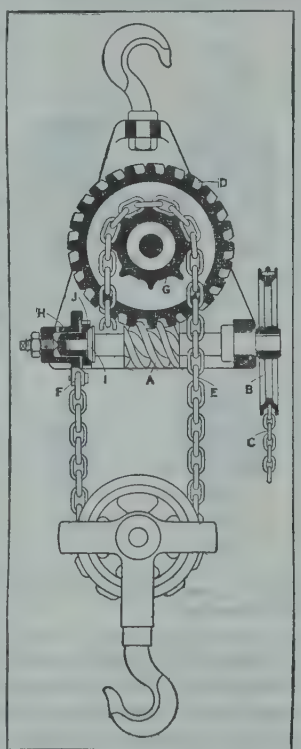

FIG. 7.—WORM-GEAR PULLEY BLOCK WITH AUTOMATIC BRAKE

Blocks, for lifting very heavy weights, are sometimes provided with an electric motor for driving the worm. The worm-wheel shaft then sometimes carries a spur-pinion gearing, with a spur-wheel on the lifting shaft, whereby a much greater advantage is obtained with a small loss by friction of the spur gearing.

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(E. G. Co.)

PULLMAN, now a part of the city of Chicago. The place was founded in 1880 by George Mortimer Pullman (1831–97), the inventor of the Pullman sleeping car, and the founder (1867) of the Pullman Palace Car Company, who attempted to make it a "model town." Even the public works were the property of the Pullman Company and were managed as a business investment. Popular discontent with the conditions led to the annexation of Pullman to Chicago in 1889, but until 1910 the corporation held most of the property. In June and July 1894 a bitter railway strike developed in the Pullman works.

PULLMAN, a city of Whitman county, Washington, U.S., 75 mi. S. of Spokane, in the Palouse river valley, at an altitude of 2,750 ft. It is on federal highway 195, and is served by the Northern Pacific and the Union Pacific railways. Pop. (1950) 12,022. The State college of Washington (established 1890) is located there (college enrolment 5,100), the campus and experiment station occupying about 1,400 ac. Pullman was settled about 1884 and incorporated as a city in 1889.

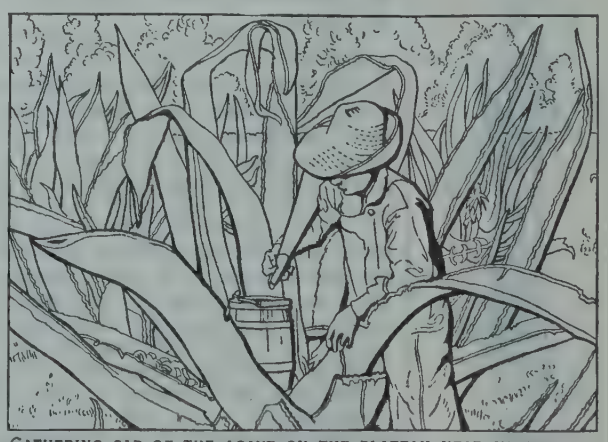
PULLMAN INCORPORATED (DELAWARE), a holding company formed in 1927, has three important subsidiaries: The Pullman Company (Chicago)—originally incorporated in 1867 as Pullman's Palace Car Company, with a capital of $100,000—is the largest operator of sleeping and other super-comfort railway cars in the world, controlling practically all the business in the United States and Mexico and part of that in Canada; Pullman-Standard Car Manufacturing Company (Chicago), the world's largest car building unit, and the Pullman-Standard Car Export Corporation (New York). At the beginning of 1940 The Pullman Company owned some 7,000 cars of which about 6,000 were sleeping cars. Over 200 of these were of the new light-weight and streamlined type. There were 750 parlour cars of different combinations, 143 composite cars, including baggage-club and other variations, and 15 private cars for special parties. In the year 1939, 15,655,135 revenue passengers were carried in Pullman cars, equal to a daily average of 42,890 in 5,100 cars. The passenger mileage was 8,485,399,123mi., or an average distance of 542 miles. Pullman-Standard Car Manufacturing Company in 1940 had 9 plants and 3 wheel foundries with these annual capacities: 2,370 passenger, 74,700 freight cars; 49,000 tons forgings, 287,500 wheels. Pullman-Standard Car Export Corporation's capacity is 1,500 freight and 150 passenger cars annually. (G. A. K.)

PULP: *see* PAPER MATERIALS.

PULPIT, a raised platform with enclosed front, whence sermons are delivered. Pulpits were probably derived from the *ambones* in the early Christian Church. (*See* AMBO.) There are many old pulpits of stone, though the majority are of wood. Those in churches are generally hexagonal or octagonal; and some stand on stone bases, and others on slender wooden stems, like columns. The designs vary according to the periods in which they were erected, having panelling, tracing, cuspings, crockets and other ornaments. Some are extremely rich, and ornamented with colour and gilding. A few also have rich canopies or sounding-boards. Their usual place is in the nave, mostly on the north side, against the second pier from the chancel arch. Out-door pulpits were common in the mediaeval period, and stood near a road or cross. Pulpits, for reading during the meals of the monks, are found in refectories.

Shortly after the Reformation the canons ordered pulpits to be erected in all churches. Many of the time of Elizabeth and James are beautifully carved, and are of Flemish workmanship. The pulpits in mosques, known as "mimbars," are canopied and approached by a straight flight of steps. These have a doorway at the foot, with an enriched lintel and boldly moulded head; the work is of wood, often inlaid, gorgeously painted and gilt.

PULQUE or **PULQUE FUERTE,** the national beverage of the Mexican natives. It is prepared by fermenting the juice of a number of species of the agave (*Agave americana,* etc.). The cultivation of the agave for purposes of pulque manufacture constitutes a considerable local industry. The juice of the agave termed *aguamiel* is allowed to ferment naturally for about ten days, and the product is termed *madre pulque.* A small quantity is added to fresh aguamiel, and a rapid fermentation is induced, the pulque being ready in a day or two. It has a heavy flavour, resembling sour milk, but it is esteemed by the natives because of its cooling and, according to them, nutritious properties.



GATHERING SAP OF THE AGAVE ON THE PLATEAU NEAR MEXICO CITY
In the making of pulque, the favourite drink of the Mexican people, the sap is sucked out of the plant into a tube, and from there poured into a pail or skin bag and allowed to ferment for about ten days

PULSE, throbbing or beating; in physiology the rhythmical beating due to the changes of blood tension in the arteries consequent on the expansion and contraction of their elastic tissues in response to the ejection of blood by the heart (*see* VASCULAR SYSTEM). In botany, a collective term for beans, peas, lentils

and other members of the family Leguminosae (*q.v.*).

PULSOMETER: *see* VACUUM.

PULTUSK, a town of Poland, on the Narew. Pop. (1946) 8,187. The town was entirely destroyed by fire in 1875, but was rebuilt on a more modern scale. In 1703 Charles XII of Sweden defeated and captured a Saxon army there, and in 1806 Napoleon defeated the Russians. The town was occupied by the Germans in 1915 and again in 1939. It was formerly part of the large estate of the bishops of Plock, whose former palace, dating from 1319, was destroyed in the fire.

PULVERIZED FUEL. The use of coal in the form of dust for raising steam has been known from isolated experiments for about the last forty years, but the fact that it was one of the most difficult methods of burning coal long delayed the development of the practice.

The theoretical advantages of burning crushed coal become obvious when one considers that if a cubic inch of coal, which has an exposed surface of six square inches, is crushed into cubes each of which has a side one-hundredth of an inch in length, the area of the exposed surface is multiplied one hundred times, and a more intimate mixing of the coal and air is rendered possible, and this without using a large excess of air. It is considered good practice under normal conditions with an average boiler furnace under conditions of mechanical stoking if 150 to 200 per cent of excess air is being admitted to the furnace. Under pulverized coal conditions of firing no difficulty is experienced in working regularly with not more than 20 to 30 per cent of excess air.

Inasmuch as coal-dust cannot be burnt in the ordinary way, special burners have to be provided. These differ in design, but the principles underlying all of them are the same. The coal is dried, pulverized, and the dust passing to the furnace is conveyed to a burner, mixed with air and burnt in the form of a jet. A point common to all the systems is that of the fineness to which it is necessary to reduce the coal. It has to be so fine that all of it will pass through a 100 mesh screen (that is to say a screen containing $100 \times 100 = 10{,}000$ apertures to the square inch) and 85 per cent of it through a 200 mesh screen.

There are a number of different forms of burners, the dust being driven into the fire-box by means of either fans or compressed air. In one system the air pressure is exerted in the tank, which is connected with the furnace by means of a pipe and the dust forced in a stream, unmixed with air, through the pipe to the furnace. In another it is drawn as required from the storage bin, mixed with air, and carried in suspension through pipes to the furnace at a high velocity. In yet another system the dust from the feed worm is blown into the fire-box.

Whilst the chief use of powdered fuel is in its application for raising steam, it is also largely used in cement works and in steel furnaces.

The economies claimed in respect of the use of coal in the powdered form over the lump coal are:—

(1) A reduction (by reason of the more complete combustion) in the amount of fuel necessary to secure a given heat result.

(2) Ability to use low-grade fuel.

(3) Saving in labour as stoking is rendered unnecessary.

(4) Flexibility of the operation, coal dust firing in this respect being almost equal to oil firing.

(5) Elimination of "banking" and easier disposal of ashes.

(6) Ease of control of furnace conditions in the case of metallurgical furnaces.

Of late years oil has been taking the place of coal in the generation of power in the movement of ships. Thus of the ships under construction in the year 1927 only about 31 per cent were those in which coal will be used, 69 per cent being driven by oil either to raise steam or used in internal combustion (Diesel) engines. The relative comparative efficiencies and costs of oil versus coal driven ships may be expressed as follows:—

The high efficiency of oil engines gives 1 S.H.P. for $\frac{4}{10}$ lb. of oil and 1 lb. of oil costs $\frac{4.3}{100}$ of a penny, so that 1 S.H.P. in a Diesel engine costs $\frac{1.7}{100}$ of a penny. In an ordinary marine steam engine and boiler, 1 S.H.P. requires 1·7 lb. of coal, which (with coal at 24/– per ton) costs $\frac{1.3}{100}$ of a penny, and one coal produced S.H.P. costs $\frac{2.2}{100}$ of a penny. In the particular case of "King George V.," built in 1926 and using high pressure steam, this has been reduced to $\frac{1.4}{100}$ of a penny, so that it has been demonstrated that coal is a cheaper fuel than oil for ship propulsion where high pressure steam is used, *i.e.*, 500 to 600 lb. per square inch. With pulverized fuel still further economies would be secured.

In America the development in the use of pulverized coal since 1920 has been exceptionally rapid and probably the world's consumption of pulverized fuel at the present time exceeds 150 million tons annually. In the United States of America the use of pulverized coal per annum has been estimated as follows:—

Cement kilns	50 million tons
Metallurgical furnaces	20 „ „
Steam boilers	30 „ „

On the Brazilian Central Railway some locomotives are being worked with pulverized coal derived from local deposits of inferior quality in place of using high-grade imported lump coal. In England also a system for locomotive use has been successfully developed.

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PUMA, a name for one of the largest cats (*Felis concolor*) of the New World. It is called "couguar" by the French and "panther" by hunters of the United States (*see* CARNIVORA).

FROM MANN, WILD ANIMALS IN AND OUT OF THE ZOO (THE SMITHSONIAN SERIES)
THE PUMA OR MOUNTAIN LION. (FELIS CONCOLOR)

Though often spoken of as the mountain lion, on account of the tawny colour of its upper parts, it rather resembles the leopard of the Old World in size and habits: measuring from nose to root of tail about 40 in., the tail being rather more than half that length. The head is small and has no mane. The ears are large and rounded. The tail is cylindrical, with some bushy hairs near the end, but no distinct tuft. The lower parts, inner surface of the limbs, throat, chin, and upper lip are dirty white; the outside of the ears, and a patch on each side of the muzzle black; the end of the tail dusky. The young are born spotted a dusky brown and with the tail ringed.

The puma has a wide range, extending from Canada in the north to Patagonia in the south, and formerly was generally distributed in suitable localities from the Atlantic to the Pacific Ocean. In Central America it is still common in the dense forests which clothe the mountain ranges. Though an expert climber, it is by no means confined to wooded districts, being also found in scrub and reeds along the banks of rivers and in the open pampas and prairies. Its habits resemble those of the rest of the group to which it belongs. It rarely attacks man.

PUMICE, a very porous, froth-like, volcanic glass. It is an igneous rock which was almost completely liquid at the moment of effusion and was so rapidly cooled that there was no time for it to crystallize. When it solidified the vapours dissolved in it were suddenly released and the whole mass swelled up into a froth which immediately consolidated. Had it cooled under more pressure it would have formed a solid glass or obsidian (*q.v.*);

in fact if we take fragments of obsidian and heat them in a crucible till they fuse they will suddenly change to pumice when their dissolved gases are set free. Hence it can be understood that pumice is found only in recent volcanic countries. Any type of lava, if the conditions are favourable, may assume the pumiceous state; but basalts and andesites do not so often occur in this form as do trachytes and rhyolites. Pumices are most abundant and most typically developed from acid rocks; for which reason they usually accompany obsidians, in fact in Lipari and elsewhere the base of a lava flow may be black obsidian while the upper portion is a snow white pumice.

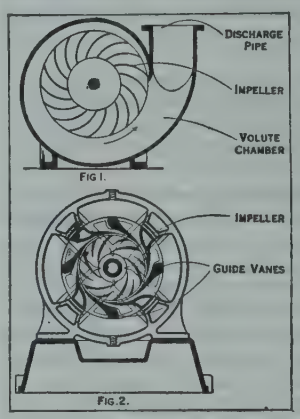
Small crystals of various minerals occur in many pumices; the most common are feldspar, augite, hornblende and zircon. If they are abundant they greatly diminish the economic value of the rock, as they are hard and wear down more slowly than the glassy material; consequently they produce scratches. The cavities of pumice are sometimes rounded, and may also be elongated or tubular owing to the flowing movement of the solidifying lava. The glass itself forms threads, fibres and thin partitions between the vesicles. Rhyolite and trachyte pumices are white, contain 60% to 75% of silica and the specific gravity of the glass is 2.3 to 2.4; andesite pumices are often yellow or brown; while pumiceous basalts, such as occur in the Sandwich Islands, are pitch black when perfectly fresh.

Good pumice is found in Iceland, Hungary, Nevada, Teneriffe, New Zealand, Pantelleria and the Lipari Islands. The last-named are the chief sources of pumice for the arts and manufactures. At Campo Bianco in Lipari there is an extinct volcanic cone with a breached crater from which a dark stream of obsidian has flowed. For industrial purposes the best varieties are obtained from Monte Pelato and Monte Chirica. The pumice is extracted by shafts and tunnels driven through the soft incoherent stone.

Among the older volcanic rocks pumice occurs, but usually has its cavities filled up by deposits of secondary minerals introduced by percolating water; hence it is of no value for industrial purposes. Pumice, in minute fragments, has been shown to have an exceedingly wide distribution over the earth's surface at the present day. It occurs in all the deposits which cover the floor of the deepest portion of the oceans, and is especially abundant in the abysmal red clay. In some measure this pumice has been derived from submarine volcanic eruptions, but its presence is also accounted for by the fact that pumice will float on water for months, and is thus distributed over the sea by winds and currents. After a long time it becomes waterlogged and sinks to the bottom, where it gradually disintegrates and is incorporated in the muds and oozes which are gathering there. After the great eruption of Krakatoa in 1883 banks of pumice covered the surface of the sea for many miles and rose in some cases for four or five feet above the water level. In addition much finely broken pumice was thrown into the air to a great height and was borne away by the winds, ultimately settling down in the most distant parts of the continents and oceans. Pumice stone has been satisfactorily used as a packing material for vinegar generators, its porous nature affording large oxidation surfaces, which are favourable to the development of dilute alcoholic liquids (washes) into vinegar. (J. S. F.)

PUMP, a machine to raise or move fluids. The method to be adopted in raising the elevation or the pressure of a fluid depends largely on the volume to be handled and the magnitude of the lift. For large volumes the centrifugal pump is almost universally used. In its modern forms this type is capable of pumping against any pressure up to about 1,500 lb. per sq.in. Where small volumes are to be handled, under high heads, the reciprocating pump is more suitable, while where corrosive liquids are to be pumped, other types of air-lift pumps often offer advantages. (*See* VACUUM.)

Centrifugal Pump.—In its simplest form the centrifugal pump consists of an impeller fitted with vanes and rotating in a closed casing. Water is supplied to the centre of the impeller. Due to its rotating in the impeller its pressure is increased by centrifugal force, and it is delivered at the periphery with an increased pressure and a high velocity. The kinetic energy involved in this exit velocity would be wasted if no means were available for converting it into pressure energy before leaving the pump, and various means are adopted for affecting this conversion. In the majority of pumps the impeller is surrounded by a spiral volute chamber (fig. 1) whose area gradually increases in the direction of flow, so that the velocity is gradually reduced before the water leaves the pump. Such a device is capable of converting at most about 40% of the kinetic energy into pressure energy. Where higher efficiencies are required a ring of guide vanes is used, surrounding the impeller (fig. 2). These vanes are so designed as to receive the water without shock on leaving the wheel and to direct it through passages having gradually diverging walls into the collecting volute from which it is fed to the discharge pipe. In these passages the pressure increases as the velocity is gradually reduced, and under favourable circumstances such an arrangement is capable of converting some 75% of the kinetic energy into pressure energy.



FROM BIGSON, "HYDRAULICS AND ITS APPLICATIONS" (CONSTABLE & CO.)

FIG. 1.—CENTRIFUGAL PUMP WITH VOLUTE CHAMBER

FIG. 2.—CENTRIFUGAL PUMP WITH GUIDE VANES SURROUNDING IMPELLER

The necessary peripheral speed of a centrifugal pump increases with the working head, and since fluid frictional losses increase rapidly with the speed, the efficiency begins to fall off appreciably if the working head per impeller is more than about 150 feet. Where very high heads have to be handled, multi-stage pumps are used in which the water passes through one impeller after another in series. Pumps of this type are extensively used for boiler feed work and for hydraulic power pumping stations.

The characteristics of a centrifugal pump depend essentially on the vane angles of its impeller, and under suitable conditions its overall efficiency may attain a value as high as 85%. At the inner periphery the vane angle β (fig. 3) should be such that the water enters the impeller without shock. This condition is satisfied if tan $\beta = f_2/u_2$ where f_2 is the radial component of the velocity of the water, and u_2 is the peripheral velocity of the impeller at this point. At the point of discharge the vanes may either be radial, or may be curved forwards, or backwards from the direction of rotation depending upon the duty for which the pump is designed. If γ be the vane angle at this point, and if u_3 be the peripheral velocity and f_3 the radial component of velocity of the water, the gain of pressure head in the impeller is, neglecting frictional losses, equal to

$$\frac{u_3^2 - f_3^2 \operatorname{cosec}^2 \gamma + f_2^2}{2g} \text{ feet}$$

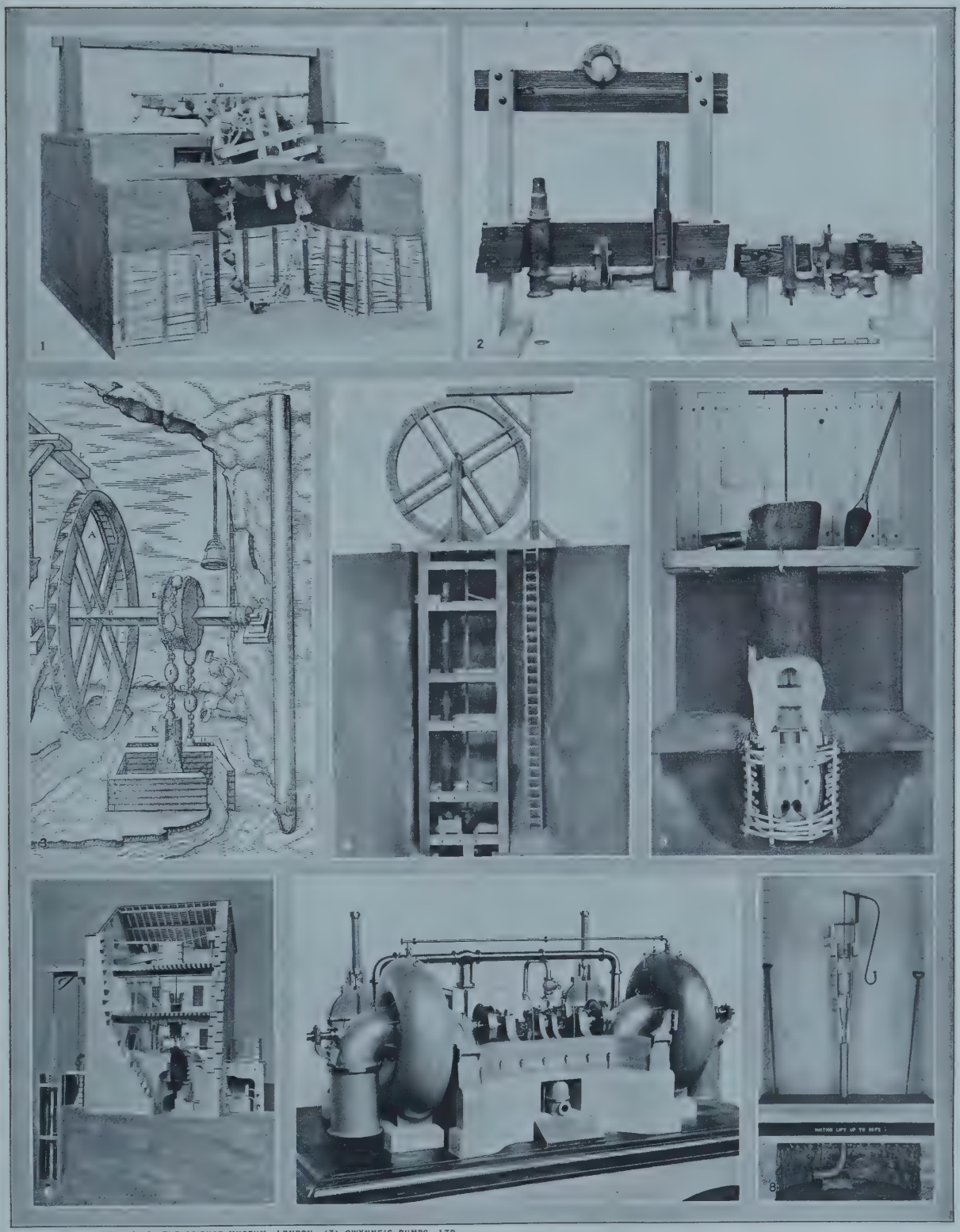
while if K represents the proportion of the kinetic energy of discharge which is converted into pressure energy in the volute chamber or guide vanes, the total gain of pressure in the pump is given by

$$u_{32}(K+1) + f_3^2 \operatorname{cosec}^2 \gamma (K-1) - 2Ku_3 f_3 \cot \gamma \text{ feet.}$$

In the majority of pumps the angle γ is between 30° and 75°, the value increasing with the height of lift.

Reciprocating Pumps.—These may be either of the single acting or double acting type. In the former, water is drawn into the pump through a suction valve on one stroke, and is forced out through the delivery valve on the return stroke. By fitting suction and delivery valves on both sides of the plunger, the pump becomes double acting.

The acceleration and retardation of the plunger at the ends of the stroke causes corresponding retardations and accelerations in the supply and delivery columns, and if these are long considerable momentum effects may be experienced. If the speed is



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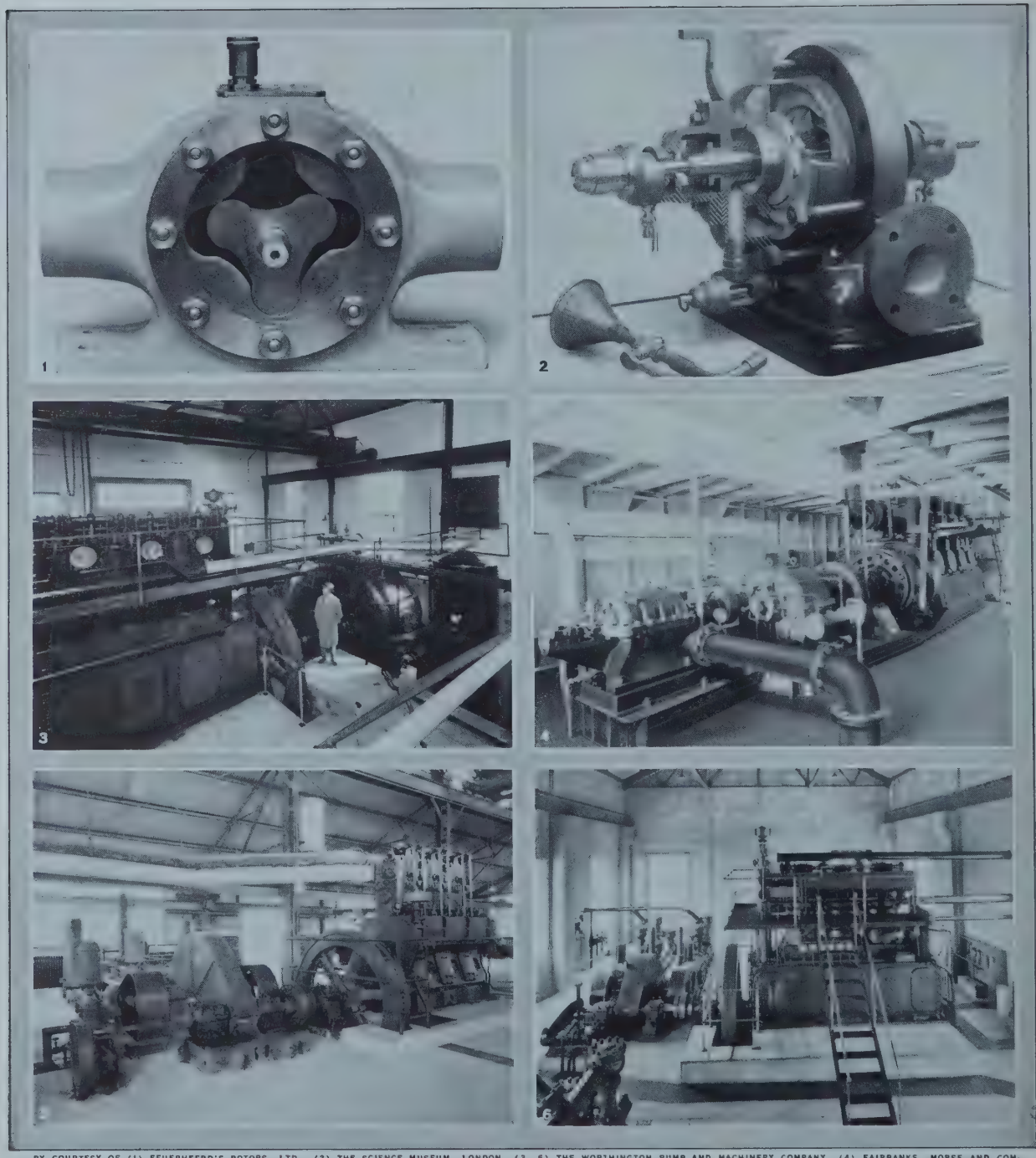
DEVELOPMENT OF PUMPING MACHINERY

1. Model of an Egyptian chain of pots, by means of which water was pumped from the Nile many centuries ago. 2. Copy of the Roman pumps salvaged from the ruins of ancient Rome. 3. Sixteenth-century rag and chain mine pump, using a bundle of rags. 4. Model of a 16th-century Saxon reciprocating mine pump. 5. Model of a 16th-century Saxon wooden hand pump, whose cylinder consisted of a hollow tree-trunk, part of which is cut away to show construction. 6. Model of an early 18th-century French Newcomen mine pumping plant, with top and front removed for inspection of interior. 7. Centrifugal land drainage pump (1874–76). 8. Early 18th-century model of French lead hand pump

PUMP



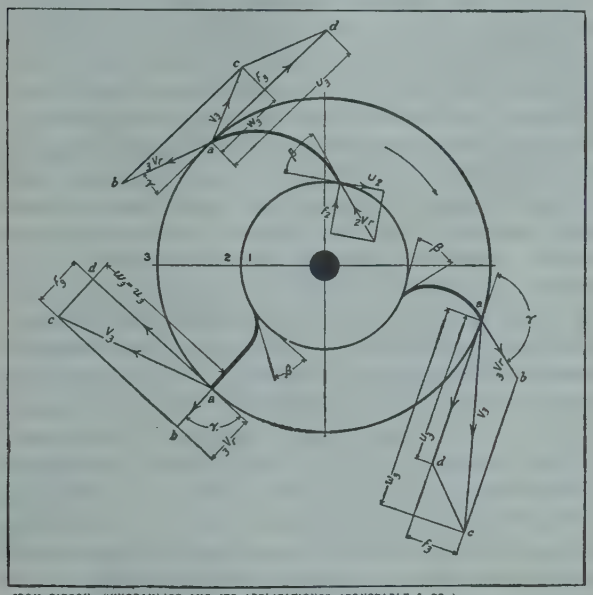
BY COURTESY OF (1) FEUERHEERD'S ROTORS, LTD., (2) THE SCIENCE MUSEUM, LONDON, (3. 6) THE WORTHINGTON PUMP AND MACHINERY COMPANY, (4) FAIRBANKS, MORSE AND COMPANY. (5) THE DE LA VERGNE MACHINE COMPANY

VARIOUS TYPES OF PUMPS

1. Rotary displacement pump
2. Section of a two-stage turbine pump
3. A 330 h.p. Diesel engine, connected to an 80-in. drainage pump, to the right
4. High pressure Diesel pump set, showing multi-stage pump to the left
5. A 200 h.p. Diesel engine, direct connected to a high-pressure plunger pump serving an oil pipe line
6. A 4-cycle air injection engine used in petroleum pipe line stations

sufficiently high the columns may be unable to maintain contact with the plunger and "cavitation" is set up, which gives rise to considerable shock in the pump. To avoid this an air vessel should always be fitted on the suction side of the pump, and often on the delivery side. This equalizes the flow along the pipe lines.

For low speed pumps, disc valves of rubber or metal, which are returned to their seat either by the action of a spring or by their own elasticity, are usually used. For high speed pumps mechanically operated valves are often used.

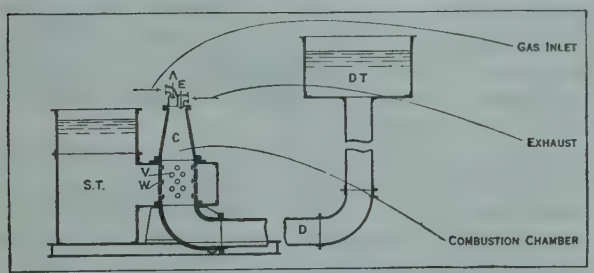


FROM GIBSON, "HYDRAULICS AND ITS APPLICATIONS" (CONSTABLE & CO.)

FIG. 3.—VELOCITY DIAGRAMS FOR VANES OF CENTRIFUGAL PUMP, HAVING DIFFERENT DEGREES OF BACKWARD CURVATURE

Rotary Pumps.—Pumps of the rotary type are well adapted for working over a wide range of speeds with comparatively low head and with widely varying discharges. They have the advantage over the reciprocating pump that the discharge is practically continuous, while the efficiency does not fall off nearly so quickly with discharge variations as the centrifugal pump.

There are two main types of rotary pump. In one a drum mounted eccentrically in its casing carries one or more sliding diaphragms which make contact with the interior of the casing. In the other type two rotating drums are used mounted on parallel axes and coupled together by two equal gear wheels mounted on the shafts outside the casing.



FROM GIBSON, "HYDRAULICS AND ITS APPLICATIONS" (CONSTABLE & CO.)

FIG. 4.—HUMPHREY GAS PUMP

Humphrey Gas Pump.—In the Humphrey Gas Pump water is raised by the direct action of the pressure accompanying the explosion and expansion of a gas-air mixture. At the beginning of the power stroke a compressed charge of air and gas in the combustion chamber C (fig. 4) is ignited by an electric spark and expands forcing the column of water D between the combustion chamber and the delivery tank DT towards the tank and discharging part of it in the process. Due to the momentum of this column, expansion continues until the pressure at the lower part of the water column falls to atmospheric, when the suction valves V, communicating with the suction tank ST, open and water is drawn through them into the pipe. At the same time the exhaust valve is opened. When the momentum of the water column is exhausted it oscillates back, driving the products of combustion out of the combustion chamber until it reaches the exhaust valve, which it closes by impact; on the next rebound of the water column the gas inlet valve opens and a fresh charge is drawn in; at the end of the outward oscillation the gas inlet valve is closed and the returning oscillation compresses the charge which is fired as the column comes to rest.

The Air Lift Pump.—This consists of an open ended vertical lift pipe, of which the lower end is submerged in the liquid to be raised, and the upper end delivers into a discharge tank at the height which is required. Air is supplied from an air compressor through an air pipe to the lower end of the lift pipe, and rising in the form of small bubbles through the liquid in this pipe forms a mixture having a specific gravity lower than that of the liquid itself. The pressure of the liquid surrounding the pipe then raises the lighter mixture above the supply level and out of the top of the lift pipe. The possible lift depends upon the amount of air supplied and upon the depth of submersion of the bottom of the lift pipe. For best results the depth of submersion should be approximately 1·5 times the height of the lift. For high efficiency the air should be supplied to the lift pipe through a foot-piece having a series of small openings so arranged as to distribute the air in a series of small bubbles through the liquid. If well designed such a pump is capable of converting some 60% of the energy in the compressed air at the foot-piece into useful work in lifting water. Air lift pumps have been constructed for lifting against heads of upwards of 400 ft., and with lift pipe diameters up to about 15 inches.

Jet Pump.—In the jet pump a high pressure water supply is conducted to a small nozzle, whence it issues into a suction chamber as a jet having a high velocity and a relatively low pressure. The suction chamber surrounding the jet is connected to the suction reservoir. If the pressure at the jet is sufficiently low, water is lifted into this chamber and is forced by the impact of the high velocity jet into a discharge pipe, whose suction gradually increases in the direction of flow. There the kinetic energy is partially converted into pressure energy, enabling the pump to discharge against a head considerably higher than that of the suction reservoir. Owing to the loss due to eddy formation accompanying the admixture of the high and low velocity water, the efficiency of such a pump is low and does not usually exceed about 20%. When the fluid used for the high pressure jet is steam, the pump becomes the boiler feed injector so largely used in locomotive work.

The Hydraulic Ram.—This is an apparatus devised to utilize the energy of a water supply at a low head, to pump up part of this water to a height greater than that of the supply head. It consists of an inclined supply pipe leading straight into a valve-box which is fitted with a waste valve opening inwards, and a delivery valve opening outwards. This valve discharges the water into an air vessel from which it is delivered in a steady stream to the discharge pipe.

The action of the ram is as follows: The waste valve being opened, water is free to escape, and flow is set up along the supply pipe. The velocity of flow increases under the influence of the supply head until the dynamic pressure on the under side of the valve becomes sufficiently great to overcome its weight. The valve now closes rapidly and the sudden check to the momentum of the supply column causes a rapid increase of pressure in the valve-box until this pressure becomes sufficiently great to open the delivery valve. Water then escapes through this valve into the air vessel, compresses the air, and flows away along the rising main. As soon as the momentum of the supply column is destroyed the delivery valve closes, the water below the valve partaking of the backward motion thus instituted. This motion, once set up, can only be checked by a reduction of pressure in

the valve-box below that corresponding to the statical head of the supply, and consequently the pressure in the valve-box is reduced rapidly until at some instant the waste valve reopens, and the whole cycle of operations is repeated. The efficiency of the hydraulic ram falls off as the ratio of the delivery head to the supply head is increased. When this ratio does not exceed about 4 : 1, the efficiency may be high as 75%. If the ratio is increased to 20 : 1 the efficiency does not exceed about 25%.

A pumping device known as the "Hydrotomat" has been recently introduced which also utilizes a large quantity of water under a low head to raise a portion of itself to some greater height. This works by alternately compressing and exhausting air in a series of containers.

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PUMPKIN, the fruit of certain varieties of *Cucurbita pepo* or of *C. moschata,* members of the family Cucurbitaceae. The names pumpkin and squash, especially in America, are applied rather inconsistently to certain varieties of both these species. The quick-growing, small-fruited bush or nontrailing varieties of *C. pepo* (*see* SQUASH) are called squash in America, while the long-season, long-trailing, large-fruited varieties are called pumpkin. The fruits are large, generally 10–20 lb. or more, yellowish to orange in colour and vary from oblate through globular to oblong. The rind is smooth and usually lightly furrowed or ribbed; the fruit stem is hard and woody, ridged or angled, and in *C. pepo* not flared at its point of attachment to the fruit. The very largest varieties of "pumpkin" are more properly designated as winter squash, *C. maxima,* and may weigh 75 lb. or more. Varieties cross-pollinate very readily within each of the three species mentioned, but the species do not cross naturally. A few interspecific crosses have been recorded but the hybrids were highly self-sterile and set no fruit with their own pollen. Neither pumpkins nor squashes will cross with cucumbers or with melons.

Pumpkins are commonly grown in Great Britain, Europe and North America for human food and also for livestock feed. The varieties commonly called pumpkin produce very long vines and are usually planted in hills of 2–3 plants each, about 8 × 8 ft. apart. They are also planted at wide intervals in fields of corn. Pumpkins mature in early fall and can be stored a few months in a dry place well above freezing. They are prepared for food in a wide variety of ways. (V. R. B.)

PUNAN. The name applied to a number of peoples in Borneo, all of them, except the Punan Ba, forest nomads in the area of the headwaters of the major rivers. They live in isolated groups of 30 to 40, subsisting on the wild sago palm and game hunted with the blowpipe. Physically and culturally they are very similar to the other peoples of the island; none of them is Negrito or demonstrably aboriginal in Borneo. Some of the groups differ widely from each other and there is no indication why they should all be called Punan. As a result of this similarity of name European accounts of them are almost inextricably confused. Three "Punan" peoples, however, are certainly distinct: the settled Punan Ba of western Borneo; the Penan (wrongly named Punan) of the Baram and Balui; and the Punan Aput and Busang of the northern Apo Kayan. (R. NM.)

PUNCH, the abbreviated form of Punchinello (Ital. *Policinella, Pulcinella*), the most popular of the puppets or marionettes (*q.v.*), and the chief figure in the "Punch and Judy" show. It is of Italian origin, though its history is by no means free from obscurity. The earlier etymologists sought to trace the name to various mythical individuals, by whom, it was alleged, the type was first furnished. F. Galiani adopts the theory which derives it from the name of Puccio d'Aniello, a vintager of Acerra near Naples, who, having by his wit and grotesque appearance vanquished some strolling comedians in their own sphere, was induced to join the troop, and whose place, by reason of his popularity, was supplied after his death by a masked actor who imitated his dress and manner. The claims of other individuals—Paolo Cinella, Polliceno and Pulcinella, a Neapolitan dealer in fowls—have also found supporters, and the derivation of the name and character from some old mystery representing Pontius (O. Eng. *Pownce;* Fr. *Ponce*) Pilate and Judas, or the Jews, was formerly popular. It has even been suggested that the title is a modification of πολὺ κινέω (I move much) as expressive of the restlessness which is characteristic of the puppet; and the assumption that the character was invariably of diminutive size has given rise to its reference to the word *pollice,* the thumb (cf. *Däumling,* Tom Thumb). The most plausible theory, however, regards the name in its Italian form as a diminutive of *pulcino,* fem. *pulcina,* a chicken. It is sometimes stated that, in consequence of the habit of using the word "chicken" as a term of endearment, it came to mean "a little child," and hence "a puppet" (W. Skeat). The choice, however, seems to lie between the theory of Quadrio, that it was applied on account of the resemblance of the hooked nose to a beak, and that of J. Baretti, which ascribes its employment to the nasal squeak and timorous impotence of the original character. With respect to the development of the modern type, it has been assumed that the whole family of Italian *maschere* (Arlecchino, Brighella and the like) are modified survivals of the principal Oscan characters of the *Atellanae,* and that Punchinello is the representative of Maccus, the fool or clown. In proof of this it is urged that Acerra, the supposed residence of Puccio d'Aniello and the traditional source of the character, is in the neighbourhood of Aversa, the old Atella; and reference is also made to a bronze statue of Maccus, discovered at Rome in 1727, an engraving of which has been preserved in Ficoroni's *Le Maschere sceniche e le figure comiche d'antichi Romani.* But the resemblance of the statue to the puppet is scarcely a striking one, and the large nose and deformed figure are somewhat hazardous ground on which to base a theory.

Andrea Perrucci (1699) and Gimma assert with some show of authority that Silvio Fiorillo, a comedian named after his principal part, Captain Matamoros (the Italian *Miles Gloriosus*), invented the Neapolitan Pulcinella. It was afterwards improved by Andrea Calcese, surnamed Ciuccio, who died of the plague in 1656, and who, according to Gimma, imitated in the character the peasants of Acerra. This would place the origin of the Italian Pulcinella somewhere about the commencement of the 17th century, the original character appearing to have been that of a country clown, hook-nosed, shrill-voiced, cowardly, boastful and often stupid, yet given at times to knavish tricks and shrewd sayings. In thorough accordance with this date, we find that the earliest known appearance of Polichinelle in France is at the beginning of the reign of Louis XIV, in the show of the puppet-playing dentist Jean Brioché. The date of its introduction into England has been disputed, J. Payne Collier being of opinion that Punch and King William came together, a second theory suggesting an earlier origin with the Huguenot refugees.

It is more than probable that it crossed the channel in the wake of the Royalists. Apart from the general references by S. Pepys (1662) and by J. Evelyn (1667) to an Italian puppet show at Covent Garden, the former makes mention (1669) of some poor people who called their fat child Punch, "that word being become a word of common use for all that is thick and short." An allusion to "Punchinellos" is also to be found in Butler's satire on English imitation of the French, and Aubrey speaks of "a Punchinello holding a dial" as one of the ornaments of Sir Samuel Lely's house at Whitehall. But, though the puppet did not travel in the train of William of Orange, allusions to it became far more frequent after the Revolution of 1688, and the skill of the Dutch in their treatment of puppet mechanism may have enhanced its attractiveness. In 1703 it was introduced at Bartholomew Fair into a puppet play of the creation of the world; in 1709 (*Tatler,* No. 16) it was to be found in a representation of the Deluge, though in a different part from that of the Momus Polichinelle of Alexis Piron's *Arlequin-Deucalion* (1722); and in 1710 (*Spectator,* No. 14) it is mentioned as a leading figure in Powell's

puppet-show at Covent Garden. The alleged satire on Robert Walpole, entitled *A Second Tale of a Tub, or the History of Robert Powell, the Puppet-Showman* (1715), furnishes some details of Punch performances, and has an interesting frontispiece representing Powell with Punch and his wife. The Judy (or Joan, as she appears to have been sometimes called) is not of a specially grotesque order, but the Punch is easily recognizable in all but the features, which are of the normal puppet type.

The older Punchinello was far less restricted in his actions and circumstances than his modern successor. He fought with allegorical figures representing want and weariness as well as with his wife and with the police, was on intimate terms with the patriarchs and the seven champions of Christendom, sat on the lap of the queen of Sheba, had kings and dukes for his companions. Powell seems to have introduced a trained pig which danced a minuet with Punch, and the French (among whom Punch is now usually styled Guignol, originally a puppet hailing from Lyons) occasionally employed a cat in the place of the dog Toby, whose origin is somewhat uncertain. A typical version of the modern play, with illustrations, was published by Payne Collier and Cruikshank in 1828 (3rd ed., 1844).

PUNCHING AND SHEARING MACHINES. The quickest method of making holes in, or severing, materials is by punching or shearing, and there are few forms of manufacture that do not utilize machines for these operations. Paper, card, leather, cotton, cloth, slate, tin, brass, iron and steel all undergo such treatment. Circular and other shaped holes are made, pieces are punched out to give various outlines, and various shapes are sheared off. The most striking examples are in steel works, where blades of 12 feet in length will shear through 2 in. cold steel plate, or hot slabs 43 in. by 20 in. thick are cut through. Many industries are suited by hand-worked machines, others require belt, electric motor or steam-engine drive, while the largest punches and shears are worked hydraulically. Hand machines are employed by tinsmiths and other light metalworkers, also by boxmakers, and these machines rest on the bench. Larger punches or shears are actuated by treadle, the latter machines having blades up to about 4 feet in length. Some have blades formed to cut curves in tinplate or iron plate, instead of using a die to stamp the outlines, and corrugated blades are used for shearing corrugated iron. Blacksmiths and others make use of a combined type of machine, with a single lever moving the punch and the shear blade. This principle is also applied in many big machines of the engineering works, but using power drive.

Punching and shearing are alike in action which amounts to a rather violent separation of the fibres of the material. In soft substances there is little injury, because the cutting edges can be

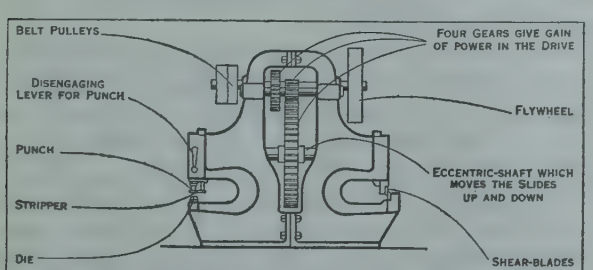


DIAGRAM OF A PUNCHING AND SHEARING MACHINE, WHICH PUNCHES AT ONE END AND SHEARS AT THE OTHER

made of a keen angle, but iron and steel become more or less torn unless very thin, and the edge reveals minute cracks. For certain purposes these would be undesirable, as tending to increase under stress; consequently plates and strips for steam-boilers are not punched, but drilled for reasons of safety. And where structures are subject to heavy loads of a fluctuating nature, the best plan is undoubtedly to ream punched holes, the reamer taking away the cracked and torn walls and leaving a smooth and whole surface. Shorn plates for boilers and certain other constructions are also machined on the edges, by turning, planing or milling, until a clean faultless metal is left. Obviously in order to ensure neat punching or shearing, as well as to minimize cracks and damaged edges, the tools should be kept ground up sharp, and set so that the material is well supported at the moment of impact. In a great many cases a slotted finger, termed a *stripper*, is fixed a fraction of an inch above the material, so that as the punch rises after the stroke the material cannot be pulled up with it, but is automatically stripped off. Some substances, especially when laid in piles for simultaneous treatment, must be clamped down firmly to prevent faulty results, while the thicker steel plates are held immovably by a mechanically-operated clamping device which comes into play just before the descent of the slide. Hydraulic vice rams perform this function in the large hydraulic shears of the steel-works. In rolling-mills, plates and slabs are transported under the shear on sets of power-driven rollers.

Types of Punching and Shearing Machines.—The power-driven punching machines vary in design according to whether the material is thin or thick. For the general run of tinware and similar thin stock the crank-driven power-presses are used, being of much the same or identical design as for other operations on sheetmetal parts. The machine frame must be stiff, and if necessary braced with tie-rods to prevent spring, otherwise the act of penetration will cause the punch and die to come out of alignment, and they will be injured, and poor work will result. The slide which moves the punch up and down must be well fitted, as any slackness will have a similar effect. The fit of the punch in the die, through which it pushes the punching, must be fairly close to ensure getting a sharp impression around the edges. The fit is closer in very thin metal than it need be in thick stuff. Many special mandrels or supports are attached to presses to carry the lower die when the object is of a difficult outline, such as a pipe.

For engineering manufactures, including all sorts of steel construction (boilers excepted), ships, agricultural machinery, tanks, cisterns, piping, fencing, railway carriage and wagon frames and so on, the punching machines are either single or multiple, or are combined in one frame with a shearing machine, so that one drive actuates each slide (see the sketch). The punch slide has a disengaging device, rendering the punch inoperative until the attendant has accurately located the plate beneath it, whereupon he pulls a little lever and the punch descends. The purpose of the flywheel is to give a reserve of energy to carry the punch or shear through the metal. The larger machines possess self-contained jib cranes, enabling heavy plates to be slung and moved along as necessary without keeping the shop crane engaged. Punching-machines only have an eccentric action to the slide (similar in principle to that of the diagram) and are often double-ended, using a differently sized punch in each slide. Instead of eccentric motion, powerful levers are often utilized in collaboration with a central eccentric which rocks them and so moves each slide. Sometimes a third slide is included in a double-ended punching and shearing machine to cut angle-iron, which requires a special shape of blade. Provision for shearing off angles, tees, channels, girders or H-irons is incorporated in some machines, there being apertures of corresponding section through which the shapes are pushed and sheared by a knife behind. The framings of such machines are frequently made in either cast-steel or steel plates riveted together, to afford extra strength without such weight as is necessary for cast-iron framings.

Multiple punching is greatly in favour because of the economy of production. The regular machines may have an attachment to take two or three punches, but otherwise a special machine has to be used, with a wider slide than usual. The punches are either adjustable as to distance apart, or fixed in this respect. Plates and bars for tanks, agricultural machines, carriages and wagons and various machinery may have any number up to 100 holes pierced at a stroke. If several rows must be put through a sheet (as for mine screens) the sheet can be handled rapidly on an automatic spacing table, which feeds it accurately to the successive positions past the punches. Alternatively the plate may remain stationary and the punching head travel intermittently to the successive positions.

The massive shears required in steel works and those making

big boilers are actuated by powerful gearing and eccentrics, or by hydraulic cylinders. The parts must be extremely strong in order to withstand the enormous force exerted at the moment of shearing and powerful spring buffers are often provided to take the shock as the blade goes through the plate. In these, as in most other shears, the blade is set at an angle so that it only shears progressively from one end to the other.

Hydraulic action furnishes a simpler mode of actuating a punch or shear slide than gearing in some of the shipyards, for punching big holes necessary in some of the plates. Portable machines for either punching or shearing are often used in the yards, being either carried about or transported on wheels. The working of a lever operates the pump and sends water to the actuating cylinder. Small machines are termed punching bears.

Rotary shears are so named because bevel-edged discs are used for the shearing. Some cut straight, others in circles, the plate being rotated on a central stud. Both circles and rings are sheared thus in large numbers for the tinware industry and other branches requiring these forms to build up shapes, or to stamp to further outline in dies. Some are built as *slitting shears*, that is suitably to make a long straight cut to divide a plate in two, or shear it up into strips, and there are also *scroll shears* which will cut intricate outlines between the discs, the attendant suitably manoeuvering the sheet as he feeds it along. (F. H.)

PUNCTUATION, the art of "pointing" a literary composition so as to divide it into sentences and portions of sentences, which the "points" mark at their close, thus indicating what would in speech be pauses or changes of expression (Lat. *punctum*, a point). The uses of the chief "points" are thus explained in the "Rules for Compositors" at the Oxford University Press, compiled by Mr. Horace Hart:—

The "full stop" or "period" (.) marks the end of a sentence. The "colon" (:) is at the transition point of the sentence. The "semicolon" (;) separates different statements. The "comma" (,) separates clauses, phrases and particles. (The terms "period," "colon," "comma," were borrowed from the Greek grammarians, who originally described either the whole sentence or a part of it in this way.) The "dash" (—) marks abruptness or irregularity. The "exclamation" (!) marks surprise. The "interrogation" or "query" (?) asks a question. The apostrophe (') marks elisions or the possessive case. "Quotes," quotation-marks or "inverted commas" (" ") define quoted words. Interpolations in a sentence are marked by various forms of bracket () or parenthesis. Usage and practice vary however. The subject may be studied in such works as H. Beadnell's *Spelling and Punctuation*, P. Allardyce's *Stops: or how to punctuate*, and T. L. de Vinne's *Correct Composition*. In the earlier forms of writing the letters ran on continuously in lines; only by degrees were words divided up by spacing within the line; later came the distribution into sentences by points, and the introduction by Aldus Manutius (16th century) of a regular system for these. The chief signs were derived from the dots of the Greek grammarians, but these have often changed meanings; thus the Greek interrogation mark (;) becomes the semicolon. (*See* PALAEOGRAPHY and TYPOGRAPHY.)

PUNIC WARS, a name specially appropriated to the wars between Rome and Carthage in the 3rd and 2nd centuries B.C. The origin of these conflicts is to be sought in the position which Rome acquired about 275 B.C. as suzerain and protector of all Italy. Her new obligation to safeguard the peninsula against foreign interference made it necessary that she should not allow the neighbouring island of Sicily to fall into the hands of a strong and expansive power. Carthage, on the other hand, had long been anxious to conquer Sicily and so to complete the chain of island posts by which she controlled the western Mediterranean.

First Punic War (264–241 B.C.[1]).—The proximate cause of the first outbreak was a crisis in the city of Messana, commanding the straits between Italy and Sicily. A band of Campanian mercenaries, which had forcibly established itself within the town and was being hard pressed in 264 by Hiero II. of Syracuse, applied for help both to Rome and Carthage and thus brought a force from either power upon the scene. The Carthaginians, arriving first, occupied Messana and effected a reconciliation with Hiero. The Roman commander nevertheless persisted in throwing troops into the city, and by seizing the person of the Carthaginian admiral during a parley induced him to withdraw. The Romans thus won an important strategic post, but their aggression met a declaration of war from Carthage and Syracuse.

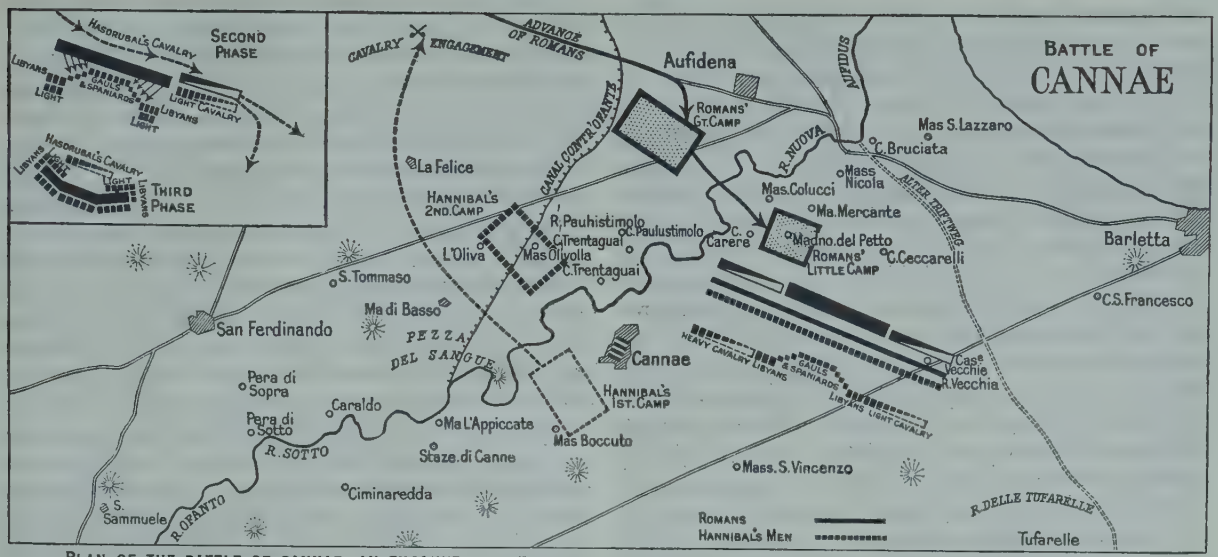
Operations began with a joint attack upon Messana, which the Romans easily repelled. In 263 they advanced with a considerable force into Hiero's territory and induced him to seek peace and alliance with them. Having thus secured their foothold on the island they set themselves to wrest it completely from Carthage. In 262 they besieged and captured the enemy's base at Agrigentum, and proved that Punic mercenary troops could not stand before the infantry of the legions. But they made little impression upon the Carthaginian fortresses in the west of the island and upon the towns of the interior which mostly sided against them. Thus in the following campaigns their army was practically brought to a standstill.

In 260 the war entered upon a new phase. Convinced that they could gain no serious advantage so long as the Carthaginians controlled the sea and communicated freely with their island possessions, the Romans built their first large fleet of standard battleships. At Mylae, off the north Sicilian coast, their admiral C. Duilius defeated a Carthaginian squadron of superior manoeuvring capacity by a novel application of grappling and boarding tactics. This victory left Rome free to land a force on Corsica and expel the Carthaginians (259), but did not suffice to loosen their grasp on Sicily.

After two more years of desultory warfare the Romans decided to carry the war into the enemy's home territory. A large armament sailed out in 256, repelled a vigorous attack by the entire Carthaginian fleet off Cape Ecnomus (near Agrigentum) and established a fortified camp on African soil at Clypea. The Carthaginians, whose citizen levy was utterly disorganized, could neither keep the field against the invaders nor prevent their subjects from revolting. A single campaign compelled them to sue for peace, but the terms which the Roman commander Atilius Regulus offered were intolerably harsh. Accordingly they equipped a new army in which, by the advice of a Greek captain of mercenaries named Xanthippus, cavalry and elephants formed the strongest arm. In 255, under Xanthippus's command, they offered battle to Regulus, who had taken up position with an inadequate force near Tunis, outmanoeuvred him and destroyed the bulk of his army. A second Roman armament, which subsequently reached Africa after defeating the full Carthaginian fleet off Cape Hermaeum, did not venture to reopen the campaign, but withdrew all the remaining troops.

The Romans now directed their efforts once more against Sicily. In 254 they carried the important fortress of Panormus (Palermo) by an attack from the sea; but when Carthage threw reinforcements into the island the war again came to a standstill. In 251 at last the Roman general L. Metellus brought about a pitched battle near Panormus in which the enemy's force was effectively crippled. This victory was followed by an investment of the chief Punic base at Lilybaeum by land and sea. The besiegers met with a gallant resistance, and in 249 were compelled to withdraw by the loss of their fleet in a surprise attack upon the neighbouring harbour of Drepanum (Trapani), in which the admiral Claudius Pulcher was repulsed with a loss of 93 ships. Meanwhile other losses in storms on the high seas so reduced the Roman fleet that the attack upon Sicily had to be suspended. At the same time the Carthaginians, who felt no less severely the financial strain of the prolonged struggle and had a war in Africa on their hands, reduced their armaments and made no attempt to deliver a counter-attack. The only noteworthy feature of the ensuing campaigns is the skilful guerrilla war waged by a new Carthaginian commander, Hamilcar Barca, from his strong positions on Mt. Ercte (247–244) and Mt. Eryx (244–242) in western Sicily, by which he effectually screened Lilybaeum from the Roman land army.

[1]The chronology here given is the traditional one, but recent researches tend to show that many events have been antedated by one year



PLAN OF THE BATTLE OF CANNAE, AN ENCOUNTER OF THE SECOND PUNIC WAR, WHERE THE ROMANS WERE PRACTICALLY ANNIHILATED BY HANNIBAL IN 216 B.C.

In 242 Rome resumed operations on sea. By a magnificent effort on the part of private citizens a fleet of 200 warships was equipped and sent out to renew the blockade of Lilybaeum. The Carthaginians hastily collected a relief force, but in a battle fought off the Aegates or Aegusae islands (west of Drepana) their fleet was caught at a disadvantage and mostly sunk or captured (March 10, 241). This victory, by giving the Romans undisputed command of the sea, rendered certain the ultimate fall of the Punic strongholds in Sicily. The Carthaginians accordingly opened negotiations and consented to a peace by which they ceded Sicily and the Lipari islands to Rome and paid an indemnity of 3,200 talents (about £800,000).

The Interval Between the First and Second Wars (241–218 B.C.).—The loss of naval supremacy not only deprived Carthage of her predominance in the western Mediterranean, but exposed her oversea empire to disintegration under renewed attacks by Rome. The temper of the Roman people was soon made manifest during a conflict which broke out between the Carthaginians and their discontented mercenaries. Italian traders were allowed to traffic in munitions of war with the mutineers, and a gross breach of the treaty was perpetrated when a Roman force was sent to occupy Sardinia, whose insurgent garrison had offered to surrender the island (239). To the remonstrances of Carthage the Romans replied with a direct declaration of war, and only withheld their attack upon the formal cession of Sardinia and Corsica and the payment of a further indemnity.

From this episode it became clear that Rome intended to use her victory to the utmost. To avoid complete humiliation Carthage had no resource but to humiliate her adversary. The recent complications of foreign and internal strife had indeed so weakened the Punic power that the prospect of renewing the war under favourable circumstances seemed remote enough. But the scheme of preparing for a fresh conflict found a worthy champion in Hamilcar Barca, who sought to compensate for the loss of Sicily by acquiring a dominion in Spain where Carthage might gain new wealth and form a fresh base of operations against Rome. Invested with an unrestricted foreign command, he spent the rest of his life in founding a Spanish empire (236–228). His work was continued by his son-in-law Hasdrubal and his son Hannibal, who was placed at the head of the army in 220. These conquests aroused the suspicions of Rome, which in a treaty with Hasdrubal confined the Carthaginians to the south of the Ebro, and also guaranteed the independence of Saguntum, a town on the east coast which pretended to a Greek origin. In 219 Hannibal laid siege to Saguntum and carried the town in spite of a stubborn defence. It has always been a debatable point whether his attack contravened the new treaty. The Romans certainly took this view and sent to Carthage to demand Hannibal's surrender. But his defiant policy was too popular to be disavowed; the Carthaginian council upheld Hannibal's action, and drew upon itself a declaration of war.

Second Punic War (218–201 B.C.).—It seemed as though the superiority of the Romans at sea must enable them to choose the field of battle. They decided to embark one army for Spain and another for Sicily and Africa. But before their preparations were complete Hannibal began that series of operations by which he dictated the course of the war for the greater part of its duration. Realizing that so long as Rome commanded the resources of an undivided Italian confederacy no foreign attack could beat her down beyond recovery, he conceived the plan of cutting off her supply of strength at the source by carrying the war into Italy and causing a disruption of the League. His chances of ever reaching Italy seemed small, for the sea was guarded by the Roman fleets and the land route was long and arduous. But the very boldness of his enterprise contributed to its success; after a six months' march through Spain and Gaul and over the Alps, which the Romans were nowhere in time to oppose, Hannibal arrived in the plain of the Po with 20,000 foot and 6,000 horse, the pick of his African and Spanish levies (autumn 218: for details *see* HANNIBAL).

His further advance was here disputed by some Roman troops which had been recalled from the Spanish expedition. But the superiority of the Carthaginian cavalry and the spread of insurrection among the Gaulish inhabitants forced the defenders to fall back upon the Apennines. At the end of the year the Roman army was reinforced by the division from Sicily and led out to battle on the banks of the Trebia (*q.v.*). Hannibal, by superior tactics, repelled the assailants with heavy loss, and thus made his position in north Italy secure.

In 217 the campaign opened in Etruria, into which the invading army, largely reinforced by Gauls, penetrated by an unguarded pass. A rash pursuit by the Roman field force led to its being entrapped on the shore of Lake Trasimene (*q.v.*) and destroyed with a loss of 40,000 men. This catastrophe left Rome completely uncovered; but Hannibal, having resolved not to attack the capital before he could collect a more overwhelming force, directed his march towards the south of Italy, where he hoped to stir up the peoples who had formerly been Rome's most stubborn enemies. The natives, however, were everywhere slow to join the Carthaginians, and a new Roman army under the dictator Q. Fabius Maximus ("Cunctator"), which, without ever daring to close with Hannibal, dogged his steps on his forays through Apulia and Campania, prevented his acquiring a permanent base of operations

The eventful campaign of 216 was begun by a new aggressive move on the part of Rome. An exceptionally strong field army, estimated at 85,000 men, was sent forth in order to crush the Carthaginians in open battle. On a level plain near Cannae (*q.v.*) in Apulia, which Hannibal had chosen for his battle-ground, the Roman legions delivered their attack. Hannibal deliberately allowed his centre to be driven in by their superior numbers, while Hasdrubal's cavalry wheeled round so as to take the enemy in flank and rear. The Romans, surrounded on all sides and so cramped that their superior numbers aggravated their plight, were practically annihilated, and the loss of citizens was perhaps greater than in any other defeat that befell the Republic. The moral effect of the battle was no less momentous. The south Italian nations at last found courage to secede from Rome, the leaders of the movement being the people of Capua, the second greatest town of Italy. Reinforcements were sent from Carthage, and several neutral powers prepared to throw their weight into the scale on Hannibal's behalf. At first sight it seems strange that the battle of Cannae did not decide the war. But the resources of Rome, though terribly reduced in respect both of men and of money, were not yet exhausted. In north and central Italy the insurrection spread but little, and could be sufficiently guarded against with small detachments. In the south the Greek towns of the coast remained loyal, and the numerous Latin colonies continued to render important service by interrupting free communication between the rebels and detaining part of their forces. In Rome itself the quarrels between the nobles and commons, which had previously unsettled her policy, gave way to a unanimity unparalleled in the annals of the Republic. The guidance of operations was henceforth left to the senate, which by maintaining a persistent policy until the conflict was brought to a successful end earned its greatest title to fame.

The subsequent campaigns of the Italian War assume a new character. Though the Romans contrived at times to raise 200,000 men, they could only spare a moderate force for field operations. Their generals, among whom the veterans Fabius and M. Claudius Marcellus frequently held the most important commands, rarely ventured to engage Hannibal in the open, and contented themselves with observing him or skirmishing against his detachments. Hannibal, whose recent accessions of strength were largely discounted by the necessity of assigning troops to protect his new allies or secure their wavering loyalty, was still too weak to undertake a vigorous offensive. In the ensuing years the war resolved itself into a multiplicity of minor engagements which need not be followed out in detail. In 216 and 215 the chief seat of war was Campania, where Hannibal vainly attempted to establish himself on the coast but experienced a severe repulse at Nola. In 214 the main Carthaginian force was transferred to Apulia in hopes of capturing Tarentum. Though Croton and Locri on the Calabrian coast had fallen into his hands, Hannibal still lacked a suitable harbour by which he might have secured his oversea communications. For two years he watched in vain for an opportunity of surprising the town, while the Romans narrowed down the sphere of revolt in Campania and defeated other Carthaginian commanders. In 212 the greater part of Tarentum and other cities of the southern seaboard at last came into Hannibal's power. But in the same year the Romans found themselves strong enough to place Capua under blockade. They severely defeated a Carthaginian relief force, and could not be permanently dislodged even by Hannibal himself. In 211 Hannibal made a last effort to relieve his allies by a feint upon Rome itself, but the besiegers refused to be drawn away from their entrenchments, and eventually Capua was starved into surrender. Its fall was a sign that no power could in the long run uphold a rival Italian coalition against Rome. After a year of desultory fighting the Romans in 209 gained a further important success by recovering Tarentum. Though Hannibal still won isolated engagements, he was being slowly driven back into the extreme south of the peninsula.

In 207 the arrival of a fresh invading force produced a new crisis. Hasdrubal, who in 209–208 had marched overland from Spain, appeared in north Italy with a force scarcely inferior to the army which his brother had brought in 218. After levying contingents of Gauls and Ligurians he marched down the east coast with the object of joining hands with his brother in central Italy for a direct attack upon Rome. By this time the drain of men and money was telling so severely upon her confederacy that some of her most loyal allies protested their inability to render further help. Yet by a supreme effort the Romans raised their war establishment to the highest total yet attained and sent a strong field army against either Carthaginian leader. The danger to Rome was chiefly averted by the prompt insight and enterprise of the consul C. Nero, who commanded the main army in the south. Having discovered that Hannibal would not advance beyond Apulia until his brother had established communications with him, Nero slipped away with part of his troops and arrived in time to reinforce his colleague Livius, whose force had recently got into touch with Hasdrubal near Sena Gallica (Sinigaglia). The combined Roman army frustrated an attempt of Hasdrubal to elude it and forced him to fight on the banks of the Metaurus (*q.v.*). The battle was evenly contested until Nero by a dexterous flanking movement cut the enemy's retreat. Hasdrubal himself fell and the bulk of his army was destroyed.

The campaign of 207 decided the war in Italy. Though Hannibal still maintained himself for some years in Calabria, this was chiefly due to the exhaustion of Rome after the prodigious strain of past years and the consequent reduction of her armaments. In 203 Italy was finally cleared of Carthaginian troops. Hannibal, in accordance with orders from home, sailed back to Africa, and another expedition under his brother Mago, which had sailed to Liguria in 205 and endeavoured to rouse the slumbering discontent in Cisalpine Gaul and Etruria, was driven back on the coast and withdrawn about the same time.

Campaigns in Sicily and Spain.—Concurrently with the great struggle in Italy the Second Punic War was fought out on several other fields. It will suffice merely to allude to the First Macedonian War (214–205) which King Philip V. commenced when the Roman power seemed to be breaking up after Cannae. The diversions which Roman diplomacy provided for Philip in Greece and the maintenance of a patrol squadron in the Adriatic prevented any effective co-operation on his part with Hannibal.

In view of the complete stagnation of agriculture in Italy the Romans had to look to Sardinia and Sicily for their food supply. Sardinia was attacked by a Carthaginian armament in 215, but a small Roman force sufficed to repel the invasion. In Sicily a more serious conflict broke out. Some isolated attacks by Punic squadrons were easily frustrated by the strong Roman fleet. But in 215 internal complications arose. The death of Hiero II., Rome's steadfast friend, left the kingdom of Syracuse to his inexperienced grandson Hieronymus. Flattered by the promises of Carthaginian emissaries the young prince abruptly broke with the Romans, but before hostilities commenced he was assassinated. The Syracusan people now repudiated the monarchy and resumed their republican constitution, but they were misled by false threats of terrible punishment at the hands of Rome to play into the hands of the Carthaginians. The attacks of a Roman army and fleet under Marcellus which speedily appeared before the town were completely baffled by the mechanical contrivances of the Syracusan mathematician Archimedes (213). Meantime the revolt against Rome spread in the interior, and a Carthaginian fleet established itself in the towns of the south coast. In 212 Marcellus at last broke through the defence of Syracuse and in spite of the arrival of a Carthaginian relief force mastered the town by slow degrees. A guerilla warfare succeeded in which the Carthaginians maintained the upper hand until in 210 they lost their base at Agrigentum. They were dislodged from their remaining positions, and by the end of the year Sicily was wholly under the power of Rome.

The conflict in Spain was second in importance to the Italian war alone. From this country the Carthaginians drew large supplies of troops and money which might serve to reinforce Hannibal; hence it was in the interest of the Romans to challenge their enemy within his Spanish domain. Though the force which Rome at first spared for this war was small in numbers and rested entirely upon its own resources, the generals Publius and Gnaeus Scipio by skilful strategy and diplomacy not only won over the peoples north of the Ebro and defeated the Carthaginian leader Hasdrubal

Barca in his attempts to restore communication with Italy, but carried their arms along the east coast into the heart of the enemy's domain. But eventually their successes were nullified by a rash advance. Deserted by their native contingents and cut off by Carthaginian cavalry, among which the Numidian prince Massinissa rendered conspicuous service, the Roman generals were slain and their troops were destroyed in detail (212 or 211).

Disturbances in Africa prevented the Punic commanders from reaping the full fruit of their success. Before long the fall of Capua enabled Rome to transfer troops from Italy to Spain, and in 209 the best Roman general of the day, the young son and namesake of the recently slain P. Scipio, was placed in command. The new leader signalized his arrival by a bold and successful *coup-de-main* upon the great arsenal of Carthago Nova (*see* CARTAGENA). Though he was unable to prevent Hasdrubal Barca from marching away to Italy, Scipio profited by his departure to push back the remaining hostile forces the more rapidly. A last effort by the Carthaginians to retrieve their losses with a fresh army was frustrated by a great victory at Ilipa (*q.v.*), near Corduba, and by the end of 206 they were driven out of Spain.

The War in Africa.—In 205 Scipio, who had returned to Rome to hold the consulship, proposed to follow up his victories by an attack upon the home territory of Carthage. Though the presence of Hannibal in Italy at first deterred the senate from sanctioning this policy, the general popularity of the scheme overbore all resistance. Scipio was granted a force which he organized and supplemented in Sicily, and in 204 sailed across to Africa. He was there met by a combined levy of Carthage and King Syphax of Numidia, and for a time penned to the shore near Utica. But in the winter he extricated himself by a surprise attack upon the enemy's camp, which resulted in the total loss of the allied force by sword or flame. In the campaign of 203 a new Carthaginian force was destroyed by Scipio on the Great Plains not far from Utica, their ally Syphax was captured, and the renegade Massinissa (*q.v.*) reinstated in the kingdom from which Syphax had recently expelled him. These disasters induced the Carthaginians to sue for peace, but before the very moderate terms which Scipio offered could be definitely accepted a sudden reversal of opinion caused them to recall Hannibal's army for a final trial of war, and to break off negotiations. In 202 Hannibal assumed command of a composite force of citizen and mercenary levies stiffened with a corps of his veteran Italian troops. After an abortive conference with Scipio he prepared for a decisive battle at Zama (*q.v.*), an inland site not yet identified with certainty. Scipio's force was smaller in numbers, but well trained throughout and greatly superior in cavalry. His infantry, after evading an attack by the Carthaginian elephants, cut through the first two lines of the enemy, but was unable to break the reserve corps of veterans. The battle was ultimately decided by the cavalry of the Romans and their new ally Massinissa, which by a manoeuvre recalling the tactics of Cannae took Hannibal's line in the rear and completely destroyed it. The Carthaginians having thus lost their last army again applied for peace and accepted the terms which Scipio offered. They were compelled to cede Spain and the Mediterranean islands still in their hands, to surrender their warships, to pay an indemnity of 10,000 talents (about £2,400,000) within 50 years and to forfeit their independence in affairs of war and foreign policy.

The Second Punic War, by far the greatest struggle in which either power engaged, had thus ended in the complete triumph of Rome. This triumph is not to be explained in the main by any faultiness in the Carthaginians' method of attack. The history of the First Punic War, and that of the second outside of Italy, prove that the Romans were irresistible on neutral or Carthaginian ground. Carthage could only hope to win by invading Italy and using the enemy's home resources against him. The failure of Hannibal's brilliant endeavour to realize these conditions was not due to any strategical mistakes on his part. It was caused by the indomitable strength of will of the Romans, whose character during this period appears at its best, and to the compactness of their Italian confederacy, which no shock of defeat or strain of war could entirely disintegrate. It is this spectacle of individual genius overborne by corporate and persevering effort which lends to the Second Punic War its peculiar interest.

The Third Punic War (149–146 B.C.).—The political power of Carthage henceforth remained quite insignificant, but its commerce and material resources revived in the 2nd century with such rapidity as to excite the jealousy of the growing mercantile population of Rome and the alarm of its more timid statesmen. Under the influence of these feelings the conviction—sedulously fostered by Cato the Elder, the Censor—that "Carthage must be destroyed" overbore the scruples of more clear-sighted statesmen. A *casus belli* was readily found in a formal breach of the treaty, committed by the Carthaginians in 154, when they resisted Massinissa's aggressions by force of arms. A Roman army was despatched to Africa, and although the Carthaginians consented to make reparation by giving hostages and surrendering their arms, they were goaded into revolt by the further stipulation that they must emigrate to some inland site where they would be debarred from commerce. By a desperate effort they created a new war equipment and prepared their city for a siege (149). The Roman attack for two years completely miscarried, until in 147 the command was given to a young officer who had distinguished himself in the early operations of the war—Scipio Aemilianus, the adopted grandson of the former conqueror of Carthage. Scipio made the blockade stringent by walling off the isthmus on which the town lay and by cutting off its sources of supplies from oversea. His main attack was delivered on the harbour side, where he effected an entrance in the face of a determined and ingenious resistance. The struggle did not cease until he had captured house by house the streets that led up to the citadel. Of a population probably exceeding half a million only 50,000 remained at the final surrender. The survivors were sold into slavery; the city was razed to the ground and its site condemned by solemn imprecations to lie desolate for ever. The territory of Carthage, which had recently been much narrowed by Massinissa's encroachments, was converted into a Roman province under the name of "Africa."

BIBLIOGRAPHY.—1. *Ancient Authorities.* For the First Punic War Polybius, bk. 1, provides a trustworthy and impartial account, but owing to his conciseness leaves many problems of chronology and strategy unexplained. For the Second War bk. 2 and 3 of Polybius present a complete and detailed record down to Cannae; bk. 7–15 contain fragmentary notices of which the most continuous deal with the campaigns of Scipio. Livy (bk. 23–30) gives a continuous and detailed narrative, partly based upon Polybius and other good authorities, partly upon untrustworthy Roman annalists. The Third War is described in Appian's *Res Libycae,* ch. 67 *sqq.,* and the fragments of Polybius, bk. 36–39.

The subsidiary authorities are: Diodorus, bk. 20–27, 32; Appian, *Res libycae, hispanicae, hannibalicae;* Zonaras' epitome of Dio Cassius, fr. 43, 54, 57; Plutarch's *Lives of Fabius and Marcellus;* Cornelius Nepos's *Lives of Hamilcar and Hannibal,* and short references in Justin, Eutropius, Aurelius Victor and Orosius. The sources and methods of composition of these authors have been discussed in numerous articles and dissertations, mostly German, of which the most important are mentioned in Niese's work (quoted below). These essays have brought out few certain results, but they trend to show that the narratives, so far as they are not based on Polybius or earlier authorities, are of little value.

2. *Modern Works.* *a.* For general accounts *see* the respective passages in the general histories of Rome, especially Mommsen (Eng. trans., 1894, vol. ii), Ihne (Eng. trans., vol. ii) and de Sancti's; also C. Neumann, *Das Zeitalter der punischen Kriege* (Breslau, 1883), and R. B. Smith, *Rome and Carthage* (1881).

The battles are methodically examined in J. Kromager, *Antike Schlachtfelder* (1912 *et seq.*), and in Kromager-Veith, *Schlachten-Atlas zur antiken Kriegsgeschichte* (Leipzig, 1922). *See* also H. Delbrück, *Gesch. der Kriegskunst* (1901–07).

b. For the First War.—O. Meltzer, *Geschichte der Karthager,* ii. 252–356 (1879–86); J. Beloch, *Griechische Geschichte,* vol. iii, pt. i, pp. 664–684 (Strasbourg, 1893–1904); B. Niese, *Geschichte der griechischen und makedonischen Staaten,* ii, 174–199 (Gotha, 1893–1903); W. W. Tarn, "The Fleets of the First Punic War," in *Journal of Hellenic Studies* (1907), pp. 48–60. For the chronology, *see* F. Reuss, in *Philologus* (1901), pp. 102–148, and especially P. Varese, in *Studi di storia antica,* vol. iii (1902).

c. For the period 241–238.—O. Gilbert, *Rom und Karthago 513–536 A.U.C.* (Leipzig, 1876); Meltzer, *op. cit.* ii, 357–456.

d. For the Second War.—Thomas Arnold, *The Second Punic War* (ed. William Thomas Arnold, 1886); T. A. Dodge, *Great Captains, Hannibal* (1889); G. Bossi, in *Studi di storia e diritto,* vol. x–xiii; P. Cantalupi, "Le Legioni romane nella guerra d'Annibale" *Studi di storia antica,* i, 3–48 (1891); Th. Zielinski, *Die letzten Jahre des*

zweiten punischen Krieges (Leipzig, 1880); B. H. Liddell Hart, *A Greater than Napoleon—Scipio Africanus* (1926).

e. Special articles.—On Sicily: Niese, *op. cit.* ii, 505–561. On Spain: J. Frantz, *Die Kriege der Scipionen in Spanien* (Munich, 1883).

For further bibliographical references consult B. Niese, *Grundriss der römischen Geschichte,* pp. 81–88, 94–108, 138–142 (Munich, 1906). *See* also the articles on chief personages (especially HANNIBAL and SCIPIO AFRICANUS, PUBLIUS CORNELIUS), and under ROME: *Ancient History;* ROMAN ARMY; CARTHAGE; SICILY. (M. C.)

PUNISHMENT, the infliction of some kind of pain or loss upon a person for a misdeed, *i.e.,* the transgression of a law or command. *See* CRIMINAL LAW; CRIMINOLOGY; CAPITAL PUNISHMENT; PRISON, etc.

PUNJAB, *i.e.,* land of the "five rivers" (viz., the Jhelum, Chenab, Ravi, Beas and Sutlej, all tributaries of the Indus), is the name given primarily to the triangle of country, in the Indian subcontinent, of which the Indus and the Sutlej to their confluence form the two sides, the base being the lower Himalaya hills between those two rivers. From 1848 to Aug. 1947, when British responsibilities were transferred to the dominions of India and Pakistan, the Punjab formed a British province, from which a separate North-West Frontier province was created in 1901 and from which certain territory in the east, including Delhi, was taken to form the Delhi enclave in 1912.

The geographical area of the Punjab, in addition to the British province, comprised about 35 states under the personal government of rulers who had treaty relations with the British crown. The largest of these states was Bahawalpur (17,494 sq.mi.; population 1,340,000 in 1951), on the left bank of the Sutlej and Indus. Except for Bahawalpur, all the other states lay in that portion of the Punjab which, after partition, was assigned to India. These were then formed into two groups: the Patiala and East Punjab States Union (10,099 sq.mi.; population 3,320,000), a "B" state under the constitution of the Republic of India; and the Himachal Pradesh (10,600 sq.mi.; population 1,100,000), a part "C" state under that constitution, administered by a chief commissioner of the government of India. The area of the West Punjab, assigned by partition to Pakistan, is 62,015 sq.mi., its population 20,634,000; that of the East Punjab, assigned to India, is 37,428 sq.mi., its population 12,638,611.

Partition set the boundary in the Punjab between India and Pakistan roughly along the line of the Sutlej up to beyond Ferozepur and then due north between Lahore and Amritsar to the boundary of Kashmir along the line of the Ravi. Under British rule, the Punjab was divided into five divisions: Umballa (Ambala), Jullundur, Lahore, Rawalpindi and Multan. Partition gave the Umballa and Jullundur divisions to India (East Punjab) and the Rawalpindi and Multan divisions to Pakistan (West Punjab). The Lahore division was divided so that the East Punjab took the Amritsar district and part of the Lahore district except the Chunian and Lahore tahsils (including, of course, the city of Lahore). The West Punjab took from the Lahore division, in addition to the Chunian and Lahore tahsils, the districts of Sialkot, Gujranwala and Sheikhupura, with certain portions of the Gurdaspur district.

The immediate result of partition in the Punjab was an outbreak of violence involving much loss of life and a mass movement of population from one part of the area to the other; so that the figures of population returned by the census of 1951 must be regarded as approximate only.

The total population of the Punjab (including states) according to the census of 1951 was 39,000,000. The Jats, who number about 6,000,000, form the backbone of the cultivating community. Large numbers of them became Sikhs or Mohammedans in the tracts where those religions predominate. The Rajputs, with a total of about 3,000,000, comprise tribes of different religions, races and social systems. By religion they are mostly Mohammedan, only about 40% being Hindus and 20% Sikhs. The Gujars are an important agricultural and pastoral tribe. Baluchis and Pathans are strongly represented in the southwest and west. Soldiers of the Punjab distinguished themselves in the Indian army's exploits in World Wars I and II.

Of the 28,490,857 people in the Punjab in 1931 about 21,893,342 spoke the provincial language, Punjabi, which varies in character in different parts of the province. About 3,988,000 spoke Hindustani (*see* HINDOSTANI LANGUAGE), this number including those whose ordinary vernacular was Hindi. These two languages were the most generally used throughout the province. The other languages in use were more or less local. The hill dialects, known as Pahari, are akin to the language spoken in Rajputana.

Physical Features.—The mountain regions of the Punjab fall under four separate groups. To the northeast of the country lies the Himalayan system, with the fringing range of the Siwaliks at its foot. In the southeastern corner the Aravalli system sends out insignificant outliers, which run across Gurgaon and Delhi districts and strike the Jumna at Delhi. The lower portion of the western frontier is constituted by the great Suliman chain; while the northwestern districts of the province are traversed by the hill system known as the Salt range.

The "five rivers" of the Punjab are each of large volume; but the great width of sandy channel in their passage through the plains, their changing courses and their shifting shoals make them worthless for steam navigation, though they all support a considerable boat traffic. They have been utilized for purposes of irrigation and have turned the sandy desert of the Punjab into a great wheat-growing area.

South of the Himalayas stretch the great alluvial plains from the Jumna on the east to the Sulimans in the west, one vast level, unbroken save by the wide eroded channels within which the great rivers ever shift their beds, by the insignificant spurs of the Aravalli range in the southeastern corner and by the low hills of Chiniot and Kirana in Jhang.

Geology.—By far the greater part of the Punjab is covered by alluvial and wind-blown deposits of the plain of the Indus. The Salt range hills form a plateau with a steeply scarped face to the south, along which there is an axis of abrupt folding, accompanied by faulting. The rocks found in the Salt range belong to the Cambrian, Carboniferous, Permian, Triassic and Jurassic systems, while Tertiary beds cover the plateau behind. The extensive and valuable deposits of salt, from which the range takes its name, occur near the base of the Cambrian beds. Gypsum, kieserite and other salts are found. Between the Cambrian and the Carboniferous beds there is an unconformity, which, however, is not very strongly marked, in spite of the lapse of time which it indicates. At the bottom of the Carboniferous series there is usually a boulder bed, the boulders having been brought from a distance and scratched and striated as if by ice. It is generally admitted that this deposit indicates a southern glacial period in late Carboniferous times. Above the sandstone series at the base of which the boulder bed lies come the *Productus* and *Ceratites* limestones. The former is believed to belong to the Upper Carboniferous and Permian, the latter to the Trias. Jurassic beds are found only in the western portion of the range.

Climate.—Because of its subtropical position, scanty rainfall and cloudless skies and the wide expanse of untilled plains, the climate of the Punjab presents greater extremes of both heat and cold than any other part of India. From the middle of April to the middle of September it is extremely hot, while from the beginning of October to the end of March there is a magnificent cool season, resembling that of the Mediterranean Riviera, with warm bright days and cool nights. Frosts are frequent in January. In the first months of the hot season, till the end of June, a dry heat is experienced, with a temperature rising to 120° F. in the shade. At the end of June the monsoon arrives, the rains break in the east of the Punjab and though the heat is less intense the air is moist; and from the middle of August the temperature gradually falls. This is the most unhealthful period of the year, being exceedingly malarious. The Punjab enjoys two well-marked seasons of rainfall: the monsoon period, lasting from the middle of June till the end of September, on which the autumn crops and spring sowings depend; and the winter rains, which fall early in January and, though often insignificant in amount, materially affect the prosperity of the spring harvest. Excepting in the Himalaya the rainfall is greatest in the east, as the Bombay monsoon is exhausted in its passage over the great plains of Sind and Rajpu-

tana, while the west winds from Baluchistan pass over an arid tract and leave such moisture as they may have collected on the western slopes of the Suliman range; so that the Punjab depends for its rain very largely on the southeast winds from the Bay of Bengal. The submontane tract has an annual average of 36 to 32 in., the eastern plains vary from 20 to 14 in. and the western plains from 10 to 5 in. (E. D. MacL.; E. Hd.)

History.—The history of the Punjab has been profoundly influenced by the fact that between Peshawar and Dera Ismail Khan the four frontier passes of the Khyber, Kurram, Tochi and Gomal serve as gateways from Afghanistan to the Punjab plains. For this reason it is ethnologically more closely related to central Asia than to India. Until 1922 no structural remains in India could be assigned with certainty to a period earlier than the 3rd century B.C.; later, excavations at Harappa and Mohenjo-Daro unearthed the remains of a civilization 5,000 years old bearing a general resemblance to that of Elam and Mesopotamia (*see* India: *History*). The first migration of which there is any evidence, however, is that of the Indo-European (Aryan) peoples who entered the Punjab in prehistoric times. Centuries later, within historical times, successive waves of other invaders swept through the frontier passes; and all these migrations and invasions added to the heterogeneity of the population.

The exact limits of the Achaemenian empire of Darius I cannot be determined, but it probably included the Indus valley and parts of the Punjab. The earliest date known for certain in Indian history is Alexander the Great's invasion of the Punjab in 326 B.C. After defeating Porus, the Indian ruler of the territories between the Hydaspes (Jhelum) and the Acesines (Chenab), Alexander advanced to the Hyphasis (Beas), beyond which his troops refused to march. Having crushed the power of the Cathaei, Malli and Oxydracae between the Acesines and the Zaradrus (Sutlej), he retired through Gedrosia (Baluchistan). His invasion was merely a large-scale raid and his death in 323 prevented the consolidation of his power in the Punjab and the Indus valley. The history of northern India proves that the mountain barrier of the northwestern frontier seldom formed a political boundary, for the kingdoms of the Persians, Mauryas, Graeco-Bactrians, Sakas, Parthians, Kushans and Ephthalites extended from Afghanistan to the Punjab plains.

The first Moslems to penetrate into northern India were the Arabs who, in A.D. 713, extended their power to the lower Punjab; but the Moslem conquest of the Punjab was the work of Mahmud of Ghazni, who overthrew the Hindushahiya dynasty ruling between Lamaghan and the Chenab and annexed their territories to his extensive central Asian empire. The Punjab remained in Ghaznevid hands until Mahmud's descendants were expelled by Mohammed of Ghur in 1186. It formed part of the sultanate of Delhi from 1206 until Baber's defeat of Ibrahim Lodi at Panipat in 1526 paved the way for the foundation of the Mogul empire, of which it remained a part until disintegration set in during the first half of the 18th century.

The religious intolerance of the Mogul emperors after the death of Akbar in 1605 led to the growth of Sikh political power in the Punjab and transformed a religious sect, founded by Guru Nanak in the second half of the 15th century, into a military organization animated with undying hatred toward Moslems. The weakness of the emperors who succeeded Aurangzeb facilitated the growth of Maratha power. From 1720 onward the Maratha peshwas adopted a policy of territorial aggrandizement and, by 1758, had overrun almost the whole of northern India as far as Peshawar. They were gradually driven southward by the Afghans under Ahmad Shah Durrani to Panipat, where they were routed with enormous losses on Jan. 14, 1761. After the death of Ahmad Shah the various Sikh groups or *misls* began to consolidate their power in the Punjab. The most important of these *misls* were the Bhangis of Gujrat, Sialkot, Lahore and Amritsar; the Ahluwalias of Kapurthala, Jullundur and Hoshiarpur; and the Kanhyas of Gurdaspur. From 1790 onward, Ranjit Singh, the head of the Sukarchakia *misl*, rose to prominence as leader of the Sikh resistance to the Afghan ruler Zaman Shah. His attempt to establish his authority over his coreligionists, the cis-Sutlejian Sikhs, brought him into contact with the British, who had extended their power to the Jumna; and an agreement was formed in 1809 by which the Sikh ruler accepted the Sutlej as his frontier. From this date his power increased rapidly. Between 1813 and 1821 he annexed Attock, Kashmir, Dera Ghazi Khan and Dera Ismail Khan. It was not until 1834, however, that Peshawar came under Sikh control

After the death of Ranjit Singh in 1839 the Punjab became the scene of widespread lawlessness, and power passed to the army of the Sikh Khalsa. Suspecting the British of contemplating annexation and eager for war, the Sikhs in 1845 invaded British territory but were defeated in desperate struggles at Moodkee, Ferozeshah, Aliwal and Sobraon. By a treaty in 1846 they were compelled to surrender all lands on the British side of the Sutlej together with the Jullundur Doab, to pay an indemnity and to limit the strength of their armed forces. The young maharaja, Dalip Singh, was to be guided by a council of regency presided over by Sir Henry Lawrence. The new arrangements did not prove acceptable to the Sikhs, and war broke out once more in 1848. After the battles of Chillianwalla and Gujrat the Punjab was annexed to British India on April 2, 1849. (*See* Sikh Wars.)

The newly conquered territories were placed under a board of administration until 1853, when the board's powers and functions were vested in a chief commissioner. Six years later the Punjab and its dependencies were formed into a lieutenant-governorship. The annexation of the Punjab, by advancing the British administrative boundary across the Indus, brought the government of India into closer contact with the Pathan tribes of the northwestern frontier. Until 1876 relations with the tribesmen were conducted by the deputy commissioners of Hazara, Peshawar, Kohat, Bannu, Dera Ismail Khan and Dera Ghazi Khan. The system of political agencies was not adopted until 1878, when a special officer was appointed for the Khyber. The Kurram, Malakand, Tochi and Wana agencies were created between 1892 and 1896. The tribes remained under the control of the Punjab government until the creation of the North-West Frontier province in 1901. In 1912 Delhi, previously included in the Punjab, was formed into a separate province.

The response of the Punjab during World War I was magnificent: of the 1,302,000 combatants recruited throughout British India, 300,000 were provided by the Punjab, of whom more than one-half were Moslems. In the postwar years communal relations in the province were embittered by the activities of the *tanzim* and *tabligh* movements organized by Moslems to combat the proselytizing of the Hindu *shuddi*. Far more serious than this communal strife were the political disturbances culminating in the Jallianwalla Bagh incident of 1919. (For the Punjab rebellion of 1919 *see* India: *History*.)

In 1921 the Punjab was raised to the status of a governor's province. From 1922 until the passing of the Sikh Shrines act, 1925, the peace was disturbed by the Akali Sikhs who wished to devote the revenues of certain shrines and temples to the spiritual benefit of the Sikh community.

The separation of Pakistan from India in 1947 was followed by the division of the Punjab into the two provinces of East and West Punjab with Hindu and Moslem majorities respectively. The boundary was delimited in Aug. 1947 by Sir Cyril Radcliffe. (C. C. D.)

Minerals.—Besides rock salt, the mineral products of the Punjab are not many. Limestone, good for building, is obtained at Chiniot on the Chenab and elsewhere. There are extensive alum beds at Kalabagh on the Indus. A small quantity of coal is found in the Salt range in disconnected beds. Petroleum is found in small quantities at a number of places in Rawalpindi and extracted by a company. In almost all parts of the Punjab there is kunkur, rough nodular limestone, commonly found in thick beds, a few feet below the ground, used for road metal and burned for lime.

Agriculture and Forestry.—As in other parts of India, there are commonly two harvests in the year. The spring crops are wheat, barley, gram, various vegetables, oilseeds and tobacco; the autumn crops are rice, millets, maize, pulse, cotton, indigo and sugar cane. Wheat has become the most important export. In the spring of 1938 an area of 11,500,000 ac. was harvested, producing 4,500,000 tons. Tea is cultivated in Kangra district. Potatoes are grown extensively on cleared areas on the hills. The Punjab produces freely many of the Indian fruits. Grapes are grown in many of the Himalayan valleys where the rain is not excessive; but they are inferior to those brought from Kabul.

The forest area of the Punjab consists of 6,251 sq.mi. of which 1,682 sq.mi. are preserved and 3,270 sq.mi. protected. The principal reserved forests are the deodar (*Cedrus deodara*) and chil (*Pinus longifolia*) tracts in the hills, the plantations of shisham (*Dalbergia sissu*) and sal (*Shorea robusta*) in the plains and the fuel rakhs or preserves (*Acacia, Prosopis,* etc.).

Manufactures and Trade.—Most of the indigenous manufactures of the Punjab are those common to most other parts of the subcontinent. Among others are woollen fabrics, carpets and shawls, silk cloths and embroidery, jewellery, ornamental metalwork, wood and ivory carving, turned and lacquered woodwork, glazed pottery, arms and armour and musical instruments. Some of these are represented by work of special kinds or special excellence, notably the silk fabrics of Multan and Bahawalpur; the carpets of Lahore and Amritsar; the kashi or glazed tilework (an ancient art still practised in a few places);

koftgari, inlaid metal work (gold wire on steel), chiefly made at Gujrat and Sialkot; shawls and other fine woollen fabrics, made by Kashmiri workpeople at Ludhiana and Nurpur, as well as in Kashmir; silk embroidery for shawls, scarfs and turbans, at Delhi, Lahore and Multan; embroidery on cloth for elephant trappings, bed and table covers, etc., at Lahore and Multan; enamelled ornaments, in Kangra and Multan; quill embroidery on leather, in Kangra and Simla; lacquered woodwork, at Pak Pattan. Cotton weaving gives employment to about 1,000,000 persons, but the most flourishing industry is the woollen factories of Amritsar, Gurdaspur and elsewhere.

The trade of the Punjab is almost wholly dependent upon agriculture. In a normal year the principal feature of the trade is the movement of wheat to Karachi, which is the natural port for the country. But in a bad season, when the rains fail, this movement is at once checked, the wheat is held up in reserve and an eastward movement in cheaper grains begins. The other chief articles of export are pulse and raw cotton. The Punjab has a transfrontier trade with Kashmir, Ladakh, Yarkand and Tibet on the north and with Afghanistan on the west.

Canals.—Irrigation for large areas is from canals and from reservoirs, and for smaller areas from wells. The canals are of two kinds: those carrying a permanent stream throughout the year, and those which fill only on the periodical rising of the rivers, the latter being known as "inundation canals." A few parts of the country present facilities for forming reservoirs, by closing the narrow outlets of small valleys and storing the accumulated rainfall. The canal system is among the finest in the world.

The old canals of Mogul days were improved or reconstructed by the British administration and are represented by the Western Jumna and Bari Doab canal. These were followed by the Sirhind canal (1883) and by the two great Colony canals, the Lower Chenab and Lower Jhelum (1892–1901). Then came the Triple Canal scheme (1912–15, comprising the Upper Jhelum, Upper Chenab and Lower Bari Doab canals), and the Sutlej valley canals (1933). Nine colonies had sprung up in these canal areas. The total length of the West Punjab canal system was 12,183 mi. in 1949, irrigating an area of 9,591,709 ac. In 1947 the Thal project was completed, at a cost of £150,000, to serve the West Punjab. The barrage stands at Daud Khel near the Indus. The area irrigated by it is 350,000 ac. in the districts of Mianwali and Shahpur. Waterlogging was attacked by lining the canals with concrete. In the East Punjab (India) the area irrigated by government works is 3,671,924 ac., the value of crops estimated in 1945–46 being more than £25,000,000. The total capital outlay in East Punjab irrigation was about £6,000,000, the revenue amounting to about £1,000,000 or 14.9% on the capital outlay. Among the important canal projects started before partition was the Bhakra dam in Bilaspur, involving the construction of a dam 670 ft. high on the Sutlej, near the village of Bhakra, 50 mi. upstream of Rupar, to irrigate 3,500,000 ac. annually, and to generate 250,000 kw. of power. Eight miles away, Nangal dam was planned to divert supplies from the Sutlej for the Nangal Hydel canal and to provide eventually 140,000 kw. The total cost of the Bhakra-Nangal project was estimated at nearly £100,000,000. When conceived, the Bhakra project was intended to serve the whole of undivided Punjab, so that the distribution of water became an issue of some difficulty as between Pakistan and India; but a joint committee of experts from both countries was composed to ensure an amicable settlement.

Railways.—The Punjab is well supplied with railways. Before partition the North-Western railway system, with headquarters at Lahore, had the largest mileage of any in the subcontinent. On partition the Indian portion of the North-Western railway was constituted into the Eastern Punjab railway, with a length of 1,855.25 mi., leaving 5,026 mi. to Pakistan, which retained the name of North-Western railway for the system and also the headquarters at Lahore.

Administration.—The British province of the Punjab up to 1947 had an autonomous government under the government of India act, 1935. The legislature consisted of 175 members, to whom the ministry was responsible, the governor ruling as a constitutional representative of the king emperor. After partition the legislature was split according to the territorial changes; and two legislatures were consequently created, for East Punjab and West Punjab, the two governors being heads of the two provinces. When India became a republic in 1950, the governor of the East Punjab became the representative of the president, but the governor of the West Punjab remained the representative of the king. The Government of India act was provisionally adapted as a constitution for each of these provinces until India's own constitution was adopted in 1950. The general elections of 1951 for the West Punjab, when the Moslem league returned to power with a large majority, were based on adult suffrage (the first time such adult suffrage had been actively applied in any election in the subcontinent); but only 30% polled. Lahore is the capital of West Punjab; Jullundur was the capital of the East Punjab pending the construction of a new capital city at Chandigarh, 20 mi. from Umballa.

Education.—The Punjab university, founded in 1882, had served the whole of the Punjab, the Kashmir state as well as the undivided province. After partition the Khalsa college at Amritsar was transferred to the control of the education department of the East Punjab, and the Punjab university at Lahore remained in Pakistan. The West Punjab at mid-century had 29 colleges for men and 5 for women; 193 high schools (one-fifth of them for girls); 1,844 secondary schools (one-tenth for girls); and 6,843 primary schools (more than one-third of them for girls). Plans moreover were made for a university at Peshawar for the North-West Frontier province. In the East Punjab the government maintained 7 arts colleges (including 2 for women); 2 training colleges (one for men and the other for women); 7 "normal" schools (*i.e.*, schools in which teachers under training practice; 1 for men and 6 for women); 75 secondary schools, for boys and girls; and many centres for vocational training. A higher-grade medical college at Ludhiana was established by missionary enterprise; also 25 technical schools for boys and girls. There were 2,429 primary schools for boys and 817 for girls in 1950–51, the enrolments being nearly 300,000 and 67,000 respectively. Compulsory primary education applied to 37 towns and to 1,420 villages for boys only. (E. D. MACL.; E. HD.)

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PUNO, a southeastern department of Peru. It includes the shores of Lake Titicaca, the high plateau on which the lake is situated, together with the mountains west, north and east enclosing the plateau. It also includes the headwaters of several tributaries of the Madre de Dios river east of the eastern cordillera and draining into the Amazon. Puno has an area of 26,133 sq.mi.; population (1950) 768,384. Connection is by the Southern railway with Cuzco, 240 mi. to the north, also with the Pacific port of Mollendo and by steamer (across Lake Titicaca) and railway to La Paz, Bolivia. A projected section of the Pan American highway will eventually traverse the department.

Around the shores of the lake (12,507 ft. above sea level) the plateau is cultivated and well settled, but the altitude is so great that only potatoes, barley and a few other cereals will mature. The department of Puno produces about 70% of all the gold of Peru. It comes chiefly from the mountain provinces of Sandia and Carabaya. Coal, salt, copper, antimony, tin, quicksilver, zinc, marble and cobalt are also found. The manufacturing of woollen goods is important and in the province of Lampa there is a considerable manufacture of pottery.

The city of Puno (pop. 19,603 in 1950), capital of the department and of the province of Puno, is located on the shore of Lake Titicaca at the lake terminus of rail lines to Arequipa (219 mi.) and its Pacific ports of Mollendo and Matarani and to Cuzco, 240 mi. to the north. There is also regular steamer service from Puno across Lake Titicaca to Guaqui, Bolivia, with a rail connection thence to La Paz.

PUNTARENAS or PUNTA ARENAS, a seaport and capital of the province of Puntarenas, Costa Rica; on the Gulf of Nicoya, an inlet of the Pacific ocean, and at the western terminus of the interoceanic railway from Limón. Pop. (1950) town, 11,611; province, 88,168. Puntarenas is the principal harbour of Costa Rica on the Pacific, and a port of call for the United States liners which ply between San Francisco, Calif., and Panamá. It has a growing export trade in coffee and bananas. The district of Puntarenas comprises the entire littoral from Burica point to the Río de las Lajas, an effluent of the Gulf of Nicoya.

PUNXSUTAWNEY, a borough of Jefferson county, Pa., U.S., 70 mi. N.E. of Pittsburgh; served by the Buffalo, Rochester and Pittsburgh and the Pennsylvania railways. Pop. (1950) 8,969. It is a trading centre for agriculture, surrounded by coal operations and gas fields. Punxsutawney was founded about 1812 and incorporated in 1845.

PUPIN, MICHAEL IDVORSKY (1858–1935), U.S. inventor, was born in Idvor, Hung. (now in Yugoslavia), Oct. 4, 1858. He went to the U.S. in 1874, graduating from Columbia university, 1883. The first to hold the John Tyndall fellowship (1886–88), he later studied physics and mathematics at Cambridge university and under H. von Helmholtz at the university of Berlin (Ph.D., 1889). He was instructor in mathematical physics at Columbia, 1890; and was appointed adjunct professor of mechanics, 1892, becoming professor of electromechanics there in 1901 and later director of the Phoenix research laboratories.

By means of inductance coils placed at predetermined intervals of the transmitting wire, he greatly extended the range of long-distance telephony, particularly over telephone cables. The patent for this invention was acquired in 1901 by the Bell Telephone company and by German telephone interests. He has made several other inventions in electrical wave propagation, electrical resonance and multiplex telegraphy. He discovered secondary X-ray radiation in 1896 and invented in the same year means for short exposure X-ray photography by the interposition of a fluorescent screen. He wrote *From Immigrant to Inventor*.

PUPPIS, one of the three southern constellations into which the large Ptolemaic constellation Argo (*q.v.*) was subdivided (*puppis:* poop). The bright new star Nova Puppis was visible during the winter of 1942.

PUQUINAN, a group of tribes of South American Indians, doubtfully constituting an independent linguistic stock. Their identity with the modern Uros has been much discussed. The area occupied (if this identity be accepted) would include the whole basin of lakes Titicaca and Poöpo, and the Salar de Uyuni in the Bolivian plateau, together with the Peruvian-Chilean coast from about 16° to 22° S. lat. Within this area they lived in scattered small groups among the Aymaran (*q.v.*) tribes. Rivet thinks that the Puquinan language (together with the Uro) is in reality a member of the Arawakan (*q.v.*) stock and that this whole group of Puquinan and Uran tribes represents a very ancient intrusion westward of the Arawakan peoples.

See G. de Crequi-Montfort and P. Rivet, "La Langue Uru ou Puquina" (*J. Soc. Américanistes de Paris* [n.s.], xvii: 211–244; xviii: 111–139, with bibliography).

PURCELL, HENRY (1659–1695), English composer, was born in Westminster. His recent biographer, Dennis Arundell, points out that the statement *aet. suae. 24* on the printed edition of his *Sonatas* in June 1683 places his birth between June and November 1659, Nov. 20, 1695, being the date of his death in his 37th year. His father Henry Purcell, or Pursell, was a gentleman of the chapel royal, whose eldest son Edward (1653–1717) became gentleman usher to Charles II, and afterward distinguished himself in the army, while Henry and Daniel, the two younger sons, became musicians. On his father's death in 1664, Henry Purcell was placed under the guardianship of his uncle Thomas Purcell (d. 1682), also a gentleman of the chapel and a man of extraordinary probity and kindness. Both he and Henry Purcell the elder sang at the coronation of Charles II. Through his uncle's interest Purcell was admitted as a chorister of the chapel and was placed under Capt. Henry Cooke (d. 1672), master of the children, an excellent teacher and a composer of anthems, to whom Samuel Pepys makes a number of references in his *Diary*. On Cooke's death Pelham Humfrey (1647–74) became master, and he again was an excellent teacher as well as a musician of genius; but as a pupil of Lully he naturally stood for the French school, and in this respect failed to influence Purcell, who took the Italian masters for his models.

Purcell's third and last master was the distinguished composer and organist Dr. John Blow (1648–1708), to whom Purcell's great indebtedness is not always sufficiently realized. In 1673, when his voice broke, Purcell was dismissed with an ex-chorister's salary of £30 a year and presented with certain articles of dress. He was also given the appointment of (unpaid) assistant to John Kingston, keeper of the king's instruments, together with a promise to succeed him. In 1677 he was appointed "composer in ordinary for the violin" in succession to Matthew Lock. Purcell had been copyist at Westminster abbey since 1677, and in 1680 he succeeded Dr. Blow as organist.

The year 1680 was the beginning of a period of great productivity. In it he wrote the music to Nathaniel Lee's *Theodosius,* the first of a long series of dramas for which he provided incidental music, and one in which an introductory ritual scene gave him unusual scope; this was followed by Thomas D'Urfey's *Virtuous Wife.* He also produced the first of his court odes or "Welcome Songs" at this date and wrote several anthems, many of which were composed especially for the prodigious basso profondo of the Rev. John Gostling (or Gosling), a singer at Canterbury and later at the chapel royal, to whom John Evelyn alludes as "that stupendous bass." Either in 1680 or the following year he married Frances Peters, and in 1682 his eldest son was born. From 1682 he held the post of organist to the chapel conjointly with his appointment at the abbey. His first printed composition was the 12 *Sonnatas of III Parts: two violins and basse: to the organ or harpsichord.* These, though avowedly based on Italian models, show great power and originality. Purcell had now become "composer in ordinary to the king" and his official life was a very full one. For each public event he composed an ode or an anthem: some of the finest of these are the ode "Swifter, Isis, Swifter Flow" (1681); the "St. Cecilia" odes; the "Fly, Bold Rebellion" (in celebration of the suppression of the Rye House Plot, 1683); two anthems written for James II's coronation: "O I Was Glad" and "My Heart is Inditing." The *Te Deum and Jubilate,* written for St. Cecilia's Day 1694, was notable as being the first English anthem with orchestral accompaniment. It was performed annually at St. Paul's cathedral until 1712 and in alternate years with G. F. Handel's Utrecht *Te Deum* until 1743. In all his anthems there is a large proportion of instrumental music.

The opera *Dido and Aeneas,* which above all Purcell's works inspires admiration and affection in an equal degree, was written to a libretto furnished by Nahum Tate at the request of Josiah Priest, a dancing master who also kept a boarding school for young gentlewomen, first in Leicester Fields and afterward at Chelsea. The date of its composition and original performance at the school has been fixed by W. Barclay Squire of the British museum as about the year 1689. In this work there is no spoken dialogue, but only recitative, and it is characterized from beginning to end by the dramatic directness which Purcell possessed in so high a degree. Dido's exquisite song of farewell is one of the flawless things in music, classical in form and in its dignified restraint, and yet of rare emotional quality. As is so often the case when he has some poignant emotion to express, Purcell chooses here to build up the song on a "ground," and the relentless reiteration of the bass contributes greatly to the dramatic effect. Graceful dance choruses, lumbering sailor dances and witches' incantations relieve the tragedy, and, avoiding an anti-climax after Dido's farewell, the composer ends with a soft and tenderly expressive chorus, "With drooping wings, ye Cupids, come," in which music and words achieve perfect union.

Although *Dido and Aeneas* stands out today as an isolated phenomenon in the age in which it is written, it was rather the peak of a movement in which Purcell's predecessors did valuable experimental work; and here, again, Blow's influence is seen, for in his only known dramatic work, *Venus and Adonis,* he sets the example of having every word sung and none spoken. He is no doubt also partly responsible for Purcell's skill in the use of a ground, and he probably encouraged, rather than discouraged, his pupil's audacities of harmony, since he himself was a notorious offender. Among the peculiarities of Purcell's idiom are the constant false relations and the use of the descending melodic minor in ascending passages, and vice versa. He had a marked preference for the flat minor keys. His fine feeling for rhythm, form and climax invests even his smaller pieces with a quality that is unmistakable. In judging Purcell's scores it should be remembered that he was practically restricted to oboes and trumpets as regards wind instruments, since even the modern flute had not come into use in his time.

In 1690 Purcell wrote the music to Betterton's *Dioclesian,* which includes a masque. He was associated with Dryden in *Tyrannic Love* (1687), *Amphitryon* (1690) and *King Arthur* (1691), in all of which the music consists of separate numbers which form no integral part of the drama. In *King Arthur,* Josiah Priest was responsible for the dances. This play, which contains the famous song "Fairest Isle," had a great success and was revived on various occasions up to 1803, and once in 1842. It was first published in 1843 by the Musical Antiquarian society. The score of Purcell's songs and music to *The Fairy Queen* (an adaptation of William Shakespeare's *A Midsummer Night's Dream*) written in 1693 was discovered in 1901 and edited for the Purcell society by J. S. Shedlock in 1903.

Purcell suffered much at the hands of his editors until, in 1876, the Purcell society was founded for the purpose of bringing out a complete and authoritative edition of his works, the majority of which were still in manuscript. There are signs of the beginning of a great Purcell revival, not only in England but also on the continent, where performances of *Dido and Aeneas* in Vienna, Münster and Basle aroused enthusiasm and interest.

Purcell died at his house in Dean's Yard, Westminster, on Nov. 21, 1695, and was buried in Westminster abbey on Nov. 26. He left a widow and three children, three others having died before him. His widow died in 1706. In 1682 and 1702 she published *Orpheus Britannicus,* a collection of his works, in two parts. A famous portrait of the composer is that by Sir Godfrey Kneller, bequeathed to the National Portrait gallery, London, by Barclay Squire. There is also an engraved portrait by R. White on the first edition of his sonatas (1683).

Other dramatic works by Purcell were *Don Quixote, The Indian Queen* and *Bon duca* (all in 1695) and many earlier works. Smaller works are the fantasias and sonatas for three or more parts, the suites and many miscellaneous pieces for harpsichord, and songs. For a complete list, *see* Grove's *Dictionary* and the publications of the Purcell society. Other publications include the *Chacony* for string quartet (Chester Ltd. 1926); *Dido and Aeneas* with Eng. and German text, ed. by E. J. Dent, and Dennis Arundell's life, *Henry Purcell* (both by the Oxford University Press, 1928); Henri Dupré, *Purcell* (Eng. trans., Knopf, New York and London, 1929); the life by Dr. W. Cummings in the *Great Musicians* series (1903) remains a standard work.

PURCHAS, SAMUEL (1575?–1626), English compiler of works on travel and discovery, was born at Thaxted, Essex, and studied at St. John's college, Cambridge, and at Oxford. In 1604 he was presented by James I to the vicarage of Eastwood, Essex, and in 1614 became chaplain to Archbishop Abbot and rector of St. Martin's, Ludgate, London. Purchas died in Sept. or Oct. 1626, according to some in a debtors' prison. As an editor and compiler he was often injudicious, careless and even unfaithful; but his collections are often the only sources of information upon questions affecting the history of exploration. His works include: *Purchas, His Pilgrimage; or, Relations of the World and the Religions Observed in All Ages* (1616); *Purchas, His Pilgrim. Microcosmus, or the Histories of Man. Relating the Wonders of His Generation, Vanities in His Degeneration, Necessity of His Regeneration* (1619); *Hakluytus Posthumus or Purchas His Pilgrimes, Contayning a History of the World in Sea Voyages and Lande Travells, by Englishmen and Others* (4 vols., 1625).

PURCHASE, in its common sense, that which is acquired by the payment of money or its equivalent. The term was early used by the lawyers (*e.g.,* Britton, in 1292) for the acquirement of property by means other than inheritance or mere act of law, including acquirement by escheat, prescription, occupancy, alienation and forfeiture; more generally, purchase in law means acquisition of land by bargain or sale, according to the law of "vendor and purchaser." (*See* Laws Relating to Real Property and Conveyancing.) A later meaning is the mechanical contrivance by which power can be used, a hold or fulcrum. This first appears (16th century) in the nautical use of the verb, to haul up a rope or cable; that is, to "gain" advantage over the rope bit by bit.

PURDAH, the curtain which screens women from the sight of men in Eastern countries; a *purdah-nashin* is a woman who sits behind the curtain (Pers. *parda*). In Anglo-Indian usage, to "lift the purdah" means to reveal a secret.

PURE LINE. A pure line consists of a self-fertilized individual and its progeny; it is a group of individuals all possessing the same hereditary constitution, in which all the factors are present in duplicate. Until W. L. Johannsen studied the effects of selection on the weights of individual seeds of the Princess bean there was no general explanation of the manner in which this process operates (*see* Breeds and Breeding; Inbreeding; Animal Breeding; Genetics; Heredity; Mendelism and Selection: *Artificial Selection*). *See* W. Johannsen, *Ueber Erblichkeit in Populationen und in reinen Linien* (1903).

PURGATORY, according to Roman Catholic faith, a state of suffering after death in which the souls of those who die in venial sin, and of those who still owe some debt of temporal punishment for mortal sin, are rendered fit to enter heaven. It is believed that such souls continue to be members of the church of Christ; that they are helped by the suffrages of the living—that is, by prayers, alms and other good works, and more especially by the sacrifice of the mass; and that, although delayed until "the last farthing is paid," their salvation is assured. Catholics support this doctrine chiefly by reference to the Jewish belief in the efficacy of prayer for the dead (2 Macc., xii, 42 *seq.*), the tradition of the early Christians and the authority of the church.

The state of purgatory is usually thought of as having some position in space, and as being distinct from heaven and hell; but any theory as to its exact latitude and longitude, such as underlies Dante Alighieri's description, must be regarded as imaginative. Most theologians since Thomas Aquinas and Bonaventura have taught that the souls in purgatory are tormented by material fire, but the Greeks have never accepted this opinion. It must be inferred from the whole practice of indulgences as at present authorized that the pains of purgatory are measurable by years and days; but here also everything is indefinite. The council of Trent, while it commands all bishops to teach "the sound doctrine of purgatory handed down by the venerable fathers and sacred councils," bids them exclude from popular addresses all the "more difficult and subtle questions relating to the subject which do not tend to edification."

The Eastern Church affirms belief in an intermediate state after death, but the belief is otherwise as vague as the expressions of the pre-Nicene fathers on the subject. The Longer Catechism of the Orthodox Church (Q. 376) states:

"Such souls as have departed with faith but without having had time to bring forth fruits meet for repentance may be aided towards the attainment of a blessed resurrection by prayers offered in their behalf, especially such as are offered in union with the oblation of the bloodless sacrifice of the Body and Blood of Christ, and by works of mercy done in faith for their memory."

The efficacy of prayers for the dead, and indirectly the doctrine of purgatory, were denied by early Gnostic sects, by Aëtius in the 4th century and by the Waldenses, Cathari, Albigenses and Lollards in the middle ages. Protestants, with the exception of a small minority in the Anglican communion, unanimously reject the doctrine of purgatory and affirm that "the souls of believers are at their death made perfect in holiness and do immediately pass into glory." Rejection of an intermediate state after death follows the Protestant idea of justification by faith as logically as the doctrine of purgatory results from the Catholic idea of justification by works.

An analogy to purgatory can be traced in most religions. Zoroaster conducts souls through 12 stages before they are sufficiently purified to enter heaven; and the Stoics conceived of a middle place of enlightenment which they called ἐμπύρωσις.

Bibliography.—The principal authoritative statements of the Catholic Church on the doctrine of purgatory were made at the council of Florence (*Decret. unionis*), and at that of Trent (Sess. vi. can. 30; Sess. xxii, c. 2, can. 3; Sess. xxv). *See* H. J. D. Denziger's *Enchiridion;* J. Bautz, *Das Fegfeuer* (Mainz, 1883) and L. Redner, *Das Fegfeuer* (Regensburg, 1856). An elaborate treatise from the Catholic standpoint is that of Cardinal Bellarmine, *De purgatorio.* The subject is discussed, moreover, in all major works on dogmatic theology. There is a representative Catholic statement in the *Catholic Encyclopaedia,* and a Protestant presentation by Rud. Hoffmann in Herzog-Hauck's *Realencyklopädie,* 3rd ed., vol. v, pp. 788–792.

PURI or **JAGANNATH,** a town and district of British India, in the province of Orissa. The town is on the seacoast, and has a railway station. Pop. (1941) 41,055. Since it contains the world-famous shrine of Jagannath (*see* Juggernaut), Puri is perhaps the most frequented of all Hindu places of pilgrimage; of recent years also it has won some popularity as a seaside health resort. The great temple of Jagannath was built in the 12th century by Choda Ganga, the greatest of the eastern Ganga kings of Kalinganagara (Ganjam).

The District of Puri has an area of 2,451 sq.mi. and a population (1941) of 1,101,939. Most of the country is flat. The middle and eastern divisions of the district, forming the southwestern part of the Mahanadi delta, consist entirely of alluvial

plains, watered by a network of channels through which the most southerly branch of that river, the Koyakhai, finds its way into the sea. The other rivers are the Bhargavi, the Daya and the Nun, all of which flow into the Chilka lake. During the rainy season the rivers come down in floods, sometimes bursting their banks and carrying everything before them. The Chilka lake is one of the largest in India; its length is 44 m., and its mean breadth 13 m. in the north and 5 m. in the south. It is separated from the sea only by a narrow strip of sand. The lake is saline and everywhere very shallow, its mean depth ranging from 3 to 5 feet.

Puri first came under the British in 1803. Later events were the rebellion of the maharaja of Khurda in 1804 and the rising of the *paiks* or peasant militia in 1817–18. In the Orissa famine of 1866 more than one-third of the population is said to have perished. The district is served by the Bengal Nagpur railway which was opened throughout from Calcutta to Madras in 1891, with a branch to Puri town.

Puri district is rich in historical remains, from rock-hewn caves to the magnificent mediaeval shrines at Bhubaneswar and Konarak. On a hill at Dhauli, 4 m. S.W. of Bhubaneswar, are rocks with edicts inscribed by Asoka in the 3rd century B.C. and an elephant carved out of the solid rock, the oldest carving of an elephant known in India. In the hills of Udayagiri and Khandagiri are Jaina caves hewn out of the rock, and some (such as the Rani Gumpha or queen's palace) profusely carved, between the 3rd and 1st centuries B.C. The greatest architectural glory of the district is its collection of temples built between the 8th and 13th centuries A.D. Bhubaneswar is crowded with Saiva shrines of which the largest is the Lingaraj, while the Raja Rani temple has been described by Fergusson as one of the gems of Orissa art. More magnificent, even in its ruin, is the sun-god's temple of Konarak, of which Sir John Marshall writes: "There is no monument of Hinduism, I think, that is at once so stupendous and so perfectly proportioned."

PURIFICATION. Purification denotes the processes employed to prepare individuals or communities for contact with persons or things otherwise dangerous, or to prevent the consequences of contact with such persons or things. To deal first with the latter aspect, a man may unwittingly violate a tabu and such is the sense of social solidarity that the whole community feels itself menaced with calamity. He must be purified. The society must be protected. All conditions of diminished social activity on the part of an individual are dangerous. (*Andaman Islanders*, p. 303.) Thus, "among most or all African tribes a sin, wrong doing or breach of custom is not merely a matter demanding punishment or redress but it imparts a bane or evil influence which remains unless the necessary purification follows. The point to be emphasized is that this mysterious force affects not the evil-doer but the person injured, so that it is he who must be purified. For instance, a man who is wounded is purified by the one who wounded him." (C. Dundas, *Kilimanjaro and its People*, 1924, p. 155.) Contact with persons and things possessing this dangerous potency is often essential. In this sense cleanliness is very close to godliness. In general food is regarded as something that may only be approached with ritual precautions. (*Andaman Islanders*, p. 273.) The savage must come to his meals clean. Primitive communities insist on the purification of the successful warrior. (*Andaman Islanders*, p. 133; *Ila Speaking Peoples*, I., 179; *Akamba* 198, *see* note; *The Sema Nagas*, p. 175; and *42nd Annual Report, Bureau of American Ethnology*, p. 423.) The sacrificial priest must be purified before he touches the holy object. He must be purified again when the rite is over.

It is evident that the dangerous qualities whose effect has to be neutralized are in one aspect of a spiritual nature and that intention, motive, purpose are not essential elements. The automatic effect of a breach of the law gives strength to the social order since, where the results of sin may affect all or any of the members of the society it is the business and interest of each man to keep the law and to see that his neighbour keeps it.

Whenever and wherever sin has come to be viewed as a breach of a divine order, punished by the Divinity, a judge of the heart of man, a just judge, motives and purposes assume importance. Purification is here directed to the conscience. The preventive action of the rites of purification comes in course of time to include deep, permanent modifications of the personality of the sinner, so that he sins no more. Coercion comes from within and is self-determined. *See* Bibliography to article ANTHROPOLOGY.

PURIM, a Jewish festival on Adar 14 and 15, to commemorate the deliverance of the Jews from Haman, the minister of Ahasuerus (Artaxerxes?), as related in the book of Esther (lit. lots, Heb. פּוּר, Esther iii. 7; ix. 24, 26, possibly from Assyrian *puru*, stone or Vedic *pûrti*, portion): so called from the lots cast by Haman to determine an auspicious day for the massacre. The origin of the festival is much disputed: some hold that it developed from a primitive spring festival because (a) it is celebrated just before the advent of the New Year in *Nisṣan* and that the preliminary fasting was actually ordained in Esther iii. 7; iv. 16 for *Nisṣan*. But the fasting is a later institution (on this see *Jew. Enc.*, x. 278); (b) the feast is secular rather than religious: it has all the characteristics of a spring carnival including the ironical crowning of the buffoon-king or vegetation-god who was put to death after mockery (*cf.* Frazer, *Golden Bough*, ed. ii., vol. iii., pp. 154): S. Langdon (*Bab. Epic of Creation*, 1923, pp. 28, 33, etc.) traces a similar festival to Marduk (*cf.* Mordecai; Ishtar-Esther?) during *Nisṣan*, with the mystic ceremony of the death and resurrection of *Bêl*, from primitive times in Babylonia. Zimmern (*see* refs. in Langdon) drew a parallel with the leading features in the scourging and death of Jesus. But the Jewish beating of Haman or burning of his effigy is late and clearly borrowed from mediaeval carnival customs, probably in the 13th century. On the contrary, during the synagogal reading of the book of Esther the reader hurries over the execution of the ten sons of Haman (Esther ix. 7–10), pronouncing them in one breath. This goes back to the Talmud (Neg. 16 b) and is ordained (1) to denote their simultaneous death and (2) to avoid gloating over a fallen foe. If Purim were purely a Babylonian feast, the Jews of Palestine and Egypt would hardly have accepted or retained it long after their connection with the Persian Empire ceased, whereas Purim has always been most popular. (c) On the other hand, there are features in the Jewish liturgy which strongly suggest a secular origin and it is most likely that this festival, first secular and national, ultimately became sanctified and was made a religious occasion. The growth of this process may be traced in the service. The name of God is absent from the *Megillah* and various devices of the scribe make good the deficiency, *e.g.*, when the letters of the Tetragrammaton occur close together they are crowned or written large: in iv. 14 "another place" is interpreted of God because "place" (*Maqōm*) is used in this way. The only religious allusions in the book are iv. 16 and ix. 31. The scroll is called *'Iggereth* or letter (ix. 26 and 29) and the reader folds the scroll so as to make it resemble a letter and holds it aloft when he recites the word "letter" in the verses just named. This tends to mark the lower or secular category of the book, *i.e.*, it is classed as an "Epistle" rather than as a "Gospel." For the service itself *see* Singer's *Authorized Daily Prayer Book*, p. 276 (and p. ccvi. of *annotated ed.*), where the alphabetical poem (אַשְׁרֵי הָאִישׁ) may be noted.

A characteristic of Purim and the book of Esther often overlooked is its similarity to the Euripidean drama. A cardinal feature is the punishment of ὕβρις. Purim plays are frequent, by Christian (*e.g.*, Racine) as well as by Jewish authors.

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PURINES. The purines comprise a large group of nitrogenous compounds, a few of which occur widely distributed throughout nature. They derive their name from the fact that they can be regarded as derived from one substance, purine itself. This name was coined by the German chemist, Emil Fischer, from the two Latin words *purum* and *uricum*, the latter being chosen

because the best known purine at that time, uric acid, occurs in urine. Fischer named this compound and pointed out its relation to known purines about 14 years before he actually prepared it in the laboratory.

Of the several hundred purines known, only 12 have been isolated from natural sources. All other purines are synthetic products and are only of academic interest. The following discussion will be limited almost entirely to eight of these purines which occur widely distributed throughout nature, namely, uric acid, guanine, adenine, xanthine, hypoxanthine, caffeine, theobromine and theophylline.

THE INDIVIDUAL PURINES

Uric Acid.—This was the first purine known, being discovered in human urinary calculi by the Swedish chemist Scheele in 1776. Scheele made careful investigations of its reactions and properties, these results being still used to identify uric acid. Thirty years later it was found that uric acid occurred in guano, and still later it was found that birds' excrement consisted largely of uric acid. Guano consists of the excrement of certain South American sea birds, which, with the help of a dry climate, has been accumulating for untold years. By far the best source of uric acid, however, is the excrement of serpents, which consists of over 95% of uric acid combined with small amounts of potassium and ammonia. It is only necessary to dissolve snakes' excrement in dilute alkali, filter, and reprecipitate with mineral acid.

Uric acid, however, occurs in other ways. As the mono-sodium salt it is the substance precipitated in body tissues in cases of gout, and is responsible for the formation of the gouty nodules with the subsequent inflammation and irritation which characterize this disease. Uric acid also occurs normally in the blood of man and other animals. In man the blood normally contains less than 0.1 mg. per cu. cm. Uric acid confines itself to the animal kingdom, although other purines are common as plant products.

The following table (Givens and Hunter) shows the variation in the relative amounts of allantoin, uric acid and bases (other purines) excreted in the urines of different species of mammals.

Order and Species.	*Allantoin*	*Uric acid*	*Nitrogen (%) present as Bases*
Marsupialia:			
Opossum	76.0	19.0	6.0
Rodentia:			
Guinea-pig	91.0	6.0	3.0
Rat	93.7	3.7	2.7
Ungulata:			
Sheep	64.0	16.0	20.0
Goat	81.0	7.0	12.0
Cow	92.1	7.3	0.7
Horse	88.0	12.0	0.5
Pig	92.3	1.8	5.8
Carnivora:			
Raccoon	92.6	5.4	2.0
Badger	96.9	1.9	1.2
Dog	97.1	1.9	1.3
Coyote	95.6	2.6	1.8
Primates:			
Monkey	66.0	8.0	26.0
Man	2.0	90.0	8.0

Man stands out as eliminating 90% of his purine-allantoin nitrogen in the form of uric acid, this proportion being 11 times as much as the monkey, which is biologically his closest relative. Too much importance must not be attached to the biological significance of this, however, as the ratio is known to vary considerably, even within a species.

The origin of uric acid as an excretory product has long been a matter of interest. According to A. P. Mathews (*Physiological Chemistry,* New York, 1915), the reason for the excretion of protein nitrogen in the form of uric acid rather than urea by birds and reptiles, is to be ascribed to their environment during evolution. The birds were evolved from the reptiles, and the reptiles were probably evolved in a dry, arid region, as indicated by other body characteristics. Urea is very soluble in water, and has a great affinity for it, whereas uric acid is insoluble, with no affinity for water, so that the excretion of nitrogen as uric acid rather than urea, saves much water for the organism, and would be an important adaptation in a region comparatively devoid of water.

In man the excreted uric acid may be divided into two varieties, the endogenous and the exogenous uric acid. The endogenous uric acid, about 0.4 grams a day, is very nearly constant for a given individual, but varies slightly in amount in different persons. It represents the uric acid which is formed in the body by synthesis and by the breakdown of nuclear tissue. On a diet which is free from purines, it is independent of the amount of fat, carbohydrate, protein or number of calories ingested. It is thought to originate from the oxidation of the hypoxanthine constantly formed in muscle and other tissues.

The exogenous uric acid is that formed by the oxidation of purines taken in as part of the food, chiefly in meat. All meat, and particularly glandular meat such as liver and sweetbreads, contains varying amounts of nucleic acid, which contains about 20% of the purines guanine and adenine. In the body these two substances are changed, by means of enzymes, into two other purines, xanthine and hypoxanthine, which are both oxidized to uric acid. The amount of exogenous uric acid depends, then, on the purine intake. Furthermore, it has repeatedly been shown that uric acid and other purines, injected hypodermically into the body, can be recovered nearly quantitatively in the urine.

Man excretes ingested purines almost entirely as uric acid, although other mammals excrete theirs almost entirely as allantoin, because the human body is lacking in a specific enzyme, uricase, which oxidizes uric acid to allantoin. The small amount of allantoin excreted by the human is probably preformed in the food. In the livers and other organs of animals which excrete allantoin, we find varying amounts of uricase, and if these organs are ground up and digested with uric acid, it is oxidized to allantoin. Different animals apparently differ in the efficiency with which this reaction is performed.

When the uric acid metabolism is disturbed, for reasons which are not as yet understood, the uric acid output in the urine is lowered. As the individual constantly ingests more purine, the result is that it is stored up. At first this storage takes place in the blood, but owing to the very low solubility of uric acid and its mono-sodium salt, only a limited amount can be held in this way. The excess crystallizes out, mainly in the cartilages and joints, as acid sodium urate, and the irritation resulting from these deposits is known as gout. It is evident that a gouty person should avoid foods which contain purines, such as meat, and confine his protein diet to such foods as milk and eggs, which are virtually purine free.

Guanine and Nucleic Acid.—Guanine, one of the two amino-purines occurring in nature, takes its name from the fact that it was discovered in guano, by B. Unger in 1845. Since that time, however, it has been found widely distributed throughout the animal and plant world. It occurs in the scales and skin of the bony fishes, and in the swim bladders, to which it gives their characteristic pearly appearance. It also is the chief constituent of the excrement of spiders. Human and pig urine contain small amounts of guanine. By far its most important occurrence, however, is in organs rich in cells, such as the pancreas, liver, spleen, testicles, etc., in animals, and in the germ cells of plants. It occurs here as a constant constituent of nucleic acid, of which it constitutes about 10%.

Nucleic acid, a compound occurring in the nuclei of all cells, is built up from four molecules of phosphoric acid, four of sugar, two of pyrimidines, and one each of guanine and adenine. When taken into the body as food, the guanine and adenine are eventually excreted as uric acid. These changes are brought about by the action of enzymes, which eventually break the nucleic acid up into its component molecules. The guanine is then changed by an enzyme, guanase, into its corresponding oxygen derivative, xanthine, which is then oxidized by an enzyme, xanthine oxidase, to uric acid.

It is an extremely interesting fact that in the pig the organs are entirely lacking in guanase; it is thus impossible for it to change guanine into allantoin, and consequently the pig frequently

suffers from a form of gout, similar in all respects to that in humans, except that the deposit in the joints consists of crystalline guanine instead of acid sodium urate.

Adenine.—Adenine and guanine are the only two amino-purines, and differ from one another by only one atom of oxygen, guanine being an oxidized adenine.

Adenine, discovered by A. Kossel in 1884 among the hydrolytic products of pancreatic nucleic acid, is found in all glandular tissues, which are rich in nucleins. In addition, it occurs free in the leaves of plants, for example tea leaves and alfalfa leaves. It has also been found combined with sugar in the blood stream.

Adenine, like guanine, is one of the chief contributors to the uric acid and allantoin output of mammals. After the enzymic cleavage of the nucleic acid there are two special enzymes to take care of the adenine. One of these, adenase, replaces the amino-group by an hydroxyl, giving hypoxanthine. Another enzyme, an oxidase, oxidizes the hypoxanthine to xanthine, which is further metabolized as in the case of guanine.

Xanthine.—This purine, first discovered by Marcet, in 1817, in a urinary stone, derives its name from the Greek word, *xanthos*, meaning yellow: when it is evaporated in a dish with HNO_3, a yellow spot remains. Xanthine occurs widely distributed in animal and plant matter, wherever guanine is found, being probably derived from guanine by enzymic and putrefactive processes.

Hypoxanthine (Sarcine).—Hypoxanthine is a reduced xanthine, which was discovered by Scherer in 1850 in an extract of spleen. In general, it may be found in all nuclear tissues, and is probably there as a decomposition product of adenine, from which it is derived by the substitution of an hydroxyl by an amino-group. This change is brought about by the enzyme, adenase, as a result of either normal degradation or putrefactive processes. It is also found in small amounts in bone marrow.

Caffeine or Theine.—These two names are applied to a well-known purine discovered in 1820 in tea leaves by Ferdinand Runge. Caffeine is found only in vegetable matter, occurring to the extent of 0·8–1·7% in coffee beans, 0·1–0·8% in cocoa beans, 1–2% in Kola nuts, 2–5% in tea leaves, and 2·5–5% in guarana, the roasted fruit of *Paullinia*, which is eaten in South America. It is this purine, along with theobromine and theophylline, which gives the stimulating effects to drinks made from the above sources.

Caffeine has the notable effect of stimulating the central nervous system. In addition it is a cardiac tonic, and, in common with nearly all purines, has a strong diuretic action. In the body it is oxidized to uric acid and excreted as such. There is a tendency among many medical practitioners to warn patients to do without tea and coffee. In certain cases there are undoubtedly very good reasons why caffeine is harmful. For example, in the case of a person suffering with gout, everything must be done to lower purine ingestion, and thus to lessen the load on the already overburdened kidneys. Specially prepared brands of tea or coffee are available from which caffeine has been removed without any alteration of taste. In the case of tea this is done by extracting the leaves with light petroleum to remove the volatile oils which are responsible for the flavour. The caffeine is then removed by extraction with chloroform, after which the original petroleum extract is added to the leaves and the solvent allowed to evaporate, thus restoring to the tea its original flavour. Green coffee beans are treated with live steam and ammonia gas to swell them, the caffeine is then chloroform processed, and the beans subsequently roasted.

Theobromine.—This purine is unfortunately named, for it is devoid of bromine. It was noted first by A. Woskresensky, in 1842, in an extract of cocoa beans, where it occurs to the extent of 1·5–2·4%. This bean is the seed of the plant *Theobroma Cacao* hence the name theobromine. As in the case of caffeine and theophylline, it occurs only in plant matter, being present in the kola nut and in tea leaves, but not in coffee beans. It is a powerful diuretic, and in the body is oxidized to and excreted as uric acid.

Theophylline.—In 1888 A. Kossel discovered very small traces of this purine in tea extract.

Paraxanthine, Heteroxanthine, 1-Methylxanthine and Epiguanine have all at one time or another been isolated from human urine. They are regarded as secondary products, arising from the action of the body on caffeine (*see* p. 780).

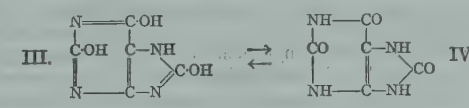
THE CHEMISTRY OF THE PURINES

Purine has the empirical formula, $C_5H_4N_4$, the atoms being joined together according to one or other of the following structural schemes:

In order to endow the many purines with names which may at once be distinctive and descriptive, each atom in the purine ring is given a number, as indicated in formula I.

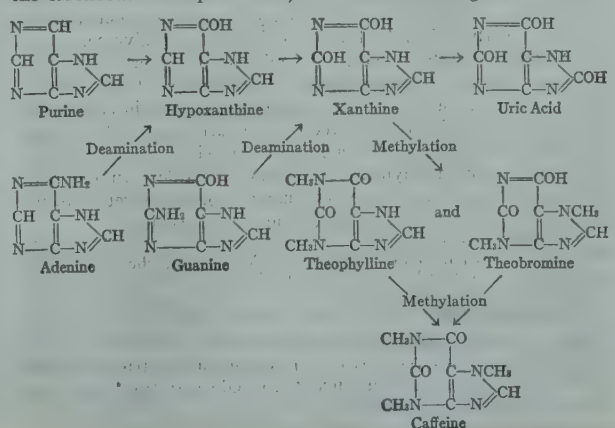
It will be noted that, as the arrows indicate, purine is a mixture of two substances which readily pass from one to another. This mutation is known as tautomerism (*q.v.*). In purine, one of the hydrogen atoms is labile and can pass from the nitrogen atom at 7 to the nitrogen at 9, and vice versa. Any of the four hydrogen atoms in purine may be substituted by any of a large number of groups, the most important being the hydroxyl group (OH), amino- (NH_2), chlorine (Cl), and methyl (CH_3) groups.

A substitution on nitrogen in either the 1 or 3 position is only possible when the hydrogen at either or both of the 2 and 6 positions is substituted by an hydroxyl. For instance, uric acid (2:6:8-trihydroxypurine) is a tautomeric substance, existing



either in the lactim form (III.) or the lactam form (IV.). As a lactim uric acid yields salts with metals, the hydrogen on oxygen being replaceable. The lactam form explains why substitution occurs on the 1 and 3 nitrogen atoms.

The following diagram explains the relationships existing between the purines. Starting with purine, and successively substituting hydroxyl groups for the hydrogen atoms attached to carbon, hypoxanthine, xanthine and uric acid are obtained, these being the mono-, di- and tri-hydroxypurines respectively. Similarly, adenine is a mono-aminopurine and guanine is a mono-aminohypoxanthine.



Uric Acid.—This dibasic acid is a white, finely crystalline substance, insoluble in water and all organic solvents. Alkaline salts of weak acids, such as potassium phosphate, sodium acetate, and particularly lithium carbonate, increase the solubility in water owing to the fact that these salts all form alkaline solutions, and the sodium salt of uric acid is much more soluble than the free acid. (Lithium salts have been used in the treatment of gout on the erroneous assumption that, lithium urate being more soluble

than sodium urate, the uric acid would be eliminated more quickly.) Uric acid, when heated, decomposes into ammonia, carbon dioxide, urea and cyanuric acid. It is unstable and decomposes if left in moderately strong alkali for any length of time. Uric acid is identified by the "murexide" reaction. The suspected substance is evaporated to dryness with nitric acid; if uric acid is present this leaves a yellow spot which when moistened by ammonia turns purple, due to ammonium purpurate formed.

Although uric acid was discovered in 1776, its structural formula was not investigated until 1875, when L. Medicus proposed the formula which has since been established by numerous syntheses.

Guanine is a white amorphous powder, insoluble in water and organic solvents. It is a much weaker acid and stronger base than uric acid. It is, however, such a weak base that ammonia will precipitate it from solution. Owing to the hydroxyl group on carbon, it will dissolve in strong bases, such as sodium hydroxide. The amino-group present in its structure makes it soluble in acids, and thus separable from uric acid. Silver nitrate precipitates guanine in either neutral or alkaline solution, and forms double salts with guanine nitrate. The nitrate is insoluble in strong nitric acid. If treated with nitrous acid, or digested with the enzyme guanase, the amino-group is replaced by hydroxyl giving xanthine.

Adenine crystallizes from water in clusters of leaflets which contain $3H_2O$. When anhydrous it melts at 360–365° F; it is a stronger base than guanine, and hence is not precipitated by ammonia, this difference affording a separation of the two bases. Like guanine, it is precipitated by phosphotungstic or picric acid, the picrate forming beautiful silky yellow needles. Nitrous acid, or the enzyme adenase, decomposes adenine, the resulting replacement of amino- by hydroxyl giving hypoxanthine. Adenine is stable to weak oxidizing agents, but unstable to even mild reducing agents. At 200° F. hydrochloric acid decomposes it completely to carbon dioxide, ammonium formate and glycine acid.

Xanthine, a white crystalline substance forming salts with both strong acids and bases, occurs in nature but is best prepared by the action of nitrous acid upon guano. When heated dry it decomposes into carbon dioxide, ammonia and hydrocyanic acid.

Hypoxanthine occurs as small colourless needles, soluble in both acids and bases. Its hydrochloride crystallizes with one molecule of water. The picrate is very insoluble, and can be used to remove hypoxanthine from solution. This purine is not precipitated by ammonia and is a strong enough acid to decompose carbonates. Hypoxanthine is obtained from adenine by deamination with nitrous acid or adenase.

Theophylline, like theobromine, is a weakly basic substance. Upon oxidation with hydrochloric acid and potassium chlorate it gives dimethylalloxan, in contrast to xanthine, hypoxanthine and uric acid, which give alloxan. When methylated, theophylline and theobromine give caffeine.

Theobromine, an isomeride of theophylline, occurs as colourless needles having a very bitter taste. It is prepared by the methylation of the lead salt of xanthine. Oxidation with hydrochloric acid and potassium chlorate gives methylalloxan and methylurea, whilst boiling with baryta produces methylamine, ammonia, carbon dioxide, formic acid and methylglycine.

Caffeine crystallizes with one molecule of water in beautiful, glistening needles, having a slightly bitter taste. They are sparingly soluble in cold water and alcohol, and soluble in chloroform. It is most conveniently prepared by the extraction of tea. Upon oxidation with hydrochloric acid and potassium chlorate it gives dimethylalloxan, methylurea and carbon dioxide. In the body, caffeine undergoes a number of changes, being excreted as uric acid and four other purine bases mentioned earlier.

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PURITANISM. The term "Puritan" was first used during the late 1560s as a label for those Englishmen who urged that the English Church proceed further in the rejection of papal practices and beliefs than it had gone since its formal separation from Rome under Henry VIII. A considerable number of reformers who had supported Henry's attacks on papal authority, which had culminated in the Act of Supremacy in 1534 abolishing the authority of the Roman papacy in England and declaring the king "the only supreme head in earth of the Church of England," had hoped that under his leadership the English Church would be radically reformed. These hopes had been in large measure disappointed. Though the king had been eager for independence from Rome and willing to see such changes in the church as the destruction of monasticism and the modification of the doctrine of purgatory, he had consistently regarded himself as an orthodox Catholic, and he had consistently moulded his policies as head of the church to his plans in foreign affairs. Indeed the Six Articles which Henry had pushed through parliament in 1539, when he had felt it safe to offend German Protestants, set up death penalties for certain Protestant heresies. Thirty years later, under Queen Elizabeth, the more ardent reformers who were still attempting to complete as they saw it the work of purifying the English Church came to be designated, and to designate themselves, as Puritans.

The main body of Puritans had no desire to be separated from the English Church. They simply desired the purification of the established ecclesiastical body. The basis for further purification seemed to them both perfectly clear and absolutely authoritative. It was on an infallible and completely sufficient Bible, rather than on a fallible church or tradition, that they rested their case, and they were horrified by the suggestion of more conservative Protestants that, though the Bible was the ultimate authority for Christians, it provided only general principles of faith and practice and left such matters as the wearing of surplices and the jurisdiction of bishops to determination by the established human authorities.

Confident of the supernatural authority on which they proposed to proceed to a "more thorough reformation," they entertained no plans for tolerating a variety of churches. They were as eager for uniformity as their opponents, and as ready to employ the secular power of the state to enforce it. They shared with Anglicans the belief that the state should have one religion and that the powers of the state should be employed to protect it. Their concern was that this one religion be the "true religion" of the Scriptures. The Puritans of Massachusetts Bay Colony in New England, who in the middle of the 17th century denounced religious toleration and harried Quakers out of the Colony, were neither inconsistent nor drunk with newly acquired power. They were realizing hopes their Puritan ancestors in England had long cherished. A society could be united only if committed to one religion, and heresy was to 16th- and 17th-century Englishmen, Anglican and Puritan alike, tantamount to anarchy or rebellion. For these reasons church and state could not be separated, and defense of the true religion was regarded as one of the proper duties of civil magistrates. Perhaps the most painful of the Puritan's dilemmas, therefore, was that recognizing this responsibility and authority of the state he yet found himself in opposition to the established church. To repudiate that church would be an act of rebellion; to accept it was to defy heaven and to lose his soul. Not until sectarian differences should come to be recognized as politically possible and even legitimate could this dilemma and with it the relation of church and state be resolved. Meanwhile, for the Puritan there remained only one tolerable possibility—the church legitimately established and defended by the state must be purified.

The conflicts which the Puritans on the basis of these principles introduced into the English Church and state during the 16th and 17th centuries revolved with varying emphasis at different periods about three matters: the forms of worship and clerical vestments; the organization of the church; and certain theological doctrines, notably the doctrine of predestination.

With the death of Henry VIII in 1547, the hopes of a more thorough reformation of the English Church, which he had disappointed, were revived. Edward VI was a child of nine when he assumed the throne and the affairs of the kingdom, which included those of the church, were at the outset directed by regents. In response to public sentiment, the heresy laws which under Henry had checked the development of Protestantism were repealed. Reformers like Miles Coverdale thereupon returned to

England from the continent, and in 1549 John Knox, the great Scottish reformer, was released from confinement in the French galleys by the intervention of the English government and welcomed to England. In the same year John Hooper, who had been driven into exile by the enforcement of Henry's Six Articles, returned to England. Shortly thereafter he was offered a bishopric. He professed two difficulties concerning the ordination ceremonies. He could not wear the prescribed clerical vestments and he could not take the oath of office which required the candidate to swear by the saints. The king removed the second of these difficulties by striking the obnoxious words from the ceremony with his own hand, and such good Protestants as Thomas Cranmer and Nicholas Ridley attempted to persuade the candidate that clerical vestments were things "indifferent," the wearing or not wearing of which touched nothing essential in religion. The term "Puritan" was not yet in use, but Hooper's position concerning clerical garb was one to which it was soon to be attached. When Hooper persisted in his objections, he was imprisoned. He finally accepted the advice of continental Protestants, admitted himself in error and was installed in office with the understanding, however, that except for public occasions he might dress as he chose.

At the death of Edward VI in 1553 and the accession of Mary, not merely Puritanism but Protestantism as a whole was threatened. Edwardian acts against Catholicism were abrogated, and in 1554 the acts separating the English Church from Rome were repealed. England was to be returned to Catholic uniformity, and execution for heresy was the accepted instrument of uniformity. The lists included Thomas Cranmer, the first Protestant archbishop of Canterbury, and John Hooper. John Knox fled to the continent where he soon joined a group of English refugees at Frankfurt. Yet even in exile the basic conflict of Anglicanism and Puritanism could not be repressed. Disagreement over the use of the Anglican vestments, ceremonies and prayer book deeply split the Frankfurt group, and Knox was finally driven out. Even in their extremity under Marian persecution, the two wings of English Protestantism, those content with the English establishment and those urging a more thorough reformation, were unable to cooperate.

The anguish of English Protestants was replaced by hope when Elizabeth mounted the throne in 1559. Exiles flocked back to England. But their expectations were soon dashed, for Elizabeth took shrewd advantage of the divisions which Puritanism introduced into the church to consolidate the powers of the monarchy. Under pressure from the crown, parliament passed Acts of Uniformity requiring what Puritans regarded as "popish superstitions." The kneeling posture at the sacrament was enjoined; certain detested clerical vestments were required; and the prayer for deliverance from "the tyranny of the Bishop of Rome" was deleted from the church service. Puritan sentiment was strong enough to come within one vote of passing a petition for reformation at the convocation of the representatives of the established church in 1562, but for both personal and political reasons Elizabeth took measures to repress it. The court of high commission was empowered "to visit, reform, redress, order, correct, and amend errors" in the church, and became a powerful engine against Puritanism.

In 1564 Elizabeth began a campaign for uniformity of clerical vestments. When the queen for political reasons refused to give her signature to a set of articles of uniformity drawn up by Archbishop Matthew Parker, he issued them under the title of *Advertisements* in 1566. The vestiarian controversy which followed served both to divide Protestantism and to discredit the Puritans, whose basic reform purposes were obscured by the fact that the point immediately at issue was a detail of clerical dress. As often happened thereafter, Puritans were made to appear as outrageously overscrupulous concerning trivial matters. Most Puritans offered only passive resistance to the queen's program, since Puritanism neither challenged the authority of the crown nor denied the importance of uniformity in religion, but a few extremists did take the decisive step which Puritan extremists thereafter occasionally followed. They set up independent congregations, ordaining their own church officers and disciplining their own members.

The main body of Puritanism turned rather to an attack on the episcopacy which had enforced the hated "popish" regulations. Leadership was provided by Thomas Cartwright, then Lady Margaret professor at Cambridge, who in 1570 contended that archbishops ought to be abolished and the functions of bishops reduced to those specified in the Scriptures. He was promptly deprived of his post at Cambridge. Puritans, however, enlisted support in parliament for a series of proposals to reform church government. The attempt was terminated abruptly when it seemed on the way to success by an order from the queen that the house consider no bills concerning religion unless they had been previously approved by the clergy. Despite this reversal, parliament took an increasing interest in Puritanism until it brought about the great Puritan triumph of 1640.

Meanwhile, Elizabeth suppressed the efforts of Edmund Grindal, who had been made archbishop of Canterbury in 1576 when Elizabeth, again for political reasons, was temporarily more tolerant of Puritanism, to improve the knowledge and discipline of the clergy by encouraging the practice of "prophesying," the holding of weekly meetings of the clergy for the exposition and discussion of passages of the Bible. Grindal's successor, John Whitgift, returned to the attack on Puritanism by insisting that all the clergy subscribe to a set of articles, one of which, requiring the assertion that the Anglican prayer book "containeth in it nothing contrary to the Word of God," was especially repugnant to Puritans. Whitgift's efforts inspired an attempt to bring about the reform of the church by setting up a presbyterian form of government within the Anglican Church. The leader in this movement was John Field. Efforts to enlist parliament in church reform were, however, blocked by the queen. The Puritan cause was little aided in this period by the appearance in 1588 of the intemperate satire on the bishops by "Martin Marprelate, Gent."

Meanwhile a few extreme Puritans had again been driven to the conclusion that reform from within the established church was impossible, and a few independent congregations had appeared. The most important of these was organized at Norwich by Robert Harrison and Robert Browne in 1581 and shortly thereafter emigrated to Middleburg, where in 1582 Browne published several treatises urging true Christians to withdraw from the Church of England and establish independent churches. Browne later recanted, but his name continued to be attached to the growing party of "Brownists," who under discouragement over the prospect of purifying the established church proposed to separate themselves from it.

Puritan confidence in the rightness of their cause may well have been the source of the optimism with which they greeted each new monarch. They were especially hopeful when after Elizabeth's death James I came to the throne in 1603. A dozen years earlier he had consented to the establishment of Presbyterianism in Scotland. He might be expected to show some favour to Puritanism in England. With high expectations the Puritans presented the new king on his way to London a plea for church reform known as the Millenary Petition because it purported to represent the desires of more than 1,000 clergymen. The king promised a conference at Hampton Court on the matter. It met in Jan. 1604, but when the new king had heard the Puritan case, he rejected it with scorn. "If this be all they have to say, I shall make them conform themselves," he declared, "or I will harry them out of the land, or else do worse." So far as abolishing the episcopacy went, his dictum was "No bishop, no king." James made himself especially obnoxious to the Puritans by publishing in 1618 his *Declaration for Sports on the Lord's Day,* which all ministers were enjoined to read to the congregations on pain of suspension and imprisonment.

One of the chief effects of James's repression of Puritanism was to drive many Puritans into separatism and exile. Among these groups of exiles was the congregation organized at Scrooby which under the leadership of John Robinson moved first to Leyden, Neth., and then in 1620 sent a colony to Plymouth in New England. Other Puritans, reluctant to take the extreme step of separation from the established church, adopted a difficult middle posi-

tion. Chiefly under the guidance of William Ames, fellow of Christ's college, they declared that independent churches on the model of the Scriptures might be set up within the established church. These would merely slough off the evils of the established church while remaining one with it in "essence." It was such a nonseparatist independent group which emigrated to Massachusetts bay in New England during the 1630s, where it had no difficulty in reaching agreement on church government with independents who had settled at Plymouth.

While Puritan aims were thus being frustrated by the crown from Elizabeth's through James's time, the Puritan cause was increasingly successful in parliament. It could be only a matter of time until the conflict between parliament and crown would be irreconcilable, and the Puritan attempt to obey both God and king would have to be abandoned. The climax came in the reign of James's successor, Charles I. Under him severity against nonconformity was increased. Meanwhile, to the conflict over liturgy and church policy was added a difference in theology. Both Anglican conformists and Puritans had hitherto been Calvinists in doctrine. Now the established clergy began to embrace the liberal doctrines of the Dutch theologian Jacobus Arminius while Puritans clung to their Calvinism. In vain parliament supported the Puritan position by passing such acts as the protestation of 1629 that anyone favouring or introducing "popery or Arminianism" should be regarded "as capital enemy to this kingdom and commonwealth." The elevation of William Laud to the archbishopric of Canterbury in 1633 seemed a direct answer to their protest, and during the following seven years ministers who preached the doctrine of predestination in opposition to Arminianism as well as those who attacked "popish ceremonies" were severely dealt with. Laud's zeal drove able and learned men like Thomas Shepard to New England. It finally precipitated the revolt of parliament.

Charles was forced by financial need to summon parliament in 1640. Thoroughly Puritan and thoroughly aroused, parliament brought about the execution of Archbishop Laud and nine years later abandoned the long-standing Puritan policy of passive resistance to bring about the execution of Charles himself. With the overthrow of both the established church and the monarchy, Puritanism strictly speaking may be said to have ended. Puritans split into two parties, Presbyterians and independents, neither of which aimed at the maintenance of the Anglican establishment. The bitter conflict in which they engaged was terminated by the force of Oliver Cromwell's army, which gave victory to the independents. When England had had its fill of civil conflict under the commonwealth and had restored the monarchy in 1660, the old lines again appeared, softened now, however, in the less sanguinary conflicts of high and low church parties within Anglicanism and Presbyterian and Congregational churches outside it. Sectarianism began to be tolerable and uniformity less than essential.

In America the term "Puritan" continued into the 19th century to be involved in bitter religious strife. The nonseparating independents who had settled at Massachusetts bay were typically Puritan in their insistence on the ultimate and complete authority of the Scriptures, on the necessity of uniformity and the evil of toleration, on the responsibility and authority of magistrates in matters of religion and on the truth of the Calvinistic theology. By the middle of the 18th century the conflicts in which American Puritanism engaged centred about the Puritan doctrine of predestination. In this period Jonathan Edwards gave powerful metaphysical formulation to the Calvinist position and rallied its waning forces. But in the generations that followed Edwardian Puritanism succumbed to the criticism of men like William Ellery Channing, and the term "Puritan" came finally to be applied to over-precise moralists or to reformers intent on such matters as the abolition of alcohol or tobacco. Historically these latter-day Puritans had little relation to the Puritanism of Elizabeth's time in old or in New England, who would have been as little interested in prohibition, for example, as modern so-called Puritans are in vestiarian reform.

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PURLIEU, a word used of the outlying parts of a place or district, sometimes in a derogatory sense. It was a term of the old English forest law and meant, as defined by John Manwood (*Treatise of the Forest Laws*), "a certain territory of ground adjoining unto the forest . . . which . . . was once forest-land and afterwards disafforested by the perambulations made for the severing of the new forests from the old." The owner of free lands in the purlieu to the yearly value of 40 shillings was known as a "purlieuman" or "purleyman."

PURLIN, in architecture, the longitudinal timbers of a roof, carried by the principal rafters or trusses and the end walls, and supporting the common rafters.

PURNEA, a town and district of former British India, in the Bhagalpur division of Bihar. The town is on the little river Saura, with a railway station. Pop. (1941) 19,036.

The DISTRICT OF PURNEA had an area of 4,998 sq.mi. and a population (1941) of 2,390,105, extending from the Ganges northward to the frontier of Nepal. It is a level tract of country, traversed by several rivers flowing from the Himalaya, the greatest of which is the Kosi, which has been known to move 20 mi. in 25 years, leaving behind it a trail of sterile sand. The principal crops are rice, pulses and oilseeds. Although the cultivation of indigo declined, that of jute greatly increased.

Branches of Eastern Bengal State railway join the Bengal and North-Western railway at Katihar (pop. 23,231). Kishanganj (pop. 10,424) is the centre of the jute trade and is a branch terminus of the Darjeeling-Himalayan railway.

PURNELL, THOMAS (1834–1889), English author, was born in Tenby, Pembrokeshire, in 1834. He studied at Trinity college, Dublin, and was assistant secretary and librarian of the Archaeological Institute of Great Britain and Ireland, 1862–66.

In 1871 he published *Dramatists of the Present Day* (London), a reprint of his series of articles which first appeared in 1870–71 in the *Athenaeum* under the pseudonym "Q." He also edited Charles Lamb's *Correspondence and Works* (1871). Other works include *Literature and Its Professors* (London, 1867); *To London and Elsewhere* (London, 1881); and *Dust and Diamonds: Essays* (London, 1888).

PURNELL, WILLIAM HENRY (1826–1902), U.S. lawyer and educator, was born on Feb. 3, 1826, in a rural area of Worcester county, Md. In 1846 he graduated from Delaware college, which later became the University of Delaware, and in 1848 he was admitted to the bar. Purnell held various state offices in Maryland, 1850–59. He was appointed deputy postmaster of Baltimore in 1861 and was chairman of the Union party state central committee, 1864–66.

After the senate in 1867 refused to confirm his appointment to the post of assessor of internal revenue at Baltimore, he practised law there. Purnell was president of Delaware college, 1870–85, and an instructor there from 1897 until his death on March 30, 1902.

PURPLE, SAMUEL SMITH (1822–1920), U.S. physician and editor, was born in Lebanon, N.Y. on June 24, 1822. After his father died in 1839, Purple began at the age of 17 to support his family by continuing his father's small shoemaking and tanning business.

He studied at Geneva Medical college and in 1844 graduated from the New York university medical college. In 1846 he became physician at the New York city dispensary, and in 1849, the year of the New York cholera epidemic, he was the board of health ward physician. Purple was editor of the *New York Journal of Medicine*, 1848–58. One of the founders of the New York Academy of Medicine, he was president of the academy, 1875–79.

Purple became a leading book collector, and from 1874 to 1886 he edited the *New York Genealogical and Biographical Record.*

See *New York Genealogical and Biographical Record* (Jan. 1901).

PURPLE, a shade varying between crimson and violet. Formerly it was used of the deep crimson colour called in Latin *purpura,* from the name of the shellfish (*Purpura*) which yielded the famous Tyrian dye. Tyrian purple during many ages was the most celebrated of all dyed colours, and possibly the first to be permanently fixed on wool or linen. Being extremely costly, robes of this colour were worn as a mark of imperial or royal rank, whence the phrase "born in the purple." In the Roman Catholic church "promotion to the purple" is promotion to the rank of cardinal.

The ancients derived their purple from the mollusc, *Purpura haemastoma,* known to Pliny as "Buccinum," and *Murex brandaris,* termed by Pliny "Purpura," the shells of which have been found adjacent to ancient dyeworks at Athens and Pompeii. The colour-producing secretion is contained in a small cyst adjacent to the head of the animal, and this pus-like matter when spread on textile material in presence of sunlight develops a purple-red colour. According to Pliny these receptacles after being laid in salt were boiled with water for several days, the liquor being tested from time to time as to its dyeing properties. Before dyeing the wool could be grounded with a second colouring matter, for which purpose alkanet root (*Anchusa tinctoria*) and "orchil" were employed. Friedländer has shown that the dye developed from the molluscs is 6:6′-dibromoindigotin. (A. G. P.)

PURPURA includes a group of loosely related diseases that are characterized by spontaneous haemorrhages into the skin and from the mucous membranes. The cutaneous haemorrhages are usually small and are referred to as petechiae or ecchymoses.

(1) Symptomatic purpuras are those that are definitely secondary to some other disease. They may occur in destructive diseases of the bone marrow such as leukemia (leucaemia), aplastic anaemia and metastatic carcinoma; in fulminant infections as haemorrhagic smallpox, haemorrhagic measles and meningococcic bacteriaemia; following the use of certain drugs as arsenical preparations, thiosulphate, sulfonamides and sedormid; and in vitamin C deficiency (scurvy). The blood platelets are usually reduced in number during the attacks, and there is often evidence of destruction of the megakaryocytes in the bone marrow from which the platelets are formed. Treatment is directed toward the underlying disease.

(2) Primary thrombopenic purpura includes all forms of unknown aetiology. During attacks the blood platelets are reduced in number and the bleeding time is prolonged. The coagulation time of the blood is unaffected. The disease varies from a mild form with little disturbance other than cutaneous haemorrhages to fulminant cases in which the patient dies because of massive bleeding from the mucous membranes or from a haemorrhage in the brain. Bleeding from mucous membranes may be more conspicuous than the cutaneous haemorrhages. The most frequent clinical form is a chronic recurrent purpura in which the patient is free from symptoms between attacks. Orthostatic purpura refers to the form in which the cutaneous haemorrhages develop in the lower extremities as a result of increased venous pressure. In addition to haemorrhages the outstanding features are the prolonged bleeding time and the reduced number of blood platelets. There is an associated disease of the blood capillaries, since they do not retract readily after they are cut and when the skin is pricked with a needle the bleeding continues longer than usual.

In cases where the loss of blood becomes serious it is usually advisable to remove the spleen since this will stop the bleeding in most instances. The beneficial effect of splenectomy is not understood since the spleen shows no recognizable disease. Primary thrombopenic purpura is believed to be a form of hypersplenism. Splenectomy is not indicated in juvenile purpuras since these usually recover spontaneously, and it is of no value in symptomatic purpuras. (E. T. Be.)

PURRAH, Purroh or Poro, a secret society of Sierra Leone, West Africa. Only males are admitted to its ranks while the Bundu is strictly reserved to women.

The Purrah had its special ritual and language, markings and symbols and exercised authority by the imposition of tabus which were enforced by various methods. In 1897 the British local government was compelled to pass a special ordinance absolutely forbidding the imposition of the tabu on all indigenous products.

See T. J. Alldridge, *The Sherbro and its Hinterland* (1901); N. W. Thomas, *Anthropological Report on Sierra Leone,* Part I. (*Law and Custom of the Timne and other tribes*).

PURSH, FREDERICK (1774–1820), American botanist, was born at Tobolsk, Siberia, in 1774. He received his education in Dresden, Germany. In 1799 he went to the United States where he devoted 12 years to botanical exploration and the scientific study of North American plants. In 1811 he visited England and in 1814 he brought out in London his important *Flora Americae Septentrionalis.* He then returned to the U.S. and resumed his botanical investigations. On one of his solitary tours afoot he discovered the hart's-tongue (*q.v.*), one of the rarest of the ferns in North America. He died at Montreal, Can., June 11, 1820.

PURSLANE, the common name for a small fleshy annual with prostrate stems, entire leaves and small yellow flowers, known botanically as *Portulaca oleracea* (family Portulacaceae). It is a native of India, which was introduced into Europe as a salad plant, and in some countries has spread so as to become a noxious weed; it is found in England but is rare. In certain parts of the United States the evil qualities of "pussly" have become proverbial. The persistence of purslane plants is due to their ability to retain moisture and thus blossom and ripen seeds long after they have been removed from the soil. The capsules opening by a lid produce many small seeds of great longevity. Besides the common purslane, some 10 other species occur in North America, chiefly in the southern United States. Some of the species of the same genus, such as *P. grandiflora* and its varieties, are grown in gardens on rockwork.

PURSUIVANT, a member of the third and lowest rank of heraldic officers, formerly an attendant on the heralds.

PURVEYANCE was a prerogative of purchasing goods for the royal household, enjoyed by all English kings up to Charles II. Certain officers attached to the king's court were charged with the duties of buying and arranging for the cartage of goods where necessary, the ancient prerogative of the King entitling him to demand carriage services from his subjects. The possibilities of abuse were obvious. Magna Carta (*q.v.*) ordered that goods should be paid for at once, and that horses and carts should not be taken for carriage duty, nor timber taken for castles without the consent of the owner. These stringent regulations were considerably modified to the King's advantage in later issues of the charter.

Many early statutes were passed against purveyance. People particularly resented the exercise of this right by royal officials and ministers for their own benefit. Statutes therefore limited its use to the immediate households of the king and queen. The name purveyor was so much hated that it was provided by statute that it should be changed to *achatour* (buyer). But statutes had little effect. In Elizabeth's reign complaints against purveyance were particularly bitter. In her early years the queen seems to have made use of her rights of purveyance to victual her navy. Later an arrangement was made by which some, if not all, counties agreed to furnish definite provisions at a fixed rate in order to get rid of the uncertainty which made the burden so much heavier. These compositions were arranged between the officers of the Board of Green Cloth and the Justices of Peace for each county at fixed prices. These fixed prices were very much lower than the market value of the goods and the difference was met by an assessment on the county. Cattle supplied in this way were kept in certain royal pastures. The parliaments of James I. determined to get rid of the abuses of purveyance, and Sir Francis Bacon made a famous speech against the purveyors in the first parliament of the reign. It was held that only the abolition of the right would put an end to its abuse. The purveyors made a practice of demanding far more goods than were necessary and sold the surplus for their own advantage. They ordered goods to be taken to remote places that people might buy from them exemption from coming with their portions. There were innumerable ways in which purveyors could make dishonest profit. Despite complaints, the right of purveyance went on until it fell into disuse during the Commonwealth. Its abolition was part of the Restora-

tion Settlement, though till the end of the century it was sometimes partially revived during royal progresses. (D. M. S.)

PURVĪTIS, VILHELMS KĀRLIS (1872–1945), Latvian landscape painter, was born in Zaube rural district, Latvia, on March 3, 1872, and attended a secondary school in Latgale province. He later abandoned his father's milling business for painting, graduating from St. Petersburg academy in 1897; awarded a Rome prize, he travelled widely in western Europe. After teaching at Tallinn cathedral school (1906–09) he directed the Riga state art school until it was closed in 1916; from 1913, when he was elected academician of St. Petersburg academy, he was also director of the state museum and professor at Riga university. He organized the independent Latvian Academy of Arts in 1919 and was its rector and professor until 1934. In 1934–36 he edited a history of art. Purvītis introduced Impressionism into northeastern Europe, developing from it the Baltic landscape style; later, his methodical compositions became more colourful and expressionistic. Many of his pictures were destroyed by military action at Jelgava, Latvia, in July 1944; others, evacuated to Bavaria, disappeared. A refugee, Purvītis died at Nauheim, Hesse, Ger., on Jan. 18, 1945.

PUSA, a village of British India, in Darbhanga district, Bihar province, near the right bank of the Burh Gandak river; and 6 mi. from the Pusa Road station on the Bengal and North-Western railway. The Government acquired an estate here in 1796, long used as a stud depot and afterwards as a tobacco farm. The estate, which covers 1,280 ac. was made over in 1904 to the Imperial Agricultural Department (of the Government of India), of which it is the headquarters. The Research Institute here comprises, in addition to a farm, an agricultural college, at which officers are trained for the higher posts in the Agricultural Department, and a research laboratory bearing the name of Mr. Phipps, an American gentleman, who contributed £30,000 towards its cost. The institute, which owed its inception to Lord Curzon, has, within the comparatively short period of its existence, done magnificent service to Indian agriculture by producing improved varieties of crops. In particular, it has achieved remarkable success by evolving strains of wheat which give a high yield, have powers of resistance to rust, are able to mature with less water than the generality of Indian wheats, and give good results under diverse conditions of soil and climate. The Pusa varieties are now grown on over 1½ million acres of the United Provinces, the Punjab and the North-Western Frontier province. The institute has also produced a heavy-yielding variety of bearded wheat suitable for areas where the crop is liable to damage by birds. The institute has introduced berseem, or Egyptian clover. It has been proved that a small irrigated area of poor land, in which berseem is followed by early maize, can provide a large herd with all the bulky green food it requires—a discovery of immense importance in a country depending so largely on cattle, where the pasture lands are for a large part of the year parched and bare. Further, valuable results have been obtained by selective breeding of cattle, *e.g.*, by doubling the milk yield of a pure herd in ten years. In order to improve both the quality and quantity of sugar production, a Sugar Bureau has been established, which gives advice to cultivators, manufacturers, etc. The institute studies soil improvement and the use of phosphates found in India.

PUSEY, EDWARD BOUVERIE (1800–1882), English divine, was born at Pusey near Oxford on Aug. 22, 1800, the son of Philip Bouverie, who took the name of Pusey on succeeding to the manor of that name. Edward Pusey was educated at Eton and at Christ Church, Oxford, and became a fellow of Oriel in 1824. He thus became a member of a society which included J. H. Newman and John Keble. Between 1825 and 1827 he studied Oriental languages and German theology at Göttingen. In 1828 the duke of Wellington appointed him to the regius professorship of Hebrew with the canonry of Christ Church.

By the end of 1833 he showed a disposition to make common cause with those who had already begun to issue the *Tracts for the Times.* "He was not, however, fully associated in the movement till 1835 and 1836, when he published his tract on baptism and started the Library of the Fathers" (Newman's *Apologia,* p. 136). He became a close student of the fathers and of that school of Anglican divines who had continued, or revived, in the 17th century the main traditions of pre-Reformation teaching. A sermon which he preached before the university in 1843, *The Holy Eucharist, a Comfort to the Penitent,* so startled the authorities that he was suspended for two years from preaching. The effect of his suspension was the sale of 18,000 copies of the condemned sermon and Pusey at once became an influence in the Anglican Church.

The movement, in the actual origination of which he had had no share, came to bear his name: it was popularly known as Puseyism (sometimes as Newmania) and its adherents as Puseyites. His activity, both public and private, as leader of the movement was enormous. He was not only on the stage but also behind the scenes of every important controversy, whether theological or academical. In the Gorham controversy of 1850, in the question of Oxford reform in 1854, in the prosecution of some of the writers of *Essays and Reviews,* especially of Benjamin Jowett, in 1863, in the question as to the reform of the marriage laws from 1849 to the end of his life, in the Farrar controversy as to the meaning of everlasting punishment in 1877, he was always busy with articles, letters, treatises and sermons. Some of his sermons before the university marked distinct stages in the history of the High Church party which he led.

The revival of confession in the Church of England practically dates from his two sermons on *The Entire Absolution of the Penitent,* in 1846. The sermon on *The Presence of Christ in the Holy Eucharist,* in 1853, first formulated the doctrine round which almost all the subsequent theology of his followers revolved, and which revolutionized the practices of Anglican worship. Of his larger works the most important are: his two books on the Eucharist—*The Doctrine of the Real Presence* (1855) and *The Real Presence . . . the Doctrine of the English Church* (1857); *Daniel the Prophet* in which he endeavours to maintain the traditional date of that book; *The Minor Prophets, with Commentary,* his chief contribution to the study of which he was the professor; and the *Eirenicon,* in which he endeavoured to find a basis of union between the Church of England and the Church of Rome.

In private life Pusey's habits were simple almost to austerity. He had few personal friends, and rarely mingled in general society; though bitter to opponents, he was gentle to those who knew him, and his munificent charities gave him a warm place in the hearts of many to whom he was personally unknown. The deaths of his wife (1839) and of his only son (1880) saddened his life. He died on Sept. 16, 1882, and was buried at Oxford in the cathedral of which he had been for fifty-four years a canon. In his memory his friends purchased his library, and endowed for it a house in Oxford, known as Pusey House.

See B. W. Savile, *Dr. Pusey, an Historic Sketch, with Some Account of the Oxford Movement* (1883); the *Life* by Canon Liddon, completed by J. C. Johnston and R. J. Wilson (5 vols., 1893–99); Newman's *Apologia,* and other literature of the Oxford Movement.

Pusey's elder brother, PHILIP PUSEY (1799–1855), was a member of parliament and a friend and follower of Sir Robert Peel. He was one of the founders of the Royal Agricultural Society, and was chairman of the implement department of the great exhibition of 1851. He was a fellow of the Royal Society, a writer on varied topics for the reviews and the author of the hymn "Lord of our Life and God of our Salvation."

PUSHBALL, a game played by two sides on a field usually 140yds. long and 50yds. wide, with a ball 6ft. in diameter and 50lb. in weight. The sides usually number 11 each, there being five forwards, two left wings, two right wings and two goalkeepers. The goal consists of two upright posts 18ft. high and 20ft. apart with a crossbar 7ft. from the ground. The game lasts for two periods with an intermission. Pushing the ball under the bar counts five points; lifting or throwing it over the bar counts eight. A touch-down behind the goal for safety counts two to the attacking side. The game was invented by M. G. Crane of Newton, Massachusetts, in 1894, and was taken up at Harvard University the next year, but has never attained any considerable vogue. In Great Britain the first regular game was played at the Crystal Palace in 1902 by teams of eight. The English rules are somewhat

different from those obtaining in the United States. Pushball was one of the games frequently played by teams of military men at the training camps during the World War. It is usually considered one of the feature events at American circuses when played by teams of Indians and cowboys on horseback. It is also played by mounted organizations of the U.S. army at various military posts. Pushball on horseback was introduced in 1902 at Durland's riding academy in New York, and has been played in England at the Military Tournament.

PUSHKIN, ALEXANDER (1799–1837), Russian poet, was born at Moscow on June 6, 1799. He belonged to an ancient family of boyars; his maternal great-grandfather was an Abyssinian general in the Russian service, ennobled by Peter the Great. In 1811 the future poet entered the newly founded lyceum of Tsarkoe Selo, situated near St. Petersburg. On quitting the lyceum in 1817 he was attached to the ministry of foreign affairs, and in this year he began to write his *Ruslan and Ly'udmila,* a romantic epic in six cantos, which was completed in 1820. Meanwhile Pushkin mixed in all the gayest society of the capital, and it seemed as if he would turn out a mere man of fashion instead of a poet. But a very daring *Ode to Liberty* written by him and circulated in manuscript in St. Petersburg came to the notice of the governor, and the young author was exiled to the south of Russia where he held official positions at Ekaterinoslav and at Kishinev.

In company with General Rayevsky he visited the baths of the Caucasus for the re-establishment of his health in 1820. The Rayevskys introduced him to the poetry of Lord Byron, and the magnificent scenery of the Caucasus kindled his own poetic genius. The first fruit of the Caucasian visit was *The Captive of the Caucasus* (1822), narrating the story of the love of a Circassian girl for a Russian officer. This was followed by the *Fountain of Bakhchisarai* (1827) which tells of the detention of a young Polish captive in the palace of the khans of the Crimea. About the same time he composed the lines on Ovid, whose place of banishment, Tomi, was not far distant, and the *Ode to Napoleon.* The next long poem was the *Gipsies* (Tsygany) (1827). During his stay in southern Russia he mixed with the secret societies then rife throughout the country. In 1823 he was allowed to leave Kishinev, where the life was hateful to him, and was transferred to Odessa where he was once more on real Russian soil, and on the coast of the sea which delighted him. But he came into conflict with his official superior, and was dismissed from the service, because of an intercepted letter in which he spoke favourably of atheism. He was ordered to reside at Mikhailovskoe, near Pskov, where he soon involved himself in trouble on all sides. In his retirement he studied old Russian popular poetry. Recollections of Byron and André Chenier gave the inspiration to some fine lines consecrated to the latter, in which Pushkin appeared more conservative than was his wont. In 1825 he wrote his tragedy *Boris Godunov,* not published till 1831, a bold effort to imitate the style of Shakespeare, thus breaking with the French traditions.

In 1825 the conspiracy of the Dekabrists broke out. Many of the conspirators were personal friends of Pushkin, especially Küchelbecker and Pustchin. The poet himself was to a certain extent compromised, but he succeeded in getting to his house at Mikhailovskoe and burning all the papers which might have been prejudicial to him. The emperor, to whom he was presented at Moscow soon after his coronation, summoned him to Moscow and assured him of pardon and "protection." The story goes that Nicholas said to Count Bludov on the same evening, "I have just been conversing with the most intelligent man in Russia." In 1829 appeared *Poltava,* a spirited narrative poem, in which the expedition of Charles XII. against Peter and the treachery of the hetman Mazeppa were described. In 1829 Pushkin again visited the Caucasus on this occasion accompanying the expedition of General Paskevich, which is described in *A Voyage to Arzrum* (pr. 1836). The lyrics are delightful. In 1831 Pushkin married Natalia Goncharov, and in the following year was again attached to the ministry of foreign affairs, with a salary of 5,000 roubles. He now began his *History of the Revolt of Pugachev of 1773* (pr. 1834) an admirable piece of historical writing. While engaged upon this he wrote *The Captain's Daughter* (1836), one of the best of his prose works. In 1832 was completed the poem *Evgeni Onegin* (1825–33), again influenced by Byron.

In 1837 the poet, who had been long growing in literary reputation, fell mortally wounded in a duel (Feb. 8) with Baron George Heckeren d'Anthès, the adopted son of the Dutch minister who had married a sister of the poet's wife. Pushkin died on Feb. 10. D'Anthès was tried by court-martial and expelled from the country. In 1880 a statue of the poet was erected at the Tver Barrier at Moscow. He left four children; his widow married an officer named Lanskoi; she died in 1863.

Pushkin's poetical tales are full of drama. *Boris Godunov* and *Evgeni Onegin* are the basis of operas by Mussorgsky and Tschaikowsky respectively. Pushkin's lyrical pieces are the finest in the language. Interspersed among his minor works will be found many epigrams. He was one of the earliest Russian novelists. Indeed most of his work after 1831 was done in prose. In 1831 he published a small volume of tales under the pen name of Ivan Belkin. These all show great narrative powers. The one long novel finished is *The Captain's Daughter,* a tale of the times of Catherine II., which exercised a great influence on later Russian novelists. The most famous of all his short stories is *The Queen of Spades* (1834). In the *History of the Manor of Goryukhino* (1857), Pushkin parodied Polevoy's *History of the Russian People,* and presented an amusing picture of the fictitious author of his own Tales, Ivan Petrovich Belkin.

See Prince D. S. Mirsky, *Pushkin* (1926), which contains a bibliography; and the bibliography in the editions of Gennadi (7 vols., St. Petersburg, 1861), and Annenkov (6 vols. St. Petersburg, 1855).

PUSHTU, PAKHSTO, PAKKHTO (Pashto), the language of the Afghans, belongs to the Eastern Iranian group, the oldest form of which is probably found in the Zend. Numerous terms are traceable to the Avesta. (*See* Paul Horn's *Grundriss der Neupersischen Etymologie*). The remainder of its vocabulary comes from Arabic, Persian and from the Indian Prakrits. Among the last, Sindhi takes first place. It has thus considerable claims to antiquity.

About 10% of the Afghans are able to read and write, and education is making rapid progress.

Structure.—There are nine declensions. The accusative is the same as the nominative. The agent and oblique forms are identical. The genitive, dative and locative are formed by adding suffixes to the oblique form. Most adjectives form the feminine by adding *a.* Pronominal suffixes are used as well as definite, personal, demonstrative and reflexive pronouns. The regular verb has two main tenses, the imperfect and the present. There are 37 classes of verbs, 13 intransitive and 24 transitive.

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PUT AND CALL: *see* Options.

PUTEOLI, an ancient town of Campania (mod. *Pozzuoli, q.v.*), Italy, on the northern shore of the Bay of Puteoli, a portion of the Bay of Naples, from which it is 6 m. W. The city was probably founded under the name of Dicaearchia by a colony of Samians from Cumae about 520 B.C., before which Misenum was the original port. In 215 the Romans introduced a garrison of 6,000 men and Hannibal besieged it in vain in 214. In 194 a Roman colony of 300 men was established. Puteoli belonged to the tribus Palatina, thus breaking the rule (the only other exception is Turris Libisonis [*q.v.*] which belonged to the Colluia) that *municipia* and *coloniae* were not enrolled in the four urban tribes. The *lex parieti faciundo,* 105 B.C., relating to building works in front of the temple of Serapis, shows that Puteoli had considerable administrative independence. Sulla retired to Puteoli after his resignation of the dictatorship in 79. Cicero had a house in Puteoli itself, and a villa on the edge of the Lucrine lake (*q.v.*), and many other prominent men of the republic possessed country houses near by. (*See* Baiae; Avernus; Lucrinus Lacus; and Misenum.) In A.D. 61 St. Paul landed here, and spent seven days before leaving for Rome (Acts xxviii. 13). Vespasian gave the town part of the territory of Capua, and installed more colonists

—whence it took the title Colonia Flavia.

The remains of Hadrian, who died at the neighbouring town of Baiae, were at first deposited at Puteoli, and Antoninus Pius erected a temple to his memory on the site of Cicero's villa. It was mainly, however, as a great commercial port that Puteoli was famous in ancient times. It exported iron from Elba, mosaics, pottery, perfumes, pozzolana earth (taking its name from the place), glass cups engraved with views of Puteoli, mineral dyes, etc., but its imports were considerably greater. During the Punic Wars it was a naval port, but in the latter part of the 2nd century B.C. it became the greatest commercial harbour of Italy and we find Lucilius about 125 B.C. placing it next in importance to Delos, then the greatest harbour of the ancient world.

The corn supply of Rome came partly through Puteoli, partly through Ostia. Seneca (*Epist.* 77) describes the joy of the inhabitants in the spring when the fleet of corn vessels from Alexandria was seen approaching, and Statius tells us that the crew of the ship which arrived first made libations to Minerva when passing the promontory which bore her name (the Punta Campanella at Sorrento).

Claudius established here, as at Ostia, a cohort of *vigiles* as a fire-brigade. Brundisium was similarly protected. There was also a station of the imperial post, sailors of the imperial fleet at Misenum being apparently employed as couriers. The artificial mole was probably of earlier date than the reign of Augustus; and by that time at any rate there were docks large enough to contain the vessels employed in bringing the obelisks from Egypt. Alaric (410), Genseric (455) and Totila (545) devastated Puteoli.

The original town of Puteoli stood on the narrow hill of the Castello. The streets of the old town preserve the ancient alinement. There are also traces of the division of lands near the town into squares by parallel paths (*decumani* and *cardines*) at regular intervals of 1,111⅓ Roman feet, postulating as the basis of the division a square with a side of 10,000 Roman feet, divided into 81 smaller squares. The market hall (*macellum*), generally known as the temple of Serapis, from a statue of that deity found there, was excavated in 1750. In the centre of the ancient city was a round colonnade with sixteen columns of Numidian marble (*giallo antico*) now in the theatre of the palace at Caserta. In the amphitheatre there were exceedingly interesting arrangements for flooding the arena, but these can only have been in use before the construction of the greater part of the subterranean portion with its cages, etc. The whole amphitheatre is 489×381 ft.; the arena 245×138 ft. Inscriptions record that it was built by the *Colonia Flavia, i.e.*, not before Vespasian. In the older amphitheatre (426×312 feet), which was found in excavations for the new railway to Naples, Nero fought in games given in honour of Tiridates, king of Armenia. Remains of thermae also exist in various places. The cathedral of S. Proculus (containing the tomb of the musician Pergolesi, d. 1736) is built into a temple of Augustus, 6 columns of which, with their Corinthian capitals, still exist. Other ruins—of a circus, of tombs, villas, etc., exist.

Puteoli was supplied with water by two aqueducts, both subterranean, one of which, bringing water from springs in the immediate neighbourhood, is still in constant use. Puteoli was reached direct by a road from Capua traversing the hills to the north by a cutting (the Montagna Spaccata), which went on to Neapolis, and by the Via Domitiana from Rome and Cumae. There was also a short cut from Puteoli to Neapolis by the tunnel of Pausilipon, made under Augustus. In 305, S. Januaris (S. Gennaro, the patron saint of Naples), bishop of Beneventum, S. Proculus, patron of Puteoli, and others, were martyrs at Puteoli.

See the study of C. Dubois, *Pouzzoles antique* (Paris, 1907) (Bibliothèque des écoles françaises d'Athènes et de Rome, fasc. 98). (T. A.)

PUTNAM, GEORGE HAVEN (1844–1930), dean of American publishers, at eighty-five (1929) the active head of one of the oldest publishing houses in the country, the house that gave to American literature such names as Washington Irving and Fenimore Cooper; with sixty-five years of publishing experience behind him, he had time to win honors as a soldier, a writer, and a man of public affairs.

This sterling American citizen, whose forefathers fought for George Washington, and who himself languished in Libby prison, upholding the Union cause, was born in England on April 2, 1844. His father, George Palmer Putnam, had founded the American publishing concern in 1837, and after that date had found it important for his publishing business to make annual trips to England. In 1841, he brought into organization the London publishing house, being the first American publisher to invade England. He was a resident of England for seven years, and it was in this way that his son came to be born in London.

It was not until 1848, that young George Haven Putnam was brought to America. Among his early memories are such outstanding figures as Washington Irving, Charles Dickens, Thackeray, Louis XVII. ("Eleazar Williams"), and Lincoln.

The major's father was a member of the Committee that invited Lincoln to New York in 1860, and the younger Putnam sat on the platform during the delivery of the Cooper Union address. After the address, he was introduced by Bryant to Lincoln.

His boyhood education was completed at Columbia grammar school, followed by studies abroad at the Sorbonne and the University of Göttingen, studies which were cut short by the beginning of the Civil War. Mr. Putnam hastened home from Europe in 1862 to enlist in the Union Army. He was taken prisoner at Cedar Creek, and sent to Libby Prison and later to Danville.

Major Putnam's outstanding contribution to publishing history was his championship of international copyright, which resulted, in 1891, in the present copyright relations between the United States and Europe. He died in New York city on Feb. 27, 1930.

PUTNAM, HERBERT (1861–), American librarian, was born in New York city on Sept. 20, 1861. He graduated from Harvard college in 1883 and thereafter studied law at Columbia university, being admitted to the bar in 1886. His calling, however, proved to be that of librarian. He was librarian of the Minneapolis Athenaeum in 1884–87, of the Minneapolis Public library in 1887–91 and, after a few years spent in the practice of law, of the Boston Public library in 1895–99. Thence he was called in 1899 to the librarianship of the Library of Congress, in Washington. He was president of the American Library association in 1898 and 1904 and wrote on library science.

PUTNAM, ISRAEL (1718–1790), American soldier, was born in Salem Village (now Danvers), Mass. on Jan. 7, 1718, and in 1740 removed to a farm in the vicinity of Pomfret, Conn. He was active in the French and Indian War, rising to the rank of major in 1758. News of the fighting at Lexington and Concord reached him while he was ploughing on his farm; he instantly left the plough in the furrow and hastened to Cambridge; and he was later made second brigadier of the Connecticut forces. He was with the force, commanded by Col. William Prescott, which on the night of June 16, 1775, fortified Breed's Hill, and on the next day he took a conspicuous part in resisting the British attack (*see* BUNKER HILL). After the evacuation of Boston he was in command of New York city till Washington's arrival (April 13, 1776), and then was put in general charge of the city's fortifications. Immediately before the battle of Long Island he succeeded Gen. John Sullivan in command of the troops on Brooklyn Heights, and in the battle of Long Island (of Aug. 27) he was in immediate command of the American side. In the retreat from New York city he took part in the battle of Harlem Heights (Sept. 16). In May, 1777, he took command of the Hudson highlands at Peekskill, which with Forts Montgomery and Clinton he abandoned in October, being out-manoeuvred by the British. After a few months' recruiting service in Connecticut he returned to the main army at White Plains. In the winter of 1778–79 he commanded the troops quartered near Redding, Conn. In May, 1779, he took command of the right wing on the west side of the Hudson. An attack of paralysis in Dec. 1779 terminated his active service in the war. He spent his last years on his farm in Brooklyn, Conn., where he died May 29, 1790. A bronze equestrian statue by Karl Gerhardt, over a sarcophagus, was erected at Brooklyn, Conn., by the State in 1888, and there is another statue (1874) in Bushnell park, Hartford, by J. Q. A. Ward.

Putnam was a brave, intrepid and very industrious soldier rather than a great general. His bluff heartiness has made him

one of the popular heroes in American history.

See W. F. Livingston, *Israel Putnam, Pioneer, Ranger and Major-General* (1901) in the "American Men of Energy" series; I. N. Tarbox, *Life of Israel Putnam* (Boston, 1876); and *Essay on the Life of the Honorable Major-General Israel Putnam* (Hartford, 1788; enlarged ed., Boston, 1818), by David Humphreys, for a time Putnam's aide-de-camp.

PUTNAM, RUFUS (1738–1824), American soldier and pioneer, was born in Sutton, Mass., on April 9, 1738 (O.S.). He served in the French and Indian War in 1757–60; was a millwright in New Braintree in 1761–68, during which time he studied surveying; and from 1769 until the American Revolution was a farmer and surveyor. He became lieutenant colonel in one of the first regiments raised after the battle of Lexington, and served before Boston. In 1777 he served in the Northern army under Gen. Horatio Gates, commanding two regiments in the second battle of Saratoga. In 1778 he laid out fortifications, including Ft. Putnam, at West Point, and in 1779 he served under Gen. Anthony Wayne after the capture of Stony Point. After the war he returned to Rutland, Mass., where he had bought a confiscated farm in 1780. In March, 1786, he founded, with other officers of the American Revolution, the Ohio Company of Associates for the purchase and settlement of Western lands. In Nov. 1787, he was appointed by the company superintendent of its proposed settlement on the Ohio, and in 1788 he led the small party which founded Marietta, Ohio. He was a brigadier-general in the army and a commissioner to treat with the Indians in 1792–93; was surveyor general of the United States in 1796–1803; and in 1802 was a member of the Ohio State Constitutional convention. He died, in Marietta, May 4, 1824. He has been called "the father of Ohio," and greatly contributed to its development.

BIBLIOGRAPHY.—John W. Campbell, *Biographical Sketches* (1838); Sidney Crawford, "Rufus Putnam, and his Pioneer Life in the North-West," vol. xii, new series, pp. 431–454, *Proceedings of the American Antiquarian Society* (1899), and Rowena Buell (ed.), *The Memoirs of Rufus Putnam* (1903), in which his autobiography, journal and other papers, in the library of Marietta college, are reprinted. His *Journal, 1757–1760,* dealing with his experiences in the French and Indian War, was edited with notes by E. C. Dawes (1886).

PUTNAM, a city of northeastern Connecticut, U.S., on the Quinebaug river, at the mouth of the Little river; the county seat of Windham county. It is served by the New York, New Haven and Hartford railroad. Pop. (1950) 8,165; (1940) 7,775. It manufactures cotton, woollen and silk goods, steam heaters and castings, phonograph needles, optical products, steel bars and pointed steel goods. Putnam was formed in 1855 and named after Gen. Israel Putnam. The city was chartered in 1895.

PUTNIK, RADOMIR (1847–1917), Serbian general, was born on Jan. 25, 1847, at Kraguyevats. After serving against Turkey in 1876 and 1877, and against Bulgaria in 1889, he was made deputy-chief of the general staff, and professor at the military academy in Belgrade. The intrigues and favouritism introduced by the kings, Milan and Alexander, caused him to be placed on the retired list, but in the autumn following the military revolution of 1903 he was appointed general and chief of the general staff. In 1906 he succeeded General Gruič as minister of war, and again held that office in 1912, during the period when the military convention with Bulgaria was negotiated.

On the outbreak of war with Turkey Putnik was made *voivode* or marshal (being the first holder of that title) and commander-in-chief, and was responsible for the rapid success of the Serbian arms at Kumanovo, Prilep and Monastir. It was largely owing to his vigilance and foresight that the treacherous night attack by which the Bulgarians opened the second Balkan War (June 29, 1913) failed as it did. When the World War broke out, he was undergoing a cure at an Austrian watering place, and was at first placed under arrest, being later released by special order of the emperor Francis Joseph and conveyed to the Rumanian frontier. Despite impaired health he resumed the position of Serbian generalissimo and inflicted upon the forces of General Potiorek three successive defeats—on the Yadar (Aug. 16–20), the Drina (Sept. 8–19) and at Rudnik, which ended on Dec. 14, 1914 with an Austrian rout and the complete evacuation of Serbia. Putnik retained the supreme command during the triple invasion of Serbia in Nov. 1915, and shared the retreat of the Serbs through Albania. When, however, the exiled Government established itself at Corfu, he and most of his staff were placed on the retired list. He himself withdrew to France. He died on May 17, 1917, at Nice.

PUTTEE or **PUTTIE.** The name adapted from the Hindu *patti,* bandage (Skr. *patta,* strip of cloth), for a covering from the ankle to the knee, consisting of a long narrow piece of cloth wound spirally, and fastened by a tape, though straps may be used. For infantrymen, the winding commences at the ankle, but mounted men reverse the process as the rubbing against the horse causes the tape to come undone. Their advantages over leggings are that they are not "hard" on the legs, can be used as bandages or slings in case of need, and occupy less space when not in wear. Worn by most armies except the German in 1918, they have gradually disappeared in favour of short leggings.

PUTTENHAM, GEORGE (d. 1590), the reputed author of *The Arte of English Poesie* (1589). The book was entered at Stationers' Hall in 1588, and published in the following year. The writer of *The Arte of English Poesie* was educated at Oxford, and at the age of 18 he addressed on eclogue entitled *Elpine* to Edward VI. In his youth he had visited Spain, France and Italy, and was better acquainted with foreign courts than with his own. In 1579 he presented to Queen Elizabeth his *Partheniades* (printed in a collection of ms. *Ballads* by F. J. Furnivall), and he wrote the treatise in question especially for the delectation of the queen and her ladies. He mentions nine other works of his, none of which are extant. There is no direct evidence beyond Bolton's ascription to identify the author with George or Richard Puttenham, the sons of Robert Puttenham and his wife Margaret, the sister of Sir Thomas Elyot, who dedicated his treatise on the *Education or Bringing up of Children* to her for the benefit of her sons.

Many later "poetics" are indebted to this book. The original edition is very rare. Professor Edward Arber's reprint (1869) contains a clear summary of the various documents with regard to the authorship of this treatise. The history of the Puttenhams is discussed in H. H. S. Croft's edition of Elyot's *Boke called the Governour.* There are other modern editions of the book, notably one in J. Haslewood's *Ancient Critical Essays* (1811–15).

PUTTING THE SHOT is the modern form of the ancient sport of putting the stone. First to use a shot instead of a stone competitively were British military sports groups, and later the idea was adopted by civilians.

While the weight varied from 14 lb. to 42 lb., the 16-lb. shot was the one adopted for men in Olympic games, national and international competitions. Weight for women's competition is 8 lb. In the United States a 12-lb. shot is used for high school boys' competition, ages 15–19.

Shot-putting is one of the few events in which a tremendous increase in distance was achieved by improved technique and not by improved equipment. Unlike the hammer-throwing record, which was raised by Irishmen, the upward move of the shot-put record from 30 ft. 11½ in. in 1876 to 58 ft. 10½ in. in 1950 can be attributed to a cosmopolitan group, including representatives of England, Ireland, Germany, Czechoslovakia, Poland and the United States.

The most remarkable individual improvement was that of Jack Torrance of Louisiana State university, U.S. Starting with a best distance of only 41 ft. 5 in. in 1931, he did 47 ft. 3 in. (1932); 52 ft. 10 in. (1933); and in 1934 moved the world's record to 57 ft. 1 in.—an improvement of almost 16 ft. in four years. The greatest individual achievement was by James E. Fuchs (Yale university and New York Athletic club, U.S.), who did not put the 16-lb. shot before entering Yale. In 1947 Fuchs did 49 ft. 8½ in.; 54 ft. 8⅜ in. (1948); 58 ft. 4⅜ in. (1949); and 58 ft. 10½ in. (1950). From July 28, 1949, to June 4, 1952, Fuchs put the shot 58 ft. or more 12 times outdoors and once indoors. Within six days, in 1950, he achieved distances of 58 ft. or more eight times, climaxing this series with a world's record of 58 ft. 10½ in., at Eskilstuna, Swed., Aug. 22.

The two best winning performances in Olympic games competition through the 1952 games were by Americans—56 ft. 2 in. by Wilbur M. Thompson (1948), and 57 ft. 1½ in. by Parry

O'Brien (1952), both using the Thompson technique.

According to Thompson, the principle involved in putting the spherical, solid iron or brass missile from the shoulder with one hand is acceleration—a gradual speeding up, in a straight line, of the movement across the seven-foot circle with the minimum amount of effort.

The put is started at the back of the circle by shifting the weight of the body to the right foot with good balance, left knee bent and the left toes raised so that the spikes clear the ground. Next, the left knee is brought close to the right knee and the right leg bent gradually as the hips cross the circle. This method of starting the put enables the shot-putter to be in a correct position when he reaches the centre of the circle and thus able to start lifting the shot immediately. The shot is lifted via the medium of the leg muscles, and the put must always be made upward and not outward, by a rhythmic movement of the arm muscles, which can be acquired by constant repetition.

See Frank G. Menke, *New Encyclopedia of Sports* (1947).

(H. Ar. Rn.)

PUTTKAMER, ROBERT VON (1828–1900), Prussian statesman, was born at Frankfurt-on-Oder on May 5, 1828. Puttkamer was the chosen instrument of the clerical conservative policy initiated by Bismarck when the growth of the Socialist movement made it expedient to conciliate the Catholic centre. As *Oberpräsident* of Silesia he had mitigated the rigour of the application of the "May laws," and as minister of public worship and of the interior he continued this policy. He was also the author of the ordinance of Jan. 2, 1880, on the simplification of German orthography.

As minister of the interior, Puttkamer's temper was in harmony with the view of Bismarck and the emperor William, and with their support he tried to re-establish the old Prussian system of rigid discipline from above.

On his initiative, on Jan. 4, 1882, a royal ordinance required all officials to give the government their unconditional support at political elections. He also interfered with the liberty of public meetings and attempted to suppress strike movements by force. This "Puttkamer regime" was intensely unpopular, and when the emperor Frederick III succeeded to the throne Puttkamer was forced to resign (June 8, 1888). He was largely rehabilitated under William.

Puttkamer died at Karzin, in Pomerania, on March 15, 1900.

PUTTY. Originally tin oxide in a state of fine division used for polishing glass, granite, etc., now known as "putty powder" or "polisher's putty." The term is applied to cement composed of fine powdered chalk (whiting) or oxide of lead (white lead) mixed with linseed oil, either boiled or raw. It is used for fixing sheets of glass in frames and for filling up nail holes, etc., in woodwork. The oxidation of the oil hardens the putty and when it is required to dry quickly, boiled oil and sometimes litharge and other driers are used. Putty is also a fine lime cement employed by masons.

PUVIS DE CHAVANNES, PIERRE CÉCILE (1824–1898), French painter, was born at Lyons on Dec. 14, 1824. His father was a mining engineer, the descendant of an old family of Burgundy. Pierre Puvis was educated at the Lyons college and at the Lycée Henri IV in Paris, and was intended to follow his father's profession when a serious illness interrupted his studies. A journey to Italy opened his mind to fresh ideas, and on his return to France he went to study painting first under Henri Scheffer and then under Thomas Couture. In 1852 he established himself in a studio in the Place Pigalle (which he did not give up till 1897), and there organized a sort of academy for a group of fellow students who wished to work from the living model. Puvis first exhibited in the Salon of 1850 a "Pietà." In 1852 and in the following years Puvis's pictures were rejected by the Salon, but the young painter was none the less warmly defended by Théophile Gautier and Théodore de Banville. His compositions at this early period show great variety, reflecting the influence of the Italian masters as well as of Delacroix and Couture. In 1859 Puvis reappeared in the Salon with the "Return from Hunting" (now in the Marseilles gallery). But not till he produced "Peace" and "War" did he really impress his critics, inaugurating a vast series of decorative paintings. For these two works a second-class medal was awarded to him. In 1864 he exhibited "Autumn" and "Sleep." One of these pictures is in the Lyons museum and the other at Lille. "Peace" and "War" were placed in the great gallery of the museum at Amiens, where Puvis completed their effect by painting four panels—a "Standard-Bearer," "Woman Weeping over the Ruins of her Home," a "Reaper" and a "Woman Spinning." Further decorations were ordered for the same building, and the artist presented to the city of Amiens "Labour" and "Repose." In 1865 a composition entitled "Ave Picardia Nutrix," allegorical of the fertility of the province, was added to the collection. In 1879 the city wished to complete the decoration of the building, and the painter executed the cartoon of "Ludus pro patria," exhibited in the Salon of 1881 and purchased by the state, which at the same time gave him a commission for the finished work. Meanwhile Puvis de Chavannes also painted easel pictures. To the Salon of 1870 he had sent a picture called "Harvest"; the "Beheading of John the Baptist" figured in the Great Exhibition of 1889; then followed "Hope" (1872), the "Family of Fisher-Folk" (1875) and "Women on the Seashore" (1879). Two paintings in the Palais Longchamp at Marseilles, ordered in 1867, represent "Marseilles as a Greek Colony" and "Marseilles, the Emporium of the East." After these, Puvis executed for the town hall of Poitiers two decorative paintings of historical subjects: "Radegund" and "Charles Martel." The Panthéon in Paris also possesses a decorative work of great interest by this painter, "The Life of Saint Geneviève," treated in three panels. In 1876 the department of fine arts in Paris gave the artist a commission to paint "Saint Geneviève Giving Food to Paris" and "Saint Geneviève Watching Over Sleeping Paris," in which he gave to the saint the features of Princess Cantacuzene, his wife. At the time of his death—on Oct. 24, 1898—the work was almost finished. After completing the first paintings in the Panthéon, which occupied him for three years and eight months, Puvis de Chavannes undertook to paint the staircase leading to the gallery of fine arts in the Lyons museum and took for his subjects the "Vision of the Antique," a procession of youths on horseback, which a female figure standing on a knoll points out to Pheidias; the "Sacred Grove"; and two allegorical figures of "The Rhône" and "The Saône." It was in the same mood of inspiration by the antique that he painted the hemicycle at the Sorbonne, an allegory of "Science, Art, and Letters." At the Hôtel de Ville in Paris, Puvis decorated the grand staircase and the first reception room. These works occupied him from 1889 till 1893. In the reception room he painted two panels, "Winter" and "Summer." The pictures in the Rouen museum (1890–1892) show the artist's power of conceiving a scheme to decorate a public building with beautiful human figures and the lines of landscape. Puvis, as a rule, adhered to the presentment of the nude; here, however, in response to some critical remarks, he has clad his figures in modern dress. After prolonged negotiations, begun as early as in 1891, with the trustees of the Boston library, U.S., Puvis de Chavannes accepted a commission to paint nine large panels for that building. These pictures, begun in 1895, were finished in 1898. In these works of his latest period Puvis de Chavannes soars boldly above realism.

Puvis de Chavannes was president of the National Society of Fine Arts (the New Salon). His principal pupils were Ary Renan, Paul Baudouin, J. F. Auburtin and Cottet.

See Marius Vachon, *Puvis de Chavannes* (1900); J. Buisson, "Puvis de Chavannes, Souvenirs Intimes," *Gazette des beaux-arts* (1899); L. Riotor, *Les Arts et les Lettres* (1901); A. Michel, *Puvis de Chavannes* (London, 1912). (H. Fr.; X.)

PUY, a geological term used locally in Auvergne for a volcanic hill. Most of the puys of central France are small cinder cones, with or without associated lava, while others are domes of trachytic rock, like the domite of the Puy-de-Dôme. The puys may be scattered as isolated hills, or, as is more usual, clustered together, sometimes in lines. They probably became extinct in late prehistoric time. Puys are also found in the Eifel, on the Bay of

Naples, in the Swabian Alps of Württemberg, and, as Sir A. Geikie has shown, in Scotland.

PUYALLUP, a city of Washington, U.S. It is served by the Chicago, Milwaukee, St. Paul and Pacific, the Great Northern, the Northern Pacific and the Union Pacific railways. Pop. (1950) 10,010; (1940) 7,880 by the federal census. It is famous for its berries and bulbs, and has three large fruit-canning and cooling plants. Primary crops of the Puyallup valley include raspberries, blackberries, blueberries, narcissus, daffodil and tulip bulbs, vegetables, dairy and poultry products. The western Washington agricultural experiment station of the state college is located there. Puyallup was platted on Feb. 18, 1877, by Ezra Meeker. The city was incorporated as Puyallup, which means "generous people" in Indian language, in 1890 with Meeker as mayor.

PUY-DE-DÔME, a department of central France, four-fifths of which belonged to Basse-Auvergne, one-sixth to Bourbonnais, and the remainder to Forez (Lyonnais). Area, 3,095 sq.mi. Pop. (1946), 478,876. It is bounded north by Allier, east by Loire, south by Haute-Loire and Cantal, and west by Corrèze and Creuse. The famous plain of the Limagne, watered by the Allier and its tributary, the Dore, has on its western flank the volcanic Puys and Monts Dore, while on its eastern side rises the largely granitic heights of the Forez (5,380 ft.). The Puys include a number of craters, now dead and often filled by lakes, which also occur behind lava dams in the valleys. The Puy de Sancy (6,188 ft.) is the highest crater, but the Puy de Dôme (4,806 ft.) gives its name to the department and has a meteorological observatory on its summit, once crowned by a Roman temple, the ruins of which still exist.

The climate of Puy-de-Dôme is usually very severe, owing to its high level and its distance from the sea; the mildest air is found in the northern valleys, where the elevation is least. During summer the hills about Clermont-Ferrand, exposed to the sun, become all the hotter because their black volcanic soil absorbs its rays. On the average 25 or 26 in. of rain fall in the year; in the Limagne, around which the mountains arrest the clouds, rainfall is less. Nevertheless the soil of this plain, consisting of alluvial deposits of volcanic origin, and watered by torrents and streams from the mountains, makes it one of the richest regions of France. In the highest altitudes the rainfall attains 64 inches.

About two-thirds of the inhabitants of the Puy-de-Dôme are engaged in agriculture. The Limagne yields a variety of products and the vine flourishes on its hill-sides. The high mountains provide pasture for large flocks of cows and sheep, and cheese-making is an important industry. The intermediate region is cultivated mainly for cereals, the chief of which are wheat, rye, oats and barley. Potatoes are largely grown, and peas, beans, beetroot, colza and tobacco. The Limagne produces fruit of all kinds—apricots, cherries, pears, walnuts and apples, yielding considerable quantities of cider. The department possesses considerable mineral wealth. There are important coal-mines at Brassac on the Allier, on the borders of Haute-Loire, at St. Elroy near the department of Allier, and at Bourg-Lastic on the borders of Corrèze. Peat, asphalt, bituminous schists, antimony, mispickel and argentiferous lead are also worked. Of the last named there are mines and foundries at Pontgibaud on the Sioule. Amethysts and other rare minerals are found, and there are numerous stone-quarries. Mont Dore, Royat and La Bourboule are watering places. The springs of St. Nectaire contain sodium and iron chlorides and bicarbonates. The waters of Châteauneuf (on the Sioule), also known to the Romans, contain iron bicarbonates; those of Châtelguyon, like the waters of Carlsbad and Marienbad, are also widely known, and there are many other mineral springs of varied character. Manufactures are grouped around Thiers, which produces a large amount of cheap cutlery, and Clermont-Ferrand, the capital. The textile industry includes wool-carding and making of linen cloths, bunting, clothing, manufactories for lace and for rubber (Clermont-Ferrand), sugar-works, manufactures of edible pastes and of fruit-preserves. The department exports grain, fruits, cattle, wines, cheese, wood, mineral waters, cutlery, etc. It is served by the Orléans and P.L.M. railway companies. Many thousands of the inhabitants, chiefly of the district of Ambert, leave it during winter and find work elsewhere. The department comprises 5 *arrondissements*—Ambert, Clermont-Ferrand, Issoire, Riom, Thiers—50 cantons and 473 communes. The chief towns are Clermont-Ferrand, Issoire, Thiers, Riom, Ambert, Mont-Dore-les-Bains, La Bourboule and Royat. Near Clermont-Ferrand is Mt. Gergovie (*see* GERGOVIA), the scene of the victory of Vercingetorix over Julius Caesar. Billom, Chamalières, Courpière, Orcival, St. Nectaire and St. Saturnin possess churches in the Romanesque style of Auvergne. There are interesting ruined feudal strongholds at Murols and Tournoël (near Volvic). Vic-le-Comte has a *sainte-chapelle* which is a beautiful example of the transition from Gothic to Renaissance architecture, and Aigueperse has a Gothic church of the 13th to the 15th century. Near Pontgibaud are the ruins (13th-century) of the Carthusian abbey of Port St. Marie. There are a few megalithic remains in the department.

PWLLHELI ("salt pit," or "pool"), a municipal borough, seaport and market town of Caernarvonshire, north Wales, 21 mi. S.W. of Caernarvon with station on the G.W.R. Pop. (1938) 3,578. Area 1.8 sq.mi. It has a sandy beach on the north side of Cardigan bay, on the shore of Tremadoc bay. The town was incorporated by Edward the Black Prince. Pwllheli commands a good view of the Merionethshire and Snowdon mountains.

PYANEPSIA, an ancient festival in honour of Apollo, held at Athens on the 7th of the month Pyanepsion (October). A hodge-podge of pulse was offered to Apollo. Another offering was the *eiresiōnē,* a branch of olive or laurel, bound with purple or white wool, round which were hung fruits of the season, pastries, and small jars of honey, oil and wine. Both are old pieces of rustic magic, for which many analogies can be found elsewhere. It was carried in procession to the temple of Apollo where it was suspended on the gate by a boy whose parents were both alive. The doors of private houses were similarly adorned. The branch was allowed to hang for a year, when it was replaced by a new one, since by that time it was supposed to have lost its virtue. During the procession a chant (also called *eiresiōnē*) was sung, the text of which has been preserved in Plutarch (*Theseus,* 22).

Aetiologists connected both offerings with the Cretan expedition of Theseus, who, when driven ashore at Delos, vowed a thank-offering to Apollo if he slew the Minotaur, which afterwards took the form of the *eiresiōnē* and Pyanepsia. His comrades on landing in Attica gathered up the scraps of their provisions which explains the origin of the hodge-podge.

See W. Mannhardt, *Wald- und Feldkulte,* ii., 214, for an exhaustive account of the *eiresiōnē* and its analogies; Sir J. G. Frazer, *Golden Bough,* vol. ii., pp. 48, 71; A. Mommsen, *Feste d. Stadt Athen,* p. 278. et seq.; J. E. Harrison, *Prolegomena to Greek Religion,* ch. iii.; L. R. Farnell, *Cults of the Greek States,* iv. 286.

PYAPON, a town in Burma, on the Pyapon river. Pop. (1931) 12,338. The district, formed in 1903, lies within the delta of the Irrawaddy. It is intersected by creeks and liable to inundation at high spring tides. The jungle is being reclaimed for rice, which is the sole crop. Area, 2,076 sq.mi.; pop. (1941) 385,008, showing an increase of 50,058 in the decade. The district has no railways and few roads, communication being by water. Other urban centres, which ship the rice to Rangoon, are Kyaiklat (10,658 in 1931), and Dedayè (6,778 in 1931).

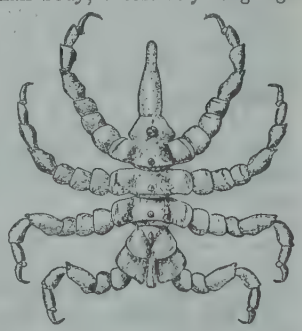
PYAT, FELIX (1810–1889), French communard, was born at Vierzon (Cher) on Oct. 4, 1810, the son of a Legitimist lawyer. Called to the bar in Paris in 1831, he threw his whole energies into journalism. The violent personalities of a pamphlet entitled *Marie Joseph Chénier et le prince des critiques* (1844), in reply to Jules Janin, brought him a six months' sojourn in La Pélagie, in the cell quitted by Lamennais. In 1848 George Sand, whom he had introduced in 1830 to the staff of the *Figaro,* now asked Ledru-Rollin to make him commissary-general of the Cher. After three months' tenure of this office he was returned by the department to the Constituent Assembly, where he voted with the Mountain, and brought forward a motion for the abolition of the presidential office. About this time he fought a duel with Proudhon, who had called him the "aristocrat of the democracy." He joined Ledru-Rollin in the attempt of June 13, 1849, after which he sought refuge in Switzerland, Belgium, and finally in England. For a glorification of regicide at the time the Orsini attempt

against Napoleon III he was brought before an English court, but acquitted, and the general amnesty of 1869 permitted his return to France, but further outbursts against the authorities compelled his return to England. The revolution of Sept. 4 brought him back to Paris, and it was he who in his paper *Le Combat* displayed a black-edged announcement of the *pourparlers* for the surrender of Metz. After the insurrection of Oct. 31, he was imprisoned for a short time. In Jan. 1871, *Le Combat* was suppressed, only to be followed by an equally virulent *Vengeur*. Elected to the National assembly, he retired from Bordeaux with Henri Rochefort and others until such time as the "parricidal" vote for peace should be annulled. He returned to Paris to join the committee of public safety, and, in Hanotaux's words, was the *âme ulcérée* of the Commune, but was blamed for the loss of the fort of Issy. He was superseded there by Delescluze, but he continued to direct the violent acts of the Commune, the overthrow of the Vendôme column, the destruction of Thiers's residence and of the expiatory chapel built to the memory of Louis XVI. He escaped across the frontier, and, though condemned to death in 1873, the amnesty of July 1880 permitted his return. He was elected to the chamber of deputies in 1888, but died at Saint-Gratien on Aug. 3, 1889.

PYATIGORSK, a town of Russia in the North Caucasus on the Podkoumok river and on a plateau 1,680 ft. above sea-level, hence its name ("five mountains"). Its sulphur springs, about 15 in number, vary from 75° to 96° F. and are used for drinking and bathing and are bottled for export. The first buildings were erected in 1812 and a great impetus was given to the town when it was linked with the Rostov-on-Don to Baku railway. Its population in 1939 was 62,875. Its springs had long been known to the Circassians of the district who addressed a petition to Ivan the Terrible in 1551 asking for protection against the Crimean Tatars. The poet M. Y. Lermontov (1814–1841) was killed here in a duel. In 1918 a skeleton, apparently Neanderthal, was reported.

See *Russ. Anthr. Journ.* (1922); "Caucasus: Ice Age," *Man,* vol. xxv (1926).

PYCNOGONIDA, or Pantopoda (rarely, Podosomata), a class of marine Arthropoda comprising about 500 known species, remotely related to the Arachnida on one side and the Crustacea on the other, but distinct from both. The Pycnogonida, or sea spiders, are characterized by a small body, excessively long legs and a subsidiary pair of egg bearing legs (ovigers) in all males but lacking in the females of some genera. There are usually eight walking legs, but species with ten legs, otherwise inseparable from their octopodous counterparts, are not uncommon, although apparently confined to the antarctic and Caribbean regions, and a 12-legged form from the antarctic is also known. In addition to the walking legs and ovigers, there may be a pair of chelate appendages (chelifores), and sensory palpi; the presence or absence of these appendages constitutes the basis of classification within the group, which includes about 50 genera divided into eight or ten families. There are no well-defined orders. Inasmuch as the Pycnogonida never have the biramous limbs of the Crustacea, or the arachnid type body consisting of a cephalothorax with six pairs of appendages and a prominent abdomen, and their chelate protonymphon larva is unique, they are best considered as a class by themselves rather than as an "appendix to the Arachnida." The occurrence of extra-legged forms is not comparable with supernumerary phenomena in other groups; it may indicate polymorphic species.



AFTER D'ARCY W. THOMPSON IN CAMBRIDGE NATURAL HISTORY (MACMILLAN & CO., LTD.)
FIG. 1.—PYCNOGONUM LITTORALE, STROM

The body of a pycnogonid consists of a cephalic segment, or head region; followed by three or four trunk somites, which may be distinctly segmented, or coalesced with the cephalic segment into a compact circular disc; and a usually small, tuberclelike abdomen, at the tip of which is the anus. The mouth is a triangular opening at the end of an elaborate suctorial appendage (proboscis), which is often much longer and larger than the body. In a typical pycnogonid (*e.g. Nymphon* or *Achelia*), the cephalic segment bears three pairs of appendages anterior and in addition to the first pair of legs: the chelifores (which may or may not be chelate); the palpi, usually flanking the proboscis, and the ovigers, which originate on the ventral surface. The extreme of reduction is found in *Pycnogonum,* which lacks both chelifores and palpi and has ovigers only in the males. There are usually four simple eyes, located in a tubercle or elaborate process on the dorsal surface of the cephalic segment, but they are often lacking in deep sea species. Because of the reduced size of the body, the digestive system has long branches into the legs, and the bulk of the gonads is also in the legs. The genital apertures are usually on the ventral surface of the second joints, but the sexual products are stored in the fourth or femoral joints of the legs. The circulatory system consists of a dorsal heart with two or three pairs of lateral ostia; there are no blood vessels. The nervous system is composed of a supra-oesophageal ganglion or "brain," and a chain of five or six ventral ganglia. There is no specialized excretory or respiratory system.

AFTER D'ARCY W. THOMPSON IN CAMBRIDGE NATURAL HISTORY (MACMILLAN & CO., LTD.)
FIG. 2.—NYMPHON STROMII, KR. MALE CARRYING EGG-MASSES ON HIS OVIGEROUS LEGS

In all species of which the habits are known, the male attaches the eggs to his ovigers in masses or clusters as they are extruded from the female, and carries them with him during the early developmental stages. In some species the larvae are then attached to hydroids, in which they form cysts, others are known to invade the medusa stage, and in many arctic and antarctic forms they remain clinging to the male until well developed. The larval stages of a Japanese species, *Nymphonella tapetis,* are parasitic in the mantle cavities of bivalve molluscs. The life cycle of the deep sea forms, especially members of the genus *Colossendeis,* is unknown.

Pycnogonids are found from the littoral zone to depths of more than 2,000 fathoms in all oceans, but are especially abundant in arctic and antarctic waters. Most species are bottom dwellers, usually living in hydroid colonies and feeding upon the soft parts and body juices of coelenterates and other soft animals, but at least two species live on the pelagic sargassum weed in mid-Atlantic, and others appear to be bathypelagic at depths of from 600 to 1000 fathoms. Some species ascend to the surface during their breeding season, swimming by treading water with their long legs. In size pycnogonids range from a spread of 3–4 mm. across the outstretched legs in such forms as the littoral *Tanystylum,* to about 50 cm. in deep sea members of the genus *Colossendeis.*

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PYCNOSTYLE, the architectural term given by Vitruvius to the inter-columniation (*q.v.*) of a temple, when the distance between these columns was equal to 1½ times their diameter.

PYDNA, BATTLE OF (168 B.C.). The Roman operations in Greece having lingered on for some time, Lucius Aemilius Paullus, "one of the few Romans of that age to whom one could not offer money," was sent to hasten a decision. Arriving at Heracleum he at once seized the pass of Pythium, which compelled Perseus king of Macedonia to fall back on Pydna.

The serried ranks of the Macedonian phalanx astonished and terrified Paullus, who, however, disguised his anxiety from his men, and advanced toward his enemy. The Roman vanguard was

dispersed and one cohort almost annihilated. Once again the sarissa (pike) carried all before it, the Roman legions being forced back until they reached the hill upon which stood their camp. Here, on account of the broken nature of the ground, the phalanx became somewhat disorganized. Paullus at once sizing up the situation "commanded his men, that wherever they should see the line of the enemy present openings, they should individually rush to these spots, and insinuating themselves like a wedge into such spaces, however narrow their extent, they should fight with impetuosity" (Livy). These tactics resulted in complete success, the phalanx being disjointed and broken up into a number of separated bodies. The II legion then charged the disorganized mass of pikemen and routed it. Perseus and his cavalry fled the field leaving the infantry to be slaughtered—20,000 were killed and 11,000 made prisoners. This battle was the last fought by the phalanx. The whole campaign was only 15 days. Thus perished the empire of Alexander the Great 144 years after his death.

See Livy XLIV.; T. Mommsen, *The History of Rome*, Book III, chap. x.; H. G. Liddell, *A History of Rome* (1855). (J. F. C. F.)

PYE, HENRY JAMES (1745–1813), English poet laureate, was born in London on Feb. 20, 1745, and educated at Magdalen college, Oxford. Of all he wrote his prose *Summary of the Duties of a Justice of the Peace out of Sessions* (1808) is most worthy of record; it is based on his own experience as a magistrate at Westminster. He was made poet laureate in 1790, perhaps as a reward for his faithful support of Pitt in the house of commons. The appointment was looked on as ridiculous, and his birthday odes were a continual source of contempt. His most elaborate poem was an epic, *Alfred* (1801). He was the first poet laureate to receive a fixed salary of £27 instead of the historic tierce of Canary wine. He died at Pinner, Middlesex, on Aug. 11, 1813.

PYGMALION, (1) son of Cilix, and grandson of Agenor, king of Cyprus. He fell in love with an ivory statue he had made; Aphrodite granted life to the image, which he married (Ovid. *Metam.* x, 243). There is no ancient authority for the introduction of the name Galatea. (2) Brother of Dido (*q.v.*).

PYGMY, a term for a diminutive human being. Homer, in the *Iliad* (iii, 6) uses it of a race of tiny folk dwelling in a far southern land, whither the cranes fly when inclement winters and piercing frosts visit the northern shores. Fierce battles were often mentioned by later writers as occurring between the pygmies and cranes, and were even represented on their vases. On these the pygmies were depicted as dwarfs with large heads, negro features, close, curly hair, and sometimes armed with lances. Aristotle firmly believed in the existence of these pygmies, whom he characterized as a race of men of small stature inhabiting the marshes of upper Egypt toward the sources of the Nile. Herodotus (ii, 32), describes how five Nasamonians, while journeying through the African desert, came at last to a plain where fruit trees grew. While gathering the fruit they were seized by some dwarfish men of strange speech, who led them to a town, where dwelt people of a similar appearance, and near which a great river flowed from west to east containing crocodiles. This river was probably the Niger, and the people referred to were no doubt the ancestors of the existing pygmies of equatorial Africa. Representations of pygmies are sculptured on the tombs at Sakkarah, the Vth Dynasty, *c.* 2500 B.C. They faithfully reproduce the racial characteristics of the present race of pygmies inhabiting the Ituri and Central forests.

Pliny mentions dwarfed races in both Asia and Africa, of the Catizi dwarfs in Thrace, and a similar race in Caria. Ctesias, a century after Herodotus, described a race of pygmies in the heart of India, as black and ugly, and only two *pygmai* in height. The Chinese author, Chao Fu-Kua, in the beginning of the 13th century, described a tribe of black pygmies dwelling in the Philippine Islands, called Hai-tan, small in size, with round, yellow eyes, curly hair, and with the teeth showing through their lips, no doubt the ancestors of the present Aëtas. The existing pygmy races are divided into two groups: (*a*) the African pygmies, Negrillos, (*b*) the Asiatic pygmies, Negritos (*q.v.*).

PYLE, HOWARD (1853–1911), U.S. artist and writer, was born at Wilmington, Del., on March 5, 1853. He was a pupil of the Art Students' league, New York, and first attracted attention by his line drawings after the manner of Albrecht Dürer. His brilliant work as an illustrator made him one of the foremost of American artists, his drawings to illustrate American colonial life, particularly in New England and New Amsterdam, being especially noteworthy; and he published a number of books of fiction, written and illustrated by himself. He also became prominent in decorative painting, his works including "The Battle of Nashville" for the capitol at St. Paul, Minn., and "The Landing of Carteret" for the Essex county court house, Newark, N.J. At his home in Wilmington, Del., he established a school of art, instruction being gratuitous, and many successful American illustrators were educated there. In 1907 Howard Pyle was elected a member of the National Academy of Design. He died in Florence on Nov. 9, 1911.

PYLON, in architecture, originally a gate, but in modern usage reserved to the huge truncated pyramidal forms, crowned with cornices, that flanked the entrances to Egyptian temples. The term is also applied to any similar large masses of masonry, often decorated with sculpture or architectural forms, used to flank the entrance to an avenue, a plaza or a bridge—especially a suspension bridge. (*See* BRIDGES; EGYPTIAN ARCHITECTURE.) Also a tower, usually of steel, to support a telegraph, telephone or electric line over an extended span. In aeronautics, a post or tower indicating a prescribed course of flight.

PYLOS (mod. Navarino), a town and bay on the west coast of Messenia, noted chiefly for the part it played in the Peloponnesian War. The bay, roughly semicircular, is protected by the island of Sphacteria (mod. Sphagia), more than 2½ mi. long. To the north lies the lagoon of Osman Aga. North of Sphagia is the rocky headland of Pylos or Coryphasium, called in modern times Palaea-Navarino or Palaeokastro, from the Venetian ruins on its summit. Most scholars have identified this with the Homeric Pylos, the home of Neleus and Nestor, and a cave on the north slope of Coryphasium is pointed out as that in which Hermes hid the stolen cattle of Apollo. But this view presents considerable difficulties, and Strabo (viii, 348, *et seq.*) argued that the Pylos of Nestor must be the place of that name in Triphylia, now known to have been an important prehistoric site. After the Dorian migration Pylos declined, and it is referred to by Thucydides (iv, 3) as a deserted headland in 425 B.C. In May of that year, the seventh of the Peloponnesian War, the Athenians sent an expedition to Sicily under command of Eurymedon and Sophocles. With them was the general, Demosthenes, who landed at Coryphasium with a body of Athenian troops and hastily fortified it. The Spartans, who were then invading Attica, withdrew their forces and attacked Pylos vigorously by sea and land, but were repulsed, and the Athenians were enabled by the arrival and victory of their fleet to blockade on the island of Sphacteria a body of 420 Spartiates with Helots. Their resistance was overcome by a rear attack directed by a Messenian, who led a body of men by a difficult path along the cliffs on the east, and the 292 Spartan survivors laid down their arms 72 days after the beginning of the blockade. Their surrender made a deep impression on the whole Greek world, which had learned to regard a Spartan surrender as inconceivable. Though Pylos should have been ceded to Sparta under the peace of Nicias (421 B.C.) it was retained by the Athenians until the Spartans recaptured it early in 409 B.C. (Diodorus xiii, 64).

In the middle ages the name Pylos was replaced by that of Avarino (Ἀβαρῖνος) or Navarino, derived from a body of Avars who settled there; the current derivation from the Navarrese company, who entered Greece in 1381 and built a castle at this spot, cannot now be maintained (*Eng. Hist. Review*, xx, 307, xxi, 106; *Hermathena*, xxxi, 430 *sqq.*). From 1498 to 1821 Navarino was in the hands of the Turks, save at two periods when it was held by the Venetians, who named it Zonklon. (*See* NAVARINO, THE BATTLE OF.)

BIBLIOGRAPHY.—*See* W. M. Leake, *Travels in the Morea*, i. 398 *sqq.* (1830), and *Peloponnesiaca*, 190 *sqq.* (1846); E. Curtius, *Peloponnesos*, ii, 173 *sqq.* (Gotha, 1852); C. Bursian, *Geographie von Griechenland*, ii, 175 *sqq.* (Leipzig, 1868); Pausanias iv, 36, and the commentary in J. G. Frazer, *Pausanias's Description of Greece*, iii, 456 *sqq.*, v. 608 *sqq.*

(1898); W. G. Clark, *Peloponnesus*, 214 *sqq.* (1858); W. Vischer, *Erinnerungen und Eindrücke aus Griechenland*, 431 *sqq.* (Basel, 1857); G. Grote, *History of Greece*, pt. ii, ch. 52; G. Busolt, *Griechische Geschichte*, iii, 1086 *sqq.*; F. M. Cornford, *Thucydides mythistoricus*, 82 *sqq.* (1907). The operations at Pylos, described by Thucydides iv 2–41, have been discussed on the basis of personal observation by Dr. G. B. Grundy (*Journal of Hellenic Studies*, xvi, 1 *sqq.*; *Classical Review*, x. 371 *sqq.*, xi. 155 *sqq.*, 448; *J.H.S.*, xviii, 232 *sqq.*) and Professor R. M. Burrows (*J.H.S.*, xvi, 55 *sqq.*; *C.R.* xi. 1 *sqq.*; *J.H.S.* xviii, 147 *sqq.*, 345 *sqq.*; *C.R.* xix, 129 *sqq.*). Though differing on many points, they agree in thinking (1) that the island of Sphagia is the ancient Sphacteria, Palaeokastro the ancient Coryphasium or Pylos; (2) that in 425 B.C. the lagoon of Osman Aga was navigable and communicated by a navigable channel with the Bay of Navarino; (3) that Thucydides, if the ms. reading is correct, underestimates the length of the island, which he gives as 15 stades instead of 24 (nearly 3 mi.), and also the breadth of the southern channel between it and the mainland. *Cf. J.H.S.*, xx, 14 *sqq.*, xxvii, 274 *sqq.*, and Frazer's summary (*op. cit.* v, 608 *sqq.*). (M. N. T.; X.)

PYM, JOHN (1584–1643), English statesman, son and heir of Alexander Pym, of Brymore, Somersetshire, a member of an ancient family which had held this seat in direct male descent from the time of Henry III. He matriculated as a commoner at Broadgates hall (now Pembroke college), Oxford, in 1599, and entered the Middle Temple in 1602. He became receiver-general of the king's revenue for Wilts., and was returned to parliament as member for Calne in 1614 and again in 1621. To the committee appointed to consider the state of religion he made his first great speech on Nov. 28, 1621; he spoke in defense of maintaining the disabilities of Roman Catholics on political grounds, and moved for a special commission for the suppression of recusancy. Pym was a chief promoter of the petition which incurred James's violent displeasure, and of the commons' answer defending their privileges, which was afterward torn from the records by the king's own hand. On the dissolution of parliament which immediately followed, Pym, with other "ill-tempered spirits," was arrested in Jan. 1622, and was confined first to his house in London, and then to Brymore. He associated himself with the party of Francis, 4th earl of Bedford, was returned for Tavistock in 1624, and represented this borough in all the ensuing parliaments.

On May 8, Pym was manager of Buckingham's impeachment. In the third parliament of Charles I, in 1628, Pym overruled Eliot in deciding that Buckingham's impeachment should now be subordinated to the struggle on general grievances. He zealously pushed on the Petition of Right, resisting the clause added by the Lords to safeguard the king's "sovereign power," declaring that "he knew not what it was." He carried up to the lords the impeachment of Roger Manwaring, and delivered a famous speech (June 9) in which he expounded the fundamental principles which guided his policy.

His name is not mentioned as actively resisting Charles's arbitrary government during the 11 years which followed the dissolution of 1629. It has not been proved that Pym, with Hampden and Cromwell, actually embarked for New England and was prevented from sailing by orders from the government. Pym himself was directly interested in the colonies, being patentee of Connecticut and Providence, and of the latter company also treasurer, and there can be little doubt that like other leaders of the opposition, he regarded the United States as a possible refuge.

Short Parliament.—On the assembly of the short parliament on April 13, 1640, Pym was the acknowledged leader. "Whilst men gazed upon each other," says Clarendon (*Hist.* ii, 68), "looking who should begin (much the greater part having never before sat in parliament), Mr. Pym, a man of good reputation . . . who had been as long in these assemblies as any man there living, broke the ice." On April 17 he spoke for nearly two hours on the national grievances, pointed out the practical injury inflicted on commerce and every sort of enterprise including colonial expansion by illegal and arbitrary taxation, and concluded by asking the lords to join in finding out causes and remedies. His words made a deep impression. On April 27 he resisted the grant of supply, and when the lords passed a resolution that supply should precede the discussion of grievances, Pym, as manager of the commons on May 1, read them a severe lecture on the breach of privilege they had committed. Finally, on the 4th, it was resolved that Pym should next day petition the king to make terms with the Scots, to avoid which Charles summarily dissolved the parliament.

All the energies of Pym were now concentrated on obliging Charles to summon another parliament. He was the author of the petition of the 12 peers to the king for redress of grievances and for calling a new parliament, and he was the promoter of the petition signed by 10,000 citizens of London. In company with Hampden he rode through the provinces, rousing and organizing public opinion. Meanwhile Charles's attempt to implicate Pym in treasonable communications with the Scots failed.

Long Parliament.—When the king was forced to call the long parliament (Nov. 3), Pym was its acknowledged author and leader. On Nov. 7 he moved for a sub-committee to examine into Strafford's conduct in Ireland. The latter's sudden arrival at London on the 9th with the intention of instantly impeaching the popular leaders of treason was met by Pym with corresponding quickness and resolution. On the 11th, after a debate of four hours in the commons, by his directions with locked doors, he carried up Strafford's impeachment to the lords, and rendered him at once powerless.

On Dec. 6 he moved the impeachment of Laud. He was the chief promoter of the case against Strafford, while the attempts of the queen to gain him over were without result, and Jan. 28, 1641 he brought up to the lords the list of charges. To the attainder, which was at this stage resolved upon, he was opposed (since he clung to the more judicial procedure by impeachment), but when overruled he supported it, at the same time procuring that the legal arguments should not be interrupted. He delivered his final speech on April 13, a great oratorical performance, when he again appealed to the Elizabethan political faith and to that of Bacon, who had so severely censured any action which divided the king from the nation. The man who violated this union was guilty of the blackest treason. "Shall it be treason," he asked, "to embase the king's coin though but a piece . . . of sixpence . . . and not to embase the spirits of his subjects; to set a stamp and character of servitude upon them?" Toward the end of his tremendous indictment of Strafford, Pym broke down, fumbled among his papers, and lost the thread of his argument. But his temporary failure did not diminish the force and effect of his words, all the more impressive because actually spoken in the presence of the sovereign. "I believe," wrote Baillie (*Letters*, i. 348) "the king never heard a lecture of so free language against his idolized prerogative."

Attempts were now once more made to gain over Pym to the administration. He had two interviews with the king, but without result, and Charles again determined to resort to force. On May 2 he endeavoured to get possession of the tower. On the 3rd the Protestation, on Pym's motion, was taken by the commons within closed doors, and afterward circulated in the country, and on the 5th Pym disclosed the army plot. These incidents decided the struggle and Strafford's fate. Pym also took the lead in the religious controversy. During the dispute between the two houses on this question on Feb. 8–9, 1641, while supporting the London petition for the abolition of the bishops, he had declared his opinion that "it was not the intention of the house to abolish episcopacy or the Book of Common Prayer, but to reform both wherein offence was given to the people." This, no doubt, expressed his real intentions and policy. When, however, it became clear that the bishops were merely the nominees of the king to carry out "innovations in religion" and preach arbitrary government, Pym was easily persuaded to support their abolition, and voted in opposition to the moderate party for the *Root and Branch* Bill of May 1641, and again for taking away their votes in October. But in his "Vindication," published in March 1643, he especially states that his action with regard to the bishops in "no way concluded me guilty of revolt from the orthodox doctrine of the Church of England."

The first act in the great political struggle had ended in the complete triumph of Pym. His chief care now was to defend the parliament from violence, since this was the only method of retaliation left at the king's disposal, and on Nov. 22 he made a great speech on the Grand Remonstrance, of which he was the chief promoter, when he referred to plots "very near the king, all driven home to the court and popish party."

Charles returned on the 25th. He immediately substituted a force commanded by Dorset for the guard already placed at Westminster, but was compelled to withdraw it, and on Pym's motion the house appointed its own watch. Charles appointed Lunsford to the tower, rejected the Grand Remonstrance and the Impressment bill, and began to assemble an armed force. In consequence Pym urged, but unsuccessfully, on Dec. 30 the summoning of the train-bands to guard the parliament, and moved the impeachment of the bishops, who had declared the proceedings of the parliament to be sinful and illegal. At the critical moment, however, Charles wavered. He renewed his offer to Pym of the exchequer on Jan. 1, 1642, and on his refusal, he determined on the impeachment of the five members on Jan. 3. But these had been forewarned of the king's plans, and when on the 5th he

entered the house of commons with an armed band to seize them, they had removed themselves in safety. (*See* LENTHALL, WILLIAM.) Charles's first look on entering was for his great opponent, and he was greatly disconcerted at not finding him in his usual place. To his question "Is Mr. Pym here?" there was no answer, and nothing remained but to retreat with his mission completely unachieved. The second act in the great national drama had thus, as the first, ended in a victory for Pym. On the 11th, with the other members, he was escorted in triumph back to Westminster, and while the other four stood uncovered, Pym returned thanks from his place to the citizens.

Civil War.—When war broke out, Pym remained at headquarters in control of the parliament and executive, and on July 4 was appointed to the committee of safety which directed the movements of the parliamentary forces. His attitude was firm but moderate. He opposed the attempt to prevent Colepepper giving the king's message to the house on Aug. 27. When Charles declined to receive the petition of parliament and advanced on London, Pym proposed (Oct. 20) the parliamentary covenant, and that those who refused it should be "cast out of the house." He succeeded in overcoming the opposition in the city to the heavy taxation now imposed. After repeated efforts to secure peace had failed, he proposed in order to carry on the war an excise, hitherto unknown in England, which met with the same violent hostility afterwards aroused by Walpole's scheme. In March he published a "Declaration and Vindication" of his public conduct, in which he threw the whole blame of the appeal to arms on the opposite party, and expressed his fidelity to the Church and constitution. In May he entered, together with the other leaders, into resultless negotiations with the queen, and on the 23rd he took up her impeachment to the lords. In June he reported on Waller's plot, which exposed the insincerity of Charles's negotiations, and on June 26 wrote a "sharp letter" to Essex on his inaction. In July, after the defeat at Adwalton Moor, he prevented the house from again initiating negotiations for peace, which he declared "full of hazard and full of danger," and on Aug. 3, after having visited Essex at Kingston, persuaded him to separate himself from the peace propositions of the Lords and to march to relieve Gloucester. He thus incurred the hatred of the peace party, and on Aug. 9 a mob of women surrounded the house calling for Pym's destruction, and were not dispersed without some bloodshed.

Pym had already proposed (Jan. 3) to the house an alliance with the Scots, and the Royalist victories now induced parliament to consent to what had before been rejected. The establishment of Presbyterianism was accepted by Pym as a disagreeable necessity, and he was one of the first to take the covenant (Sept. 25). This alliance, which was afterward destined to have so decisive an influence on the military campaign, and was the first occasion on which the two nations had united in public action, closes Pym's career. He was made master of the ordnance on Nov. 8, but died Dec. 8 at Derby House. He received a public funeral in Westminster Abbey, whence his body was ejected at the Restoration. A sum of £10,000 was voted by the parliament to pay Pym's debts and provide for his family. In 1614 Pym married Anne Hooke, or Hooker (d. 1620), by whom he had five children, including sons, Alexander, who died unmarried, and Charles, who was created a baronet; this title, together with Pym's male line, became extinct in the person of Pym's grandson Charles in 1688. Brymore then passing to his sister Mary, wife of Sir Thomas Hales.

Character.—Pym had little of the Puritan in his character or demeanour. His good humour, humanity and cheerfulness in all circumstances, "his pleasant countenance and sweet behaviour," were marked characteristics; the aspersions, however, on his morals, as well as the accusations of bribery, are completely unsubstantiated and discredited. Pym's eloquence lay rather in the clearness of his expression and in the depth and solidity of his ideas than in the more showy arts of oratory.

The article on Pym by S. R. Gardiner, in the *Dict. Nat. Biog.* with its references to authorities, must be supplemented by the same author's *Hist. of England and of the Civil War.* Pym's life has also been written at length by J. Forster in Lardner's *Cabinet Cyclopaedia, Eminent British Statesmen,* vol. iii., and by Wood in *Ath. oxon.* iii. 72, who adds a list of Pym's printed speeches. His character, drawn by Clarendon, *Hist.* iii. 30 and vii. 409, is inaccurate and obviously prejudiced. See also J. Forster's *Grand Remonstrance, Arrest of the Five Members, Life of Sir J. Eliot;* Verney's *Notes of the Long Parliament;* Whitelocke's *Memorials* (needing corroboration of other authorities); R. Baillie's *Letters; Eng. Hist. Rev.* xvii. 736; Rushworth's *Collections; Thomason Tracts,* E 153 (10), 63 (8), 172 (14), 164 (3), 200 (13) (26) (37) (49) (65), 199 (24) (49), 78 (13); *Somers Tracts* iv. 217, 355, 461, 466; *Affaniae* and *Death's Sermon,* by C. Fitzgeffrey; *Add. MSS.* Brit. Mus. 14,827; 11,692; *Lords and Commons Journals.* There are a large number of references to Pym in *Calendars of State Papers Dom.* 1619–1643, and *Colonial Series* 1574–1660, and in the *Hist. MSS. Comm. Series;* but the supposed notebook of Pym mentioned in *Rep.* x. app. vi. 82, has been shown by Gardiner to be that of another person (*Eng. Hist. Rev.,* Jan. 1895, p. 105).

PYORRHOEA is a term used to designate any one of a group of diseases (periodontoclasia or pyorrhoea alveolaris) which attack the gums and bone around the teeth. They include ulatrophia (recession of the gums), gingivitis (inflammation of the gums), alveolar resorption (wasting of the bony socket), pericementoclasia (pus pocket formation). Vincent's gingivitis, erroneously called Vincent's angina, also trench mouth, is an acute gingivitis caused by the fusiform bacillus and spirochaete of Vincent. It is the only type of periodontoclasia which is communicable. These diseases have a direct sequential relationship, although they do not always occur in the same order. A typical case may begin as recession associated with slight alveolar resorption: later it merges into gingivitis with advancing alveolar resorption; finally it develops a pus pocket (pericementoclasia), due to the detachment of the gum from the root, and still more advanced alveolar resorption. Unless checked by correct treatment this results in the loss of the tooth.

Knowledge as to the cause of periodontoclasia, while still incomplete, has advanced so far that rational treatment is now possible, and, in skilful hands, success is obtainable in nearly all cases. While infection plays a prominent part, the important factor is some influence which depresses the resistance of the tissues, thereby making infection possible. In a large percentage of cases the important depressant is an inequality of the biting surfaces of the teeth known as traumatic occlusion, resulting in unequal distribution of pressure when the jaws are brought together. Deposits of tartar, long regarded as the important factor, now only share the responsibility. Improper diet is regarded as important in the causation of periodontoclasia. This is apparently due to a failure to develop strong, resistant, supporting tissues for the teeth, because of dietary deficiencies. After the disease has become established dietary improvement is relatively ineffective.

Treatment includes the following, given in the order of their usual importance: equalizing functional stresses; raising local resistance by massage of the gums; removal of deposits of tartar, etc.; maintaining cleanliness; and building up general resistance by attention to nutrition. Preventive treatment follows the same lines, with special emphasis on stimulating the blood supply by tooth-brush massage. Orthodontic treatment, by helping to equalize functional stresses, helps in treatment and prevention.

Foci of infection may develop in the later stages of the disease, owing to the absorption of toxic material from the pus-pockets into the circulation. Also when the pocket extends to the end of the root, a typical abscess is produced. Advanced pyorrhoea or periodontal disease may usually be detected in the X-ray film, which registers the resorption of alveolar bone accompanying this disease. (J. O. McC.; P. R. S.)

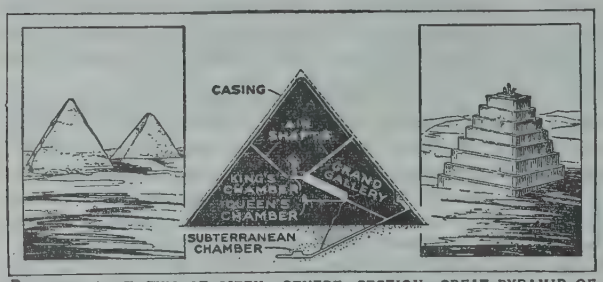
PYRAMID, the name for a class of buildings, first taken from a part of the structure,[1] and mistakenly applied to the whole of it by the Greeks, which has now so far acquired a more definite meaning in its geometrical sense, that it is desirable to employ it in that sense alone. A pyramid therefore should be understood as meaning a building bounded by a polygonal base and plane triangular sides which meet in an apex. (For figures of geometrical pyramids *see* CRYSTALLOGRAPHY, and for their mensuration *see* MENSURATION.) Such a form in architecture is best known in Middle Egypt, during the period from the IVth to the XIIth Dynasty (before 3000 B.C.)—having square bases and angles of about 50°. In other countries various modifications of the tumulus, barrow or burial-heap have arisen which have come near to this type; but these when formed of earth are usually circular, or if square have a flat top, and when built of stone are always in steps or terraces.

The origin of the pyramid type has been entirely explained by the discovery of the various stages of development of the tomb. In prehistoric times a square chamber was sunk in the ground, the dead placed in it, and a roof of poles and brushwood overlaid with sand covered the top. The Ist Dynasty kings developed a wooden lining to the chamber; then a wooden chamber free-standing in the pit, with a beam roof, then a stairway at the side to descend; then a pile of earth held in by a dwarf wall over it. By the IIIrd Dynasty this dwarf wall had

[1] The vertical height was named by the Egyptians *pir-em-us* (*see* E. Revillout, *Rev. Ég.,* 2nd year, 305–309), hence the Greek form *pyramis,* pl. *pyramides* (Herod.), used unaltered in the English of Sandys (1615), from which the singular *pyramid* was formed.

expanded into a solid mass of brickwork, about 280 by 150 ft. and 33 ft. high. This was the *mastaba* type of tomb, with a long, sloping passage descending to the chamber far below it. This pile of brickwork was then copied in stonework early in the IIIrd Dynasty (Saqqara). It was then enlarged by repeated heightening and successive coats of masonry. And lastly a smooth casing was put over the whole, and the first pyramid appeared (Medum).

The pyramids were each begun with a definite design for their



PYRAMID. LEFT: TWO AT GIZEH; CENTRE: SECTION, GREAT PYRAMID OF KHUFU, GIZEH, *c.* 3000 B.C.; RIGHT: ASSYRIAN

size and arrangement; this is plainly seen in the two largest, where continuous accretion (such as Lepsius and his followers propound) would be most likely to be met. Any section of these buildings shows how impossible it would have been for the passages to have belonged to a smaller structure (Petrie, 165). The supposition that the designs were enlarged so long as the builder's life permitted, was drawn from the compound mastabas of Saqqara and Medum; these are, however, quite distinct architecturally from true pyramids.

Around many of the pyramids peribolus walls may be seen, and it is probable that some enclosure originally existed around each of them. At the pyramids of Gizeh the temples attached to these mausolea may be still seen. As in the private tomb, the false door which represented the exit of the deceased person from this world, and towards which the offerings were made, was always on the west wall in the chamber, so the pyramid was placed on the west of the temple in which the deceased king was worshipped. The temple being entered from the east (as in the Jewish temples), the worshippers faced the west, looking towards the pyramid in which the king was buried.

The pyramid was never a family monument, but belonged—like all other Egyptian tombs—to one person, members of the royal family having sometimes lesser pyramids adjoining the king's (as at Khufu's); the essential idea of the sole use of a tomb was so strong that the hill of Gizeh is riddled with deep tomb-shafts for separate burials, often running side by side 60 or 80 ft. deep, with only a thin wall of rock between; and in one place a previous shaft has been partially blocked with masonry, so that a later shaft could be cut partly into it.

The usual construction of pyramids is a mass of masonry composed of horizontal layers of rough-hewn blocks, with a small amount of mortar; and this mass in the later forms became more and more rubbly, until in the VIth Dynasty it was merely a system of retaining walls of rough stones and mud, filled up with loose chips, and in the XIIth Dynasty the bulk was of mud bricks. There was always on the outside a casing of fine stone, elaborately finished, and very well jointed; and the inner chambers were of similarly good work. Indeed, the construction was in all cases so far sound that, had it not been for the spite of enemies and the greed of later builders, it is probable that every pyramid would have been standing in good order at this day. The casings were of massive blocks, usually greater in thickness than in height. Inside each pyramid, always low down, and usually below the ground level, was built a sepulchral chamber; this was reached in all cases by a passage from the north, sometimes beginning in the pyramid face, sometimes descending into the rock on which the pyramid was built in front of the north side. This chamber, if not cut in the rock altogether (as in Menkaura's), or a pit in the rock roofed with stone (as in Khafra's), was built between two immense walls which served for the east and west sides, and between which the north and south sides and roofing stood merely in contact, but unbonded. The gable roofing of the chambers was formed by great sloping slabs of stone, projecting from the north and south walls, on which they rested without pressing on each other along the central ridge; thus there was no thrust, though it had been provided for in the sloping form of the roof, so as to delay as long as possible the collapse of the chamber. This is best seen in the pyramid of Pepi (Petrie), opened from the top right through the roof. The roofing is sometimes of more than one layer; in Pepi's pyramid it is of three layers of stone beams, each deeper than their breadth, resting one on another, the thirty stones weighing more than 30 tons each. In the king's chamber (Gizeh) successive horizontal roofs were interposed between the chamber and the final gable roof, and such may have been the case at Abu Roash (Howard Vyse).

The passages which led into the central chambers have usually some lesser chamber in their course, and are blocked once or oftener with massive stones. In all cases some part, and generally the greater part, of the passages slopes downwards, usually at an angle of about 26°, or 1 in 2. These passages appear to have been closed externally with stone doors turning on a horizontal pivot, as may be seen at South Dahshur. This suggests that the interiors of the pyramids were accessible to the priests, probably for making offerings.

The pyramid of Medum was the first true pyramid. It was begun as a mastaba. This mastaba was then enlarged by heightening it and adding a coating, and this process, repeated seven times, resulted in a high stepped mass of masonry. Such had been made before, at the step pyramid of Saqqara; but for the first time it was now covered with one uniform slope of masonry from base to top, and a pyramid was the result. The chamber is peculiar for being entered by a vertical shaft in the floor. The great pyramid of Gizeh (Khufu's) is very different in its internal arrangements from any other. The pyramid covers upwards of 13 ac. and is about 150 ft. higher than St. Paul's cathedral. The greater number of passages and chambers, the high finish of parts of the work and the accuracy of construction all distinguish it. The chamber which is most normal in its situation is the subterranean chamber; but this is quite unfinished. The upper chambers, called the "king's" and "queen's," were completely hidden, the ascending passage to them having been closed by plugging blocks, which concealed the point where it branched upwards out of the roof of the long descending passage. Another passage, which in its turn branches from the ascending passage to the queen's chamber, was also completely blocked up. The object of having two highly-finished chambers in the mass may have been to receive the king and his co-regent (of whom there is some historical evidence) and there is very credible testimony to a sarcophagus having existed in the queen's as well as in the king's chamber. The accuracy of work is such that the four sides of the base have only a mean error of $\frac{6}{10}$ in. in length and 12″ in angle from a perfect square.[1]

The second pyramid of Gizeh, that of Khafra, has two separate entrances (one in the side, the other in the pavement) and two chambers (one roofed with slabs, the other all rock-hewn); these chambers, however, do not run into the masonry, the whole bulk of which is solid so far as is known. This pyramid has a part of the original casing on the top; and it is also interesting as having the workmen's barracks still remaining at a short distance on the west side, long chambers capable of housing about 4,000 men. The third pyramid, that of Menkaura, was cased around the base with red granite for the 16 lowest courses. Its design has been enlarged at one bound from a small pyramid (such as those of the family of Khufu) to one eight times the size, as it is at present, the passages needed therefore to be altered. But there is no sign of gradual steps of enlargement: the change was sudden. The basalt

[1]With respect to the construction of this and other pyramids, *see* Howard Vyse; on measurements of the inside of the great pyramid and descriptions, *see* Piazzi Smyth; and on measurements in general mechanical means, and theories, *see* Petrie.

Place	King	Date B.C.	Side of Base	Error	Angle	Height	Azimuth
Medum	Sneferu	4750	5,682·0 in.	6·2	51° 52′	3,619 in.	24′ 25″ W.
Gizeh	Khufu	4700	9,068·8 in.	·65	51° 52′	5,776 in.	3′ 43″ W.
„	Khafra	4600	8,474·9 in.	1·5	53° 10′	5,657 in.	5′ 26″ W.
„	Menkaura	4550	4,153·6 in.	3·0	51° 10′	2,581 in.	14′ 3″ E.
Dahshur S.	?	?	7,459·0 in.	3·7	43° 5′ / 55° 1′	4,134 in.	9′ 12″ W.
Dahshur Small	?	?	2,064·6 in.	1·1	44° 34′	1,017 in.	10′ 12″ W.

sarcophagus of this pyramid was ornamented with the panel decoration found on early tombs, unlike the granite sarcophagi of the two previous pyramids, which are plain. Unhappily it was lost at sea in 1838.

Farther south are the pyramids of Abusir, described in the work of Col. Howard Vyse, and since excavated by the Germans. Next come those of Saqqara. The construction of the step pyramid or cumulative mastaba has been noticed above; its passages are very peculiar and intricate, winding around the principal chamber, which is in the centre, cut in the rock, very high, and with a tomb-chamber built in the bottom of it, which is closed with a great plug of red granite. A doorway faced with glazed tiles bearing the name of King Neter-khet of the IIIrd Dynasty existed here; the tiles were taken to Berlin by Lepsius. Beyond these come the pyramids of Dahshur, which are in a simple and massive style, much like those of Gizeh. The north pyramid of Dahshur has chambers roofed like the gallery in the great pyramid by successive overlappings of stone, the roof rising to a great height, with no less than 11 projections on each side. The south pyramid of Dahshur has still the greater part of its casing remaining, and is remarkable for being built at two different angles, the lower part being at the usual pyramid angle, while the upper part is but 43°. Beyond the Memphitic group are the scattered pyramids of Lisht (Senusert I.), Illahun (Senusert II.) and Howara (Amenemhat III.), and the earliest pyramid of Medum (Sneferu). Illahun is built with a framework of stone filled up with mud bricks, and Howara is built entirely of mud bricks, though cased with fine stone like the other pyramids.

The dimensions of the pyramids that are accurately known (as shown in table above) are in inches.

The first two closely agree to the proportion of 7 high on 11 base, approximately the ratio of a radius to its circle. And on dividing the base at Medum by 11 the modulus is 515·64, and the base of Khufu÷11 is 824·44. These moduli are 25 cubits of 20·625 and 40 cubits of 20·611; so it appears that the form was of the same type, but with moduli of 25 and 40 cubits respectively.

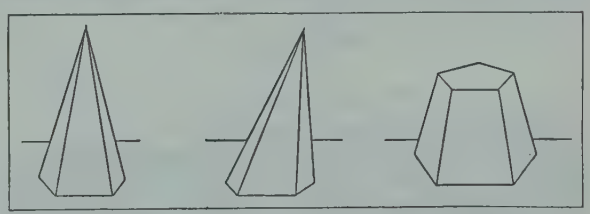
Beyond these already described there are no true pyramids, but we will briefly notice those later forms derived from the pyramid. At Thebes some small pyramids belong to the kings of the XIth Dynasty; the tomb-chamber is in the rock below. The size is under 50 ft. square. These are not oriented, and have a horizontal entrance, quite unlike the narrow pipe-like passages sloping down into the regular pyramids. (*See* Mariette, in *Bib. arch. trans.* iv. 193.) In Ethiopia, at Gebel Barkal, are other so-called pyramids of a very late date. They nearly all have porches; their simplicity is lost amid very dubious decorations; and they are not oriented. They are all very acute, and have flat tops as if to support some ornament. The sizes are very small, varying from 23 to 88 ft. square at Gebel Barkal and 17 to 63 ft. square at Meroe. The interior is solid throughout, the windows which appear on the sides being useless architectural members. (*See* Hoskin's *Ethiopia*, 148, etc.) The structures sometimes called pyramids at Biahmu in the Fayum have no possible claim to such a name; they were two great enclosed courts with sloping sides, in the centres of which were two seated statues raised on pedestals high enough to be seen over the walls of the courts.

Not one fragment of early inscription is known on the casing of any pyramid, either *in situ* or broken in pieces. Large quantities of travellers' "graffiti" doubtless existed, and some have been found on the casing of the great pyramid; these probably gave rise to the accounts of inscriptions, which are expressly said to have been in many different languages.

The mechanical means employed by the pyramid-builders have been partly ascertained. The hard stones, granite, diorite and basalt were in all fine work sawn into shape by bronze saws set with jewels (either corundum or diamond), hollows were made (as in sarcophagi) by tubular drilling with tools like our modern diamond rock-drills. (W. M. F. P.)

See Colonel Howard Vyse, *Operations at the Pyramids* (1840); Prof. C. Piazzi Smyth, *Life and Work at the Great Pyramid* (1867); W. M. Flinders Petrie, *Pyramids and Temples of Gizeh* (1883); M. D. Fraser, *The Pyramids* (Glasgow, 1894); H. Borchardt, *Die Pyramiden* (1911); M. Edgar, *The Great Pyramid* (Glasgow, 1924).

PYRAMID, in geometry, a polyhedron of which one face, called the base, is any polygon and the other faces (the lateral faces) are triangles with one vertex in common. The intersections of the lateral faces are called the lateral edges of the pyramid, and their common vertex is called the vertex of the pyramid. The perpendicular distance from the vertex to the plane of the base is called the height or altitude of the pyramid. If the base is a regular polygon the centre of which coincides with the foot of the perpendicular from the vertex to the base, the pyramid is called a regular pyramid. As in the case of prisms (*q.v.*), pyramids are classified according to their bases. The portion of a



REGULAR PYRAMID, OBLIQUE PYRAMID, AND FRUSTUM OF PYRAMID

pyramid and a plane cutting all the lateral edges is called a truncated pyramid; and if the cutting plane is parallel to the base, the truncated pyramid becomes a frustum of a pyramid. The volume of a pyramid with base B and altitude a is $\frac{1}{3}aB$. The volume of a frustum of a pyramid with bases B and B' and altitude a is $\frac{1}{3}a(B+B'+\sqrt{BB'})$. *See* SOLIDS, GEOMETRIC.

PYRAMIDION (diminutive of "pyramid"), an architectural term for the copper-gilt casing covering the apex of an obelisk; also its upper termination of pyramidal form.

PYRAMUS AND THISBE, the hero and heroine of a Babylonian love story told by Ovid (*Metam,* iv, 55–465). Their parents refused to consent to their union, and the lovers used to converse through a chink in the wall separating their houses.

At last they resolved to flee together, and agreed to meet under a mulberry tree near the tomb of Ninus. Thisbe was the first to arrive, but, terrified by the roar of a lion, took to flight. In her haste she dropped her veil, which the lion tore to pieces with jaws stained with the blood of an ox. Pyramus, believing that she had been devoured by the lion, stabbed himself. Thisbe returned to the rendezvous, and finding her lover mortally wounded, put an end to her own life. From that time the fruit of the mulberry, previously white, was always black.

See G. Hart, *Die Ursprung und Verbreitung der Pyramus-und-Thisbesage* (1889–92).

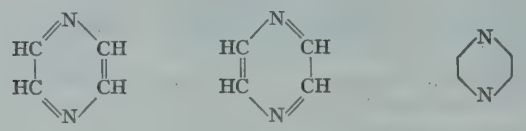
PYRARGYRITE, a mineral consisting of silver sulphantimonite, Ag_3SbS_3, known also as dark red silver ore, an important source of the metal. It is closely allied to, and isomorphous with, the corresponding sulpharsenite known as proustite or light red silver ore. "Ruby silver" or red silver ore (Ger. *Rotgültigerz*) was mentioned by G. Agricola in 1546, but the two species were completely distinguished by J. L. Proust in 1804.

The colour of pyrargyrite is usually grayish black and the lustre

metallic-adamantine; large crystals are opaque, but small ones and thin splinters are deep ruby red by transmitted light; hence the name, from Gr. πῦρ (fire) and ἄργυρος (silver). The streak is purplish red, thus differing markedly from the scarlet streak of proustite and affording a ready means of distinguishing the two minerals. The mineral occurs in metalliferous veins with calcite, argentiferous galena, native silver, native arsenic, etc. The best crystallized specimens are from St. Andreasberg in the Harz, Freiberg in Saxony and Guanajuato in Mexico. It is not uncommon in many silver mines in the United States, but rarely as distinct crystals; and it has been found in Cornish mines.

PYRAZINES, Piazines or Paradiazines, in organic chemistry, nitrogenous compounds containing a ring composed of four carbon atoms and two nitrogen atoms, the latter being at opposite ends of the ring in the so-called "*para*-position."

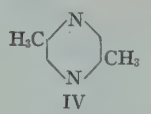
Pyrazine, $C_4H_4N_2$, crystallizes from water in colourless prisms having a heliotrope odour; it melts at 55° C. and boils at 115° C. Its structure, which is analogous to that of benzene (*q.v.*), may be described as a resonance hybrid between I and II (*see* Resonance).



I II III

As with benzene, the structure is commonly expressed by the conventional symbol III.

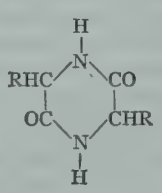
In general the pyrazines are obtained by eliminating water and hydrogen from α-aminoaldehydes or α-aminoketones (two molecular proportions in each case). α,γ-Dimethylpyrazine or ketine (formula IV), a liquid boiling at 153° C., is obtained from isonitrosoacetone, $HON{:}CH.CO.CH_3$, on reduction, as the intermediate aminoacetone, $NH_2.CH_2.CO.CH_3$ (two molecules) then loses water and hydrogen to form the cyclic compound. Pyrazines can also be made by the con-



IV

densation of 1,2-diamines with 1,2-diketones.

Important derivatives of pyrazine include: hexahydropyrazine, or piperazine; the diketopiperazines or amino-acid anhydrides of general structure V, which are obtained by the elimination of alcohol from the esters of α-amino acids; and the various groups of azine dyes (*see* Dyes, Synthetic). (G. W. Wd.)



V

PYRAZOLES, in organic chemistry a series of compounds containing a five-membered ring with three carbon atoms united to two adjacent nitrogen atoms arranged as in formula I, which represents the structure of pyrazole itself.

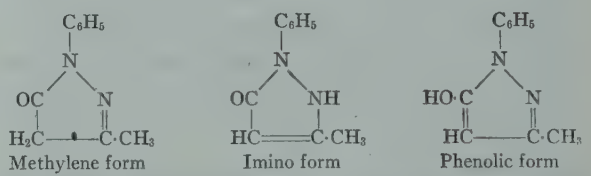
I II

The application in medicine of such pyrazole derivatives as antipyrine (*q.v.*) and pyramidone, and the production of synthetic dyes (*see* Dyes, Synthetic) of the pyrazolone type, lends a special interest to this chapter of organic chemistry.

The simplest synthesis of pyrazole is effected by heating together acetylene and diazomethane (H. von Pechmann, 1897), this process corresponding with the synthesis of pyrrole (*q.v.*) from acetylene and ammonia. The earliest synthesis of pyrazole was accomplished in 1889 by E. Buchner, who condensed ethyl diazoacetate with diethyl acetylenedicarboxylate, thus obtaining triethylpyrazole-3:4:5-tricarboxylate. The free pyrazoletricarboxylic acid on prolonged heating lost carbon dioxide and yielded pyrazole, which crystallizes in colourless needles melting at 70° C. (boiling point, 185° C.), and giving well-defined salts with acids. Pyrazole has certain chemical properties in common with pyridine and benzene; it exhibits an aromatic character and can be sulphonated or nitrated. Its 4-nitro-compound can be reduced to 4-aminopyrazole, which resembles the aromatic bases; it gives a colour reaction with bleaching powder solution and its hydrochloride is readily diazotized. Pyrazole-4-diazonium chloride couples with phenols and naphthols to form azo dyes after the manner of benzenoid diazo compounds.

Pyrazoline or 4:5-dihydropyrazole, formula II, is formed from acrolein and hydrazine hydrate and has also been obtained by the interaction of diazomethane and ethylene. It is a colourless liquid boiling at 144° C. The pyrazolines are unstable oxidizable substances resembling dihydrobenzene and its homologues; they are generally prepared by reducing the corresponding pyrazoles with sodium in alcoholic solution. On further reduction they yield pyrazolidines or tetrahydropyrazoles and when oxidized they develop blue or red colorations. This reaction, described by L. Knorr as the "pyrazoline reaction," is used for the detection of pyrazole and pyrazoline bases derived from phenylhydrazine.

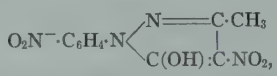
The pyrazolones (ketodihydropyrazoles), first prepared by Knorr in 1883, result from the elimination of the elements of alcohol from the hydrazones of β-ketonic acids. The most important member of this group is 1-phenyl-3-methyl-5-pyrazolone, the parent substance of antipyrine and an intermediate in the manufacture of certain pyrazolone dyes (eriochrome red, etc.). 1-Phenyl-3-methyl-5-pyrazolone, prepared by condensing together phenylhydrazine and ethyl acetoacetate, crystallizes in colourless prisms melting at 127° C. and although it is only known in this form, nevertheless it exhibits tautomerism (*see* Isomerism) and behaves as if it had one or another of the three following structures



Methylene form Imino form Phenolic form

When condensed with aldehydes, water is eliminated between aldehydic oxygen and the two hydrogens of the methylene group, thus indicating the methylene form. When methylated with methyl iodide in methyl alcohol to form the hydriodide of antipyrine (1-phenyl-2:3-dimethylisopyrazolone), the pyrazolone reacts in its imino form, the methyl group replacing the hydrogen of the imino group. Antipyrine (*q.v.*) and its therapeutically important derivatives and analogues are all constituted on the imino type. When in the production of synthetic dyes the pyrazolone is coupled with diazonium salts, it reacts in its third phenolic form, the diazo group replacing the hydrogen of the CH residue adjacent to the hydroxyl group.

Picrolonic acid,



or 4-nitro-1-p-nitrophenyl-3-methyl-5-hydroxypyrazole, is also a pyrazolone of phenolic type. Picrolonic acid closely resembles picric acid and is used to identify alkaloids and other bases owing to the formation of very sparingly soluble picrolonates.

Bibliography.—J. Schmidt, *A Text Book of Organic Chemistry*, translated by H. G. Rule (1942); P. Karrer, *Organic Chemistry*, translated by A. J. Mee (1950); A. A. Morton, *The Chemistry of Heterocyclic Compounds* (1946); G. Cohn, *Tabillarische Übersicht der Pyrazolderivate* (Brunswick, 1897). (G. T. M.; X.)

PYRENE, an aromatic hydrocarbon found with chrysene (*q.v.*) in the coal-tar distillate boiling above 360° C. and also in "Stupp" fat, a by-product from the working up of mercury ores in Idria. It was long considered to be yellow but is now known to be colourless when pure. It melts at 156° C. and boils above 360° C. Chromic acid oxidizes it successively to pyrene-quinone and pyrenic acid; permanganate oxidizes the latter substance to naphthalene-1:4:5:8-tetracarboxylic acid, which confirms the structure I ascribed to pyrene, $C_{16}H_{10}$.

I II

1,2-Benzopyrene, II, occurs in coal tar to the extent of at least 0.003% and is of interest in that it is apparently the factor mainly responsible for the carcinogenic activity of the tar (*see* Carcinogenic Hydrocarbons).

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PYRENEES, a range of mountains in southwest Europe (Span. *Pirinéos*, Fr. *Pyrénées*), separating the Iberian peninsula from France, and extending for about 240 mi., from the Bay of Biscay to Cape Creus, or, if only the main crest of the range be considered, to Cape Cerbère, on the Mediterranean sea. The main crest constitutes the Franco-Spanish frontier; except in the case of the valley of Aran, which belongs orographically to France but politically to Spain. The Pyrenees are conventionally divided into three sections, the central, the Atlantic or western and the Mediterranean or eastern. The central Pyrenees extend eastward from Canfranc to the valley of Aran, and include the highest summits of the whole chain, Aneto or Pic de Néthou (11,168 ft.) in the Maladetta ridge, Posets (11,047 ft.) and Mont Perdu or Monte Perdido (10,997 ft.). In the Atlantic Pyrenees the average altitude gradually diminishes westward; while in the eastern Pyrenees, except for one break at the eastern end of the Pyrénées Ariégeoises, the mean elevation is maintained, till a rather sudden decline occurs in the extreme eastern portion, the Albères. This threefold division is only valid so far as the elevation of the Pyrenean chain is concerned, and does not represent its geological structure or general configuration. The southern versant of the mountains is the more important. It is recognized that the range must be regarded as an elevated part of the earth's crust, the culminating portion of which is composed of a series of chains which do not coincide with the watershed, but cross it obliquely. Maps by Schrader and de Margerie (*Ann. du Club Alpin français,* 1891 and 1892) show the orderly arrangement of these chains. The primitive formations of the range are shown to be almost all continued diagonally on the Spanish side, and the central ridge thus presents the appearance of a series of wrinkles with an inclination (from northwest to southeast) greater than that of the chain as a whole. Other less pronounced wrinkles run from southwest to northeast and intersect the former series at certain points, so that it is by alternate digressions from one to the other series that the irregular crest of the Pyrenees acquires its general direction. Far from having impressed its own direction on the orientation of the chain at large, this crest is merely the resultant of secondary agencies by which the primitive mass has been eroded and lessened in bulk, and though its importance from a hydrographic point of view is still considerable, its geological significance is practically nil.

Geology.—The Pyrenees are divided into a number of longitudinal zones. The central zone (central Massifs) consists of Primary rocks, Archaean, Cambrian, Ordovician, Silurian, Devonian and Lower Carboniferous (Dinantian) together with great masses of granite. It forms most of the higher summits, but west of the Pic d'Anie it disappears beneath an unconformable covering of Cretaceous deposits. On the French side the central zone is followed by: (1) the zone of Ariège, consisting of Lower Cretaceous and Jurassic beds, together with granitic masses; (2) the zone of the Petites Pyrénées, Upper Cretaceous and Eocene; a thin outcrop of Jurassic and (3) the zone of Aragon, Eocene, and Primary rocks. On the Spanish side, from north to south, are: (1) the zone of Mont Perdu, Upper Cretaceous and Eocene with a thin outcrop of Jurassic; (2) the zone of Aragon, Eocene and (3) the zone of the Sierras, Trias, Cretaceous and Eocene. Although the number of zones is the same on the two flanks, they do not correspond. The zone of the Corbières has no equivalent in Spain, while in France there is no definite zone of Eocene like that of Aragon. The zone of the Petites Pyrénées, however, is clearly homologous with that of the Sierras. On the northern side granitic masses occur in the zone of Ariège among the Jurassic and Lower Cretaceous beds. On the southern side they are not found except in the axial zone, and the Jurassic and Lower Cretaceous deposits are reduced to a narrow band. In spite of these differences between the two flanks, the structure is to some extent symmetrical.

The tectonics of the Pyrenees are still only imperfectly understood. Some authorities consider the structure to be that of a fan, while others have shown that the phenomena of *recouvrement* play an important part there. Large masses of rock have been brought forward upon thrust planes over the edges of other beds with which they originally had no connection. Several cases have been described, but denudation has been carried further than in the Alps, and accordingly the masses overlying the thrust planes have been more completely removed.

The Pyrenean axis was outlined by the Hercynian movement and folding took place along it at the close of the Dinantian epoch and again before the Permian. Later the chain was completely submerged until early Cretaceous times, when the earth movements which raised the present mountains commenced and continued into the Oligocene period. The uplift of the Pyrenees was therefore completed before that of the Alps.

The arrangement of the Pyrenees in chains gently inclined near the centre but longitudinal everywhere else, is illustrated by the courses of the streams which flow down toward Spain. On the French side most of the longitudinal valleys have disappeared, except at the eastern end. On the south the principal streams, after cutting their way through the highest zone at right angles to the general direction of the range, become involved halfway to the plains in great longitudinal folds, from which they make their escape only after traversing long distances.

The total area of the Pyrenees is estimated at 21,044 sq.mi., two-thirds of which is on the southern versant. The mean elevation is placed at 3,930 ft., while the highest summit Pic de Néthou, is 11,168 ft. above sea level. The passes show a greater altitude than those of the Alps.

Gaves.—Four features of Pyrenean scenery are the absence of great lakes, as in the Alps; the rarity and great elevation of passes; the large number of the mountain torrents locally called *gaves,* which often form lofty waterfalls, surpassed in Europe only by those of Scandinavia; and the frequency with which the upper end of a valley assumes the form of a cirque. The highest waterfall is that of Gavarnie (1,385 ft.), at the head of the Gave de Pau; the Cirque de Gavarnie, in the same valley, is perhaps the most famous example of the cirque formation. Low passes only occur at the two extremities of the range, where the principal highroads and railways run between France and Spain; a third railway (Pau to Jaca via the pass of Somport) was opened in 1928. In the mountains themselves there are only five passes practicable for motors—the Col de la Perche, Col du Pourtalet, Col de Somport, Roncevalles road and the road through the Baztan valley.

Projects for further railway construction, including the building of tunnels on a vast scale, have been approved by the French and Spanish governments.

The metallic ores of the Pyrenees are not important. There are considerable iron mines at Vicdessos in Ariège and at the foot of Canigou in Pyrénées-Orientales. Coal deposits capable of being profitably worked are situated chiefly on the Spanish slopes and the French side has numerous beds of lignite. Mineral springs are abundant and specially noteworthy are the hot springs. The latter, among which those of Bagnères de Luchon and Eaux-Chaudes may be mentioned, are sulphurous and mostly situated high, near the margin of the granite. The lower springs, such as those of Bagnères de Bigorre (Hautes-Pyrénées,), Rennes (Aude) and Campagne (Aude), are mostly selenitic and not very warm. The use of hydroelectric power has been developed in recent years.

The amount of the precipitation, including rain and snow, is much greater in the western than in the eastern Pyrenees, causing a marked contrast between these sections of the chain in more than one respect. In the first place, the eastern Pyrenees are without glaciers, the quantity of snow falling there being insufficient. The glaciers are confined to the northern slopes of the central Pyrenees, and do not descend far down in the valleys, but have their greatest length in the direction of the chain. They form, in fact, a narrow zone near the crest of the highest mountains. There, as elsewhere in Europe, there are evidences of a much wider extension of the glaciers during the Ice Age. The best known glacier is that in the valley of Argelès. The snow line varies in different parts of the Pyrenees from 8,800 to 9,200 ft. above sea level.

A more marked effect of the high rainfall in the west is seen in the vegetation. The lower mountains in the extreme west are very well wooded, but the extent of forest declines eastward, and the eastern Pyrenees are peculiarly wild and naked, more so because there the granite massifs occur. There is a change, moreover, in the type of flora in passing from west to east. In the west the flora, at least in the north, resembles that of central Europe, while in the east it is distinctly Mediterranean in character. The Pyrenees are relatively as rich in endemic species as the Alps, and among the most remarkable instances of this is the occurrence of the sole European species of *Dioscorea* (yam), the *D. pyrenaica,* on a single high station in the central Pyrenees, and that of the monotypic genus *Xatardia,* only on a high pass between the Val d'Eynes and Catalonia. The genus most abundantly represented in the range is that of the saxifrages, several species of which are there endemic.

In their fauna also the Pyrenees present some striking instances of endemism. There is a distinct species of ibex (*Capra pyrenaica*) confined to the range, while the Pyrenean desman or water mole (*Mygale pyrenaica*) is found only in some of the streams of the northern slopes of these mountains, the only other member of this genus being confined to the rivers of southern Russia. Among the other peculiarities of the Pyrenean fauna are blind insects in the caverns of Ariège, the principal genera of which are *Anophthalmus* and *Adelops.*

The ethnology, folklore, institutions and history of the Pyrenean region form an interesting study: *see* ANDORRA; ARAGON; BASQUE PROVINCES; BEARN; CATALONIA; NAVARRE.

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structure géol. des Pyrénées (1911); L. Carez, *Resumé de la géologie des Pyrénées* (1912); on the climate and flora, T. Cook, *Handbook to the Health Resorts of the Pyrenees* (1905).

PYRÉNÉES-ORIENTALES, a department of southwestern France, bordering on the Mediterranean and the Spanish frontier, formed in 1790 of the old province of Roussillon and of small portions of Languedoc. Population (1946) 228,776, including many Spaniards. Area, 1,600 sq.mi. The department is bounded north by Ariège and Aude, east by the Mediterranean, south by Catalonia and west by the republic of Andorra. Its borders are marked by mountain peaks, on the north by the Corbières, on the northwest and southwest by the eastern Pyrenees, on the extreme southeast by the Albères, which end in the sea at Cape Cerbera. The coast is low-lying, with large lagoons. In the lowlands the climate is Mediterranean, with mild winters, dry summers and short and sudden rainstorms. Amélie-les-Bains is much frequented on account of its mild climate and sheltered position. The temperature ranges from 85° to 95° F. in summer, and in winter only occasionally falls as low as 26° or 27° F. The mean rainfall is 27 in. on the coast, but increases toward the hills. The most common wind is the *tramontane* from the north-northwest, as violent as the mistral of Provence and extremely parching. The *marinada* blows from the south-southeast.

On the Canigou massif to an altitude of 1,400 ft. are found the orange, the aloe, the oleander, the pomegranate and the olive; the vine grows to an altitude of 1,800 ft.; next come the chestnut (2,625 ft.), the rhododendron (from 4,330 to 8,330 ft.), pine (6,400) and birch (6,560); while stunted junipers grow to the summit. The cultivated land in Pyrénées-Orientales is devoted to winegrowing, market-gardening and fruit culture, the production of cereals being comparatively unimportant. The main source of wealth to the department is its wine, of which some kinds are strongly alcoholic and others are in request as liqueur wines (Rivesaltes, Banyuls). Early vegetables are grown in the irrigated lowlands, and fruit-growing is chiefly carried on in the river valleys. In iron Pyrénées-Orientales is one of the richest departments in France, the greater part of the ore being transported to the interior. Lignite and various kinds of stone are worked. The mineral waters are popular. Amélie-les-Bains has hot springs, chalybeate or sulphurous. In the arrondissement of Céret there are also the establishments of La-Preste-les-Bains, near Prats de Mollo, with hot sulphurous springs, and of Le Boulou, the Vichy of the Pyrenees. Near Prades are the hot sulphurous springs of Molitg, and a little north of Mont Canigou are the hot springs of Vernet, containing sodium and sulphur. In the valley of the Tet the sulphurous and alkaline springs of Thuès reach a temperature of 172° F. The baths of Les Escaldas, near Montlouis, are hot, sulphurous and alkaline.

The chief route (Southern railway) across the Pyrenees is from Perpignan through Montlouis, a fortified place, to Puigcerda in the Spanish province of Gerona, through the pass of La Perche, skirting in the French department an enclave of Spanish territory. Three other roads run from Perpignan to Figueras through the passes of Perthus (defended by the fort of Bellegarde), Banyuls and Balistres, the last-named being traversed by a railway. The chief towns of the three arrondissements are Perpignan, Céret and Prades: there are 18 cantons and 233 communes.

The department constitutes the diocese of Perpignan under the archbishop of Albi, and is attached to the appeal court and the *académie* (educational division) of Montpellier and to the region of the 16th army corps.

Perpignan, the capital town and a fortress of the first class, Amélie-les-Bains and Elne (*qq.v.*) are the chief towns.

Rivesaltes ([1946] 5,239) is the most populous town after Perpignan (74,984).

PYRETHRUM. The pyrethrum (family Compositae), regarded as a section of the genus *Chrysanthemum,* flowers in the early summer months, and is remarkable for the great variety of colour which it presents.

The type form is the Caucasian species *C. coccineum,* a hardy perennial, with finely cut leaves and large flower heads, having a ray of deep rose-coloured ligulate florets surrounding the yellow centre or disk. They bloom during the months of May and June, as well as later, and are always most welcome ornaments for the flower borders, and useful for cutting for decorative purposes.

The powdered flower heads of *C. coccineum* and *C. anethifolium* are the source of Persian insect powder, and *C. cinerariaefolium* yields Dalmatian insect powder. Both are important insecticide ingredients, commonly called pyrethrum.

PYRGI, an ancient town of Etruria, Italy, on the southwest coast, 9 mi. W.N.W. of Caere. The name is Greek (*πύργοι*, towers), and the place of considerable antiquity. Remains of its defensive walls exist in polygonal blocks of limestone and sandstone, neatly jointed. They enclosed a rectangular area about 200 yd. in width and at least 220 yd. in length, and there was a small harbour.

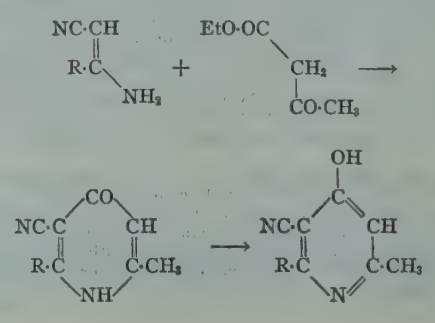
A rich temple of Leucothea there was plundered by Dionysius in 384 B.C. Later it became dependent on Caere, though it was not originally its harbour, for Alsium (*q.v.*) is a good deal nearer (5 mi. S.). The Romans planted a colony there about 200 B.C.

PYRGOS, a town of Greece, in the province of Elis and Achaea, 43 mi. S.S.W. of Patras. It is connected with its harbour, Katakolon, 7½ mi. distant, with Patras, Olympia and Kalamata (Kalámai), by rail. It has frequently been damaged by earthquakes. Pop. 22,500. Axis troops occupied it during World War II.

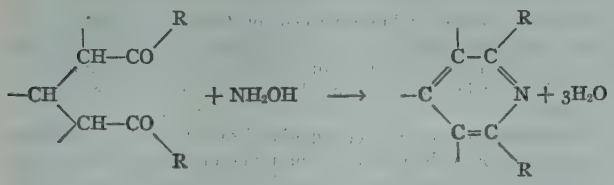
PYRIDINE is an organic compound of formula C_5H_5N. It belongs to the class of heterocyclic aromatic bases and is one of the most fully investigated members of that class. The pyridine nucleus does not occur so frequently in natural products as the condensed systems, quinoline (*q.v.*) and isoquinoline, derived from it, though it forms part of the alkaloid nicotine and of two of the known vitamins. Pyridine itself is formed in the destructive distillation of a variety of nitrogenous organic substances such as bones, coal and shale. It was first discovered by T. Anderson in his investigation (1845–51) of the oil produced in the distillation of bones, in which it occurs together with some of its homologues, notably the picolines (methylpyridines) and lutidines (dimethylpyridines). It is formed by this process only if the bones still contain unsaponified fat, since its formation is the result of interaction between acrolein formed from the glycerol of the fat and ammonia from the nitrogenous constituents. A large number of syntheses of the pyridine nucleus are known, which, though of no value for preparing pyridine itself, are used for obtaining its derivatives. Examples are:

1. Arthur Hantzsch's synthesis gives excellent yields and can be used in a variety of ways. Two molecules of a β-diketone or ketonic ester combine with one of an aldehyde and one of ammonia to give a dihydropyridine, easily oxidized to a pyridine derivative. Thus, collidine (2,4,6-trimethylpyridine) is obtained from acetoacetic ester, acetaldehyde and ammonia, the product being oxidized with nitrous fumes and the carboxyl groups eliminated by hydrolysis and heating with lime. The reaction involves the primary formation of an alkylidene-ketonic ester from one molecule of the ketonic ester and the aldehyde and of a β-amino crotonic ester from the other molecule of the ester and ammonia. It is sometimes convenient to prepare these two compounds separately and allow them to condense to the dihydropyridine.

2. A somewhat similar method (E. von Meyer) is the condensation of a β-ketonic ester with a "dinitrile," which has the structure $H_2N.CR:CH.CN$ and is formed from acetonitrile and the nitrile RCN. This leads to 4-hydroxypyridines.



3. 1, 5-diketones are converted into pyridines by hydroxylamine.



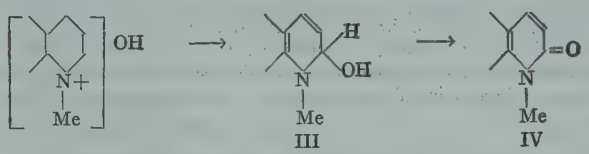
Pyridine itself is obtained commercially from bone oil. Since it is basic, it is removed from the low-boiling fraction of the oil by shaking with dilute sulphuric acid. Addition of excess sodium hydroxide gives a liquid layer consisting of pyridine and its homologues which are separated by fractional distillation. Pyridine is a stable, colourless liquid melting at −42° C. and boiling at 115.3° C. and with a characteristic and unpleasant smell. It is hygroscopic and completely miscible with water but insoluble in concentrated solutions of salts and alkali hydroxides. The higher homologues are progressively less soluble in water. Pyridine is an extremely valuable solvent, dissolving nearly all classes of organic compounds and also many inorganic salts. It is a tertiary amine and behaves as a monoacidic base; it is much weaker in this respect than ammonia, with an apparent dissociation constant of 2.3×10^{-9}; but it forms fairly stable salts, all of which are soluble in water except the mercurichloride, the chloroplatinate and the chloroaurate. Like ammonia it combines with some metals, especially those in the transitional groups of the periodic table, to give stable co-ordination compounds, and the study of these pyridine complexes has been of importance in the development of the theory of co-ordination and of the stereochemistry of the metals.

The pyridine nucleus in pyridine and its derivatives is extremely stable and shows a strong chemical resemblance to that of benzene. Its resistance to oxidation is, indeed, greater than that of the benzene nucleus since phenylpyridines are oxidized to pyridine carboxylic acids with destruction of the benzene nucleus. It was realized early that this similarity in behaviour meant similarity in structure, and W. Körner in 1869 and J. Dewar in 1871 independently put forward a formula (I) analogous to F. A. Kekulé's formula for benzene. This accounts for the known number of isomers in pyridine substitution products. The position of substituents is indicated either by the prefixes N, α, β and γ, or by numbers as in II; of the two systems the latter is to be preferred.

I II

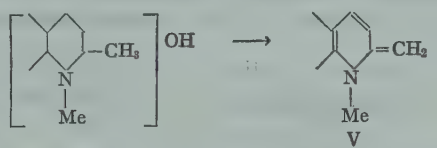
Formula I does not, however, express adequately the modern view of the structure of an aromatic compound. This is known to be a resonance hybrid of a number of states which differ in their electronic distribution. In pyridine there are the same possibilities of such states as in benzene and, although the evidence for resonance based on bond-length, heat of hydrogenation, etc., is not available with pyridine as with benzene, the analogies between the two sets of compounds are so strong that there can be no doubt of the similarity of their structures. Direct substitution takes place far less readily in pyridine than in benzene and certain reactions such as that of C. Friedel and J. A. Crafts do not occur. This behaviour recalls that of nitrobenzene, with which pyridine shows many analogies, and it arises from a similar electronic shift in the two molecules. As with nitrobenzene halogen atoms and methyl groups in the 2 and 4 positions are reactive, the latter condensing easily with aldehydes in the presence of acids. These facts are utilized in several preparative methods in the pyridine series.

As a tertiary base pyridine and its homologues combine with alkyl halides and sulphates to give quaternary ammonium salts, such as the methiodide (1-methylpyridinium iodide), $[C_5H_5N.CH_3]I$, and the "methosulphate" $[C_5H_5N.CH_3]SO_3.OCH_3$. These are typical salts of strong bases; but when they are treated with alkali, they show a characteristic behaviour common to a large number of cyclic bases. The quaternary hydroxide first formed changes, partly or wholly, into a nonbasic form in which the hydroxyl group is no longer an anion. There are two possibilities. In many cases the hydroxyl becomes covalently linked to the 2- or 4-carbon atom to give a pseudobasic form (III). The structure of the latter is revealed by its ready oxidation to a ketone, α-pyridone (IV).



III IV

With homologues of pyridine with a methyl group in the 2 or 4 position the hydroxyl ion is eliminated with a proton from that methyl group to give an anhydro base (V). The anhydro bases are of theoretical importance in the mechanism of the reactivity of these methyl groups.



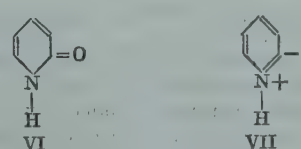
V

Of the derivatives of pyridine the carboxylic acids are of chief interest. They are often formed in the vigorous oxidation of alkaloids and other compounds derived from quinoline (*q.v.*) and isoquinoline and the elucidation of their structure was an important stage in establishing the constitution of these compounds. The monocarboxylic acids are both basic and acidic, but the dicarboxylic and polycarboxylic acids show no basic properties. In physical properties they resemble the aliphatic amino acids, having comparatively high melting points and being insoluble in ether and benzene; they should be regarded as internal salts. Examples of these acids are given in the table:

		Melting point °C.	Oxidation product of:
Picolinic acid	Pyridine-2-carboxylic acid	137	
Nicotinic acid	Pyridine-3-carboxylic acid	229	Nicotine and berberine
Quinolinic acid	Pyridine-2, 3-dicarboxylic acid	231	Quinoline
Cinchomeronic acid	Pyridine-3, 4-dicarboxylic acid	259	Quinine, cinchonine and isoquinoline

Nicotinic acid and its amide are of special interest in that they constitute the factor which is a member of the vitamin-B complex and prevents the deficiency disease pellagra in man. Another vitamin derived from pyridine is vitamin B_6 (adermin, pyridoxine) which is 2-methyl-3-hydroxy-4,5-di(hydroxymethyl)-pyridine.

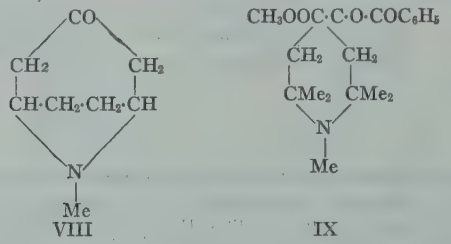
Amino- and hydroxypyridines with the substituent in the 2 or 4 position differ markedly from the 3 derivatives which resemble the corresponding benzene compounds; *e.g.*, 3-aminopyridine forms typical aromatic diazonium salts and the hydroxy compound is a true phenol. The properties of the 2 and 4 derivatives suggest that new structures such as VI and VII, of which the former is impossible in the 3 series, enter into the hybrid structure of the molecule.



VI VII

Piperidine, $C_5H_{10}N$, contains a saturated ring of five $-CH_2-$ groups and one $-NH-$ and is formed when pyridine is reduced catalytically or with sodium and alcohol. It occurs in nature in

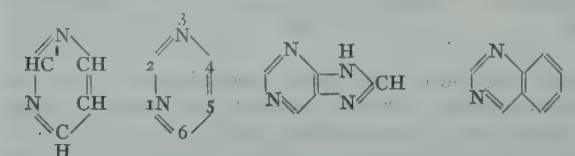
combination with piperic acid as piperine, the alkaloid of various peppers, and in coniine, the poisonous principle of hemlock, which is 2-*n*-propylpiperidine. It is a colourless liquid boiling at 106° C., miscible with water and most organic solvents and possessing a powerful ammoniacal smell. It is a much stronger base than pyridine or ammonia (dissociation constant, 1.6×10^{-3} at 25° C.) and in chemical properties behaves as a typical aliphatic secondary amine. The NH group can be readily acylated and alkylated and it gives an N-nitroso compound with nitrous acid. Exhaustive methylation leads to piperylene, 1,3 pentadiene, the double bonds rearranging to the conjugated position during the decomposition. Piperidine is of value as an alkaline catalyst in several organic condensations and was one of the earliest substances to be used as an accelerator in rubber vulcanization. Of its derivatives, the ketones with the $-CH_2-$ group in the 4 position oxidized to $-CO-$ are of interest. Compounds of this type are formed by the action of ammonia on the self-condensation products of acetone, such as phorone and mesityloxide. Their structure recalls that of tropinone (VIII), a ketone obtained by oxidizing tropine, a secondary alcohol which is the cleavage product of the alkaloids atropine and hyoscyamine, and is of the same fundamental structure as cocaine, a valuable local anaesthetic.



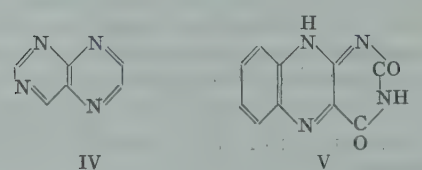
VIII IX

On this analogy a series of synthetic anaesthetics has been prepared from the 4-piperidones derived from acetone; an example is eucaine (IX). (T. W. J. T.)

PYRIMIDINES, Metadiazines or 1,3-Diazines, a group of nitrogenous organic compounds of outstanding biochemical interest, since many derivatives of pyrimidine (I) and of the condensed systems purine (II), quinazoline (III), pteridine (IV), isoalloxazine (V), containing the six-membered heterocyclic nucleus of pyrimidine, are important constituents of living organisms. Among such compounds are the pyrimidines, orotic acid and vitamin B_1; the purines, uric acid, the adenine group and the caffeine alkaloids; the quinazoline alkaloid, vasicine; the pteridines, xanthopterin and the folic acid vitamins; and the isoalloxazine, riboflavin.



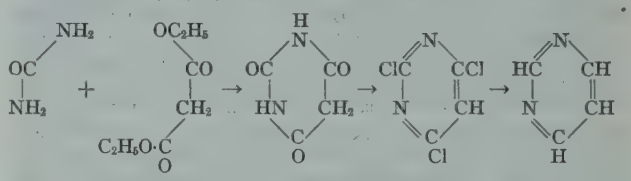
I II III



IV V

The classical researches of F. Wöhler and J. von Liebig on the structure of uric acid, which had been isolated from urinary calculi by K. W. Scheele in 1776, led to the formula proposed by L. Medicus in 1885 and to the study of a series of related naturally occurring compounds designated "purines" by E. Fischer in 1899. Of these, the adenine group including adenine, guanine, cytosine, uracil and thymine are of major interest since they occur as polymeric phosphorylated ribosides and desoxyribosides in the nucleic acids. Adenine is also a constituent of the coenzyme derived from the B-complex vitamins and of adenosine triphosphate. This occurrence of pyrimidines and purines in nucleic acids, in coenzymes and in other cell constituents, and the concept that desoxyribonucleic acids are associated with genes in the determination of inherited traits of organisms, stimulated and intensified interest in the biochemical study of these series of compounds.

Knowledge of the synthetic methods by which the pyrimidine nucleus can be built up and of the numerous transformations of the substituent groups was amassed from these biochemical investigations. The most useful and commonly used type of synthesis is that in which the nitrogenous component such as urea, guanidine or one of the amidines is condensed with a compound such as ethyl malonate or a suitable diketone. This ring formation and subsequent modification of the substituent groups is illustrated in the synthesis of pyrimidine (I) itself by condensation of urea with ethyl malonate and conversion of the resulting barbituric acid (VI) by chlorination and reduction.



VI I

Pyrimidine, a stable crystalline compound melting at 20–22° C. and boiling at 124° C. is readily soluble in water.

Considerable advance has been made toward an understanding of the biosynthesis of the nucleic acids and of its inhibition. The role of the B vitamins in purine and pyrimidine biosynthesis and that of the purine and pyrimidine antimetabolites in nucleic acid metabolism were reviewed by W. Shive and L. D. Wright in *Vitamins and Hormones.*

Considering the importance of pyrimidines in cellular metabolism it is not remarkable that they have pharmacological importance. Barbituric acid derivatives in which the two hydrogen atoms at the 5 position are replaced by alkyl groups of varying complexity are hypnotic, sedative and even anaesthetic in their action. A pyrimidine substituted sulfonamide, sulfadiazine, is widely used in the treatment of bacterial infections. (C. R. Al.)

Bibliography.—V. Meyer and P. H. Jacobson, *Lehrbuch der Organischen Chemie* (Berlin and Leipzig, 1923); T. B. Johnson, J. A. Ambler, "Researches on Pyrimidines," *J. Am. Chem. Soc.*, 33:978–85 (1911 *et seq.*); B. Lythgoe, *Quart. Revs.*, vol. iii, pp. 181–207 (London, 1949); R. Harris and K. Thimann (eds.), *Vitamins and Hormones,* vol. ix, pp. 75–130, 130–159 (1951).

PYRITE or Pyrites, a term applied to iron disulphide when crystallized in the cubic system. The original word "pyrites" (from Gr. πῦρ, fire) had reference to the fact that sparks might be elicited on striking the mineral violently, as with flint, so that πυρίτης λίθος meant a stone which struck fire. Hence the name seems to have been applied also to flint and perhaps to emery and other hard stones. Nodules of pyrite have been found in prehistoric barrows and elsewhere under conditions suggesting their use as a primitive means of producing fire. Even in late historic time it was employed in some old wheel-lock guns. The compound FeS_2 is dimorphous, and the practice is to distinguish the cubic form as pyrite and the orthorhombic as marcasite (*q.v.*).

Iron pyrites, or pyrite, belongs crystallographically to the parallel-faced hemihedral class of the cubic system. Its common forms are the cube, the octahedron and the pentagonal dodecahedron, or various combinations of them. It has a conchoidal fracture and a very indistinct cubic cleavage. Its hardness is about 6, and its specific gravity 4.9 to 5.2, being rather more than that of marcasite. Moreover, the colour of pyrite is brass-yellow, while that of marcasite when untarnished may be almost tin-white. From copper pyrites (chalcopyrite) pyrite is distinguished by its superior hardness and by its paler colour. On exposure to meteoric influences pyrite commonly becomes brown, by formation of ferric hydrate. Such a change is very common on the outcrop of mineral veins, forming what miners call "gozzan."

According to the formula FeS_2, pyrite contains theoretically 46.67% of iron and 53.33% of sulphur. Practically, however, it frequently contains other metals, such as copper, cobalt and nickel. Gold is often present, and in many gold-mining districts the precious metal is obtained mainly from auriferous pyrite. As pyrite, from its brass-yellow colour, is sometimes mistaken for gold, it has been called "fool's gold." Traces of thallium, which are present in some pyrite, may be detected in the flues of the furnaces where the metal is roasted. Arsenic is an impurity which may be of serious consequence in some of the purposes to which pyrite is applied. The presence of copper, nickel and arsenic is possibly the result in many cases of traces of kindred minerals, such as chalcopyrite, pentlandite and mispickel.

Distribution and Uses.—Pyrite is a mineral of very wide distribution, occurring under varied conditions and probably originating in various ways. It is common in mineral veins, usually associated with quartz, and is often known to miners as mundic. It occurs crystallized, commonly in cubes, in schistose and slaty rocks, and less abundantly in the younger sedimentary deposits. In coal it not infrequently forms bands and nodules known as brasses, and may also be finely disseminated through the coal as black pyrites; but much of the so-called pyrite of coal is really marcasite. Films of pyrite sometimes coat the joint planes of coal. Pyritous shales have been largely used in the manufacture of alum, and are therefore known as alum shales. Many fossils are mineralized with pyrite, which has evidently been reduced by the action of decomposing organic matter on a solution of ferrous sulphate, or perhaps less directly on ferrous carbonate dissolved in water containing carbonic acid, in the presence of certain sulphates. A similar action probably explains the origin of pyrite and marcasite in coal and lignite, in clay and shales and in limestone like chalk.

Pyrite is largely worked for the sake of the sulphur that it contains, and has displaced sulphur in the manufacture of sulphuric acid. For this purpose its value depends on the proportion of sulphur present. Pyrite low in sulphur is incapable of sustaining its own combustion without the aid of an external source of heat, and 45% of sulphur is, for economic reasons, usually regarded as the lowest percentage admissible for sulphuric acid manufacture. It is also important for this purpose that the ore should be as free as possible from arsenic (*see* SULPHURIC ACID).

An extremely important variety of pyrite is that which is more or less cupriferous and is commonly known commercially as copper pyrites (*see* CHALCOPYRITE), though distinct mineralogically from that mineral. It consists, indeed, mainly of pyrite, with a notable but variable proportion of copper, sometimes with silver and gold, and not infrequently associated with lead and zinc sulphides. The copper probably exists as disseminated chalcopyrite. Deposits of such cupriferous pyrite are widely distributed and are often of great magnitude. They are generally of lenticular form, and usually occur in or near the contact of eruptive rocks with schists or slates; the presence of the igneous rock being probably connected genetically with their origin.

The world's annual production of iron pyrite is about 4,500,000 tons. The largest producer is Spain, with about 2,000,000 tons, including the cupriferous pyrite. France yields about 200,000 tons, largely from the Sain Bel mines, department of the Rhône. Then follows Portugal, with its important output of cupriferous pyrites. In the United States the production of pyrite reaches about 170,000 tons per annum. The state of Virginia is the chief producer, followed successively by Georgia, North Carolina, Colorado, Massachusetts, California, Missouri, New York, etc. From Indiana and Ohio a quantity of pyrite is obtained as a by-product in coal mining. The United Kingdom yields but little pyrite, the annual output being not more than about 5,000 tons. Large quantities of sulphur ore were, however, formerly worked in the Vale of Avoca, County Wicklow, Ire. Finely crystallized specimens of pyrite are obtained from many other localities, especially from Cornwall, Elba and Traversella, near Ivrea, in Piedmont.

PYRO AND PIEZO ELECTRICITY: *see* ELECTRICITY.

PYROGALLOL or PYROGALLIC ACID, a trihydroxybenzene, $1,2,3\text{-}C_6H_3(OH)_3$, first prepared by K. W. Scheele in 1786 by heating gallic acid. It is used as a photographic developer and also as an oxygen absorbent in gas analysis. It has antiseptic properties and is employed medicinally in the treatment of psoriasis. The process of manufacture is still based on Scheele's procedure. Gallic acid with half its weight of water is heated in an autoclave until the pressure reaches 12 atm. and the temperature registered is 175° C. Steam and carbon dioxide are then allowed to escape, leaving in sufficient water to keep the pyrogallol liquid. The cooled solution is decolorized with animal charcoal and evaporated down until the volatile pyrogallol has distilled over into flat iron receivers. The solidified material is purified by repeated distillation or sublimation. Pyrogallol crystallizes in colourless leaflets or needles, melts at 134° C. and is easily sublimed; it distils at 309° C. under the ordinary pressure with partial decomposition. It dissolves in $2\frac{1}{4}$ parts of water at 13° C., and its aqueous solution develops a blue colour with ferrous sulphate containing a little ferric salt. Its alkaline solution, when exposed to air, rapidly becomes black because of the absorption of oxygen with the production of complex coloured substances.

(G. T. M.)

PYROLUSITE, a mineral consisting essentially of manganese dioxide (MnO_2), of importance as an ore of manganese. It is a soft, black, amorphous mineral, often with a granular, fibrous or columnar structure and sometimes forming reniform crusts. It has a metallic lustre and a black or bluish-black streak, and readily soils the fingers. The specific gravity is about 4.8.

Supposed crystals of pyrolusite have been proved to be pseudomorphs after manganite; in fact, the mineral often results by the dehydration and oxidation of manganite ($Mn_2O_3.H_2O$), and for this reason it frequently contains a little water. True crystals of manganese dioxide are referred to the rare species polianite; they are tetragonal and isomorphous with cassiterite. Pyrolusite is an alteration product of other manganese minerals—manganite, rhodochrosite, rhodonite, etc. It occurs as irregular masses and nodules in the residual clayey materials resulting from the decomposition of various rocks; for example, limestone. That it is readily deposited from solution is shown by the frequent occurrence of black dendritic markings in the crevices of rocks, excellent examples of which are seen in mocha stone (*q.v.*) and in the lithographic stone of Solenhofen, Bavaria. It is deposited by some springs and manganiferous nodules are dredged from the floor of the deep sea.

As an ore, pyrolusite is extensively mined at Ilmenau and other places in Thuringia, in north Wales, at several places in the U.S. (Vermont, Virginia, Arkansas, etc.), Nova Scotia, Brazil, India, etc. Together with the rather less important ore, psilomelane, it has various economic applications; it is extensively used for the manufacture of spiegeleisen and ferromanganese, and of various alloys, such as manganese-bronze; as an oxidizing agent it is used in the preparation of chlorine and disinfectants (permanganates); and when mixed with molten glass it oxidizes the ferrous iron to ferric iron, and so discharges the green and brown tints, hence the name pyrolusite, from Gr. πῦρ (fire) and λύειν (to wash). As a colouring material, it is used in calico printing and dyeing; for imparting violet, amber and black colours to glass, pottery and bricks; and in the manufacture of green and violet paints.

PYROMETER, an instrument for measuring high temperatures (Gr. πῦρ, fire, μέτρον, a measure). The term was first used by P. van Musschenbroek to denote an instrument wherein the expansion of a metal rod measured the temperature. Discontinuous thermoscopes, depending on the fusion of a metal or salt, have also been employed.

Prinsep prepared a series of alloys of silver and gold and of gold and platinum whose melting points, as determined by accurate instruments, covered a range of temperature from 954° C. to 1,775° C., at intervals of from 25° C. to 30° C. By placing ingots in a furnace and observing which one melted a fair idea of the temperature was obtained. Carnelley and Williams employed certain salts of known melting point; however, the Seger's cones, employed in porcelain manufacture, depend on the softening of small cones made of clay. The instruments employed to-

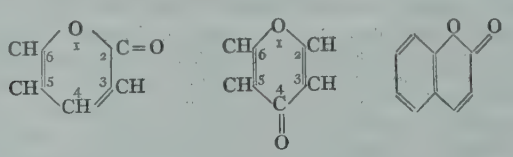
day depend either on electrical effects produced in wires inserted in the furnace and so raised to its temperature, or upon measurements made on the radiation emitted by the furnace. (*See* also THERMOMETRY for scientific forms.)

PYROMORPHITE, a mineral species composed of lead chlorophosphate $(PbCl)Pb_4(PO_4)_3$, sometimes occurring in sufficient abundance to be mined as an ore of lead.

Crystals are common, and have the form of a hexagonal prism terminated by the basal planes, often with a barrellike curvature, globular and reniform masses also being found. Between pyromorphite and the corresponding chloroarsenate (mimetite, *q.v.*) the resemblance in external characters is so close that, as a rule, it is possible to distinguish them only by chemical tests, and they were formerly confused under the names green lead ore and brown lead ore. The phosphate was first distinguished chemically in 1784, and it was named pyromorphite from Gr. πῦρ (fire) and μορφή (form), because when a fragment is fused the globule assumes a faceted form on solidifying. The colour is usually some bright shade of green, yellow or brown, and the lustre is resinous. The hardness is 3.5 and specific gravity 6.5–7.1. Pyromorphite has resulted from the alteration of galena in the oxidized portions of metalliferous veins, and is frequently met with in the upper levels of lead mines.

PYROMUCIC ACID (FUROIC ACID): *see* FURFURAL.

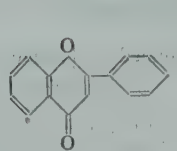
PYRONES, a term used in organic chemistry to describe a group of six-membered oxygen-containing heterocyclic compounds. Pyrones are of two main types, those derived from 1:2-pyrone (I) and those derived from 1:4-pyrone (II). The former may be regarded as cyclic esters (lactones) and the latter contain an extended ester group (O—CH=CH—CO). Like esters, they are hydrolyzed by alkali and show no ketonic properties. Pyrones possess stability similar to that of aromatic compounds; this is due to resonance (*cf.* benzene).



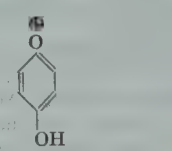
I

II

III



IV



V

1:2-Pyrone (coumalin), shown in diagram I, is a colourless liquid with a 5° C. m.p. and 120° C. b.p. at 30 mm. pressure. It is prepared by heating malic acid with concentrated sulphuric acid giving 1:2-pyrone-5-carboxylic acid (coumalic acid), and this yields 1:2-pyrone on decarboxylation. Alkaline hydrolysis of 1:2-pyrone gives crotonaldehyde. Compounds containing the 1:2-pyrone nucleus which occur naturally include phenylcoumalin (6-phenyl-1:2-pyrone) from cotobark and derivatives of coumarin (*q.v.*) (5:6-benz-1:2-pyrone), represented in diagram III.

1:4-Pyrones have been extensively investigated. 1:4-Pyrone itself forms colourless needles, m.p. 32.5° C., b.p. 215–217° C., and it may be prepared by heating chelidonic acid (*see* below) or comanic acid (1:4-pyrone-2-carboxylic acid), preferably in the presence of copper powder. A number of compounds of the 1:4-pyrone series are found in nature. For example, the leaves of the lily of the valley and the celandine (*Chelidonium majus*) contain chelidonic acid (1:4-pyrone-2:6-dicarboxylic acid). The structure of this acid was established by decarboxylation to give 1:4-pyrone and by alkaline cleavage, giving oxalic acid and acetone. Meconic acid (3-hydroxy-1:4-pyrone-2:6-dicarboxylic acid) is found in association with the opium alkaloids. Maltol (3-hydroxy-2-methyl-1:4-pyrone) is present in pine needles and larch bark; it is also formed when barley is roasted in the manufacture of malted beverages. Kojic acid (2-hydroxymethyl-5-hydroxy-1:4-pyrone) is formed during the growth of the fungus *Aspergillus flavus* on a medium containing glucose or xylose. Maltol and kojic acid show reactions characteristic of the phenols, thus demonstrating the aromatic character of the 1:4-pyrone nucleus; the acidic nature of kojic acid is caused by the hydroxyl group in position 5.

1:4-Pyrones may be synthesized by dehydration of 1:3:5–triketones. For example, 2:6-dimethyl-1:4-pyrone may be prepared by dehydration of diacetylacetone ($CH_3.CO.CH_2.CO.CH_2.CO.CH_3$). It is also formed by the reaction of concentrated hydrochloric acid with dehydracetic acid which is obtained from ethyl acetoacetate by treatment with sodium ethoxide. Chelidonic acid has been synthesized by condensing acetone with diethyl oxalate in the presence of sodium ethoxide. The intermediate ethyl acetone-dioxalate ($EtO_2C.CO.CH_2.CO.CH_2.CO.CO_2Et$), by dehydration and hydrolysis of the ester groups with concentrated hydrochloric acid, gave chelidonic acid.

The formation of pyridine derivatives from 1:4-pyrones is noteworthy in that it may be of biogenetic significance. For example, 2:6-dimethyl-1:4-pyrone, when treated with dimethyl sulphate and then with perchloric acid, gives a perchlorate which, with ammonium carbonate, yields 2:6-dimethyl-4-methoxypyridine. Similarly chelidonic acid, when heated with ammonia, gives chelidamic acid, and kojic acid, when methylated, treated with ammonia and then with phosphorus and hydriodic acid, gives 4:5-dihydroxy-2-methylpyridine. Another interesting property of pyrones is the formation of salts with acids. 2:6-Dimethylpyrone gives well-defined salts with hydrochloric, chloroplatinic and tartaric acids. The stability of these salts is associated with the resonance hybrid structure for the cation which is best represented by diagram V.

Many derivatives of 1:4-pyrones occur naturally; some have been used as dyes. They include chromones (5:6-benz-1:4-pyrones), flavones (2-phenyl-5:6-benz-1:4-pyrones; *see* diagram IV), isoflavones (3-phenyl-5:6-benz-1:4-pyrones) and xanthones (2:3-5:6-dibenz-1:4-pyrones; *see* article XANTHONE). (W. D. Os.)

PYROPHORIC ALLOYS, alloys which when filed or scratched give off bright sparks. Alloys containing about 15% iron and mixtures of rare-earth metals with small amounts of antimony, bismuth, copper and silicon are used in various lighters.

PYROPHORUS, a material which inflames spontaneously on contact with air. Homberg's pyrophorus (Gr. πῦρ, fire; φέρειν, to bear), one of the earliest known, was prepared by heating alum with finely divided carbon or organic material (lampblack, starch or flour) in a closed tube. The product, a mixture of potassium sulphide, aluminum sulphate and carbon, is spontaneously inflammable. The oxides of iron, cobalt or nickel when reduced by hydrogen at low red heat leave the metal in a state of such fine division that it becomes incandescent on exposure to air. Lead tartrate heated in a closed tube leaves a pyrophoric residue of finely divided lead. Liquid phosphine, P_2H_4, and organometallic compounds such as cacodyl, zinc diethyl, trimethylstibine, etc., are spontaneously inflammable liquids.

PYROPHYLLITE, a mineral species composed of hydrous aluminum silicate, $HAl(SiO_3)_2$. It occurs in two more or less distinct varieties, crystalline folia and compact masses; distinct crystals are not known.

The folia have a pronounced pearly lustre because of the presence of a perfect cleavage parallel to their surfaces; they are flexible but not elastic and are usually arranged radially in fanlike or spherical groups. This variety, when heated before the blowpipe, exfoliates and swells up to many times its original volume, hence the name pyrophyllite, from the Greek πῦρ (fire) and φύλλον (a leaf), given by R. Hermann in 1829. The colour of both varieties is white, pale green, grayish or yellowish; they are very soft (hardness = 1–2) and are greasy to the touch. The specific gravity is 2.8–2.9. The two varieties are thus very similar, respectively, to talc (*q.v.*) and its compact variety steatite, which is, however, a hydrous magnesium silicate. The compact variety of pyrophyllite is used for slate pencils and tailors' chalk ("french chalk") and is carved by the Chinese into small images and orna-

ments of various kinds. Other soft compact minerals (steatite and pinite) used for these Chinese carvings are included with pyrophyllite under the terms agalmatolite and pagodite.

Pyrophyllite occurs in schistose rocks, often associated with kyanite, of which it is an alteration product. Pale-green foliated masses, very like talc in appearance, are found at Beresovsk near Ekaterinburg in the Urals, and at Zermatt, Switz. The most extensive deposits are in the Deep river region of North Carolina, where the compact variety is mined, and in South Carolina and Georgia.

PYROTECHNY: *see* FIREWORKS.

PYROXENE, in mineralogy, an important group of rock-forming minerals very similar in chemical composition and general characters to the amphiboles (*q.v.*). The name (from Gr. πῦρ, fire, and ξένος, stranger) was originally given by R. J. Haüy in 1796 to the augite of the lavas of Vesuvius, in the belief that the crystals had been caught up by the lavas that contained them; but next to the feldspars the pyroxenes are the commonest constituents of igneous rocks, being especially characteristic of those of basic composition (basalt, gabbro, pyroxenite, etc.). Though crystallizing in three different systems, the pyroxenes all possess distinct prismatic cleavages, with an angle of about 87° between them. Usually the habit of these minerals is that of short prisms, but in the alkaline varieties long slender prisms are often characteristic; *e.g.*, acmite.

The pyroxenes are conveniently subdivided into three series according to the symmetry of their crystals. Chemically they are essentially metasilicates. The principal species are indicated in the accompanying table.

Rhombic Series

Enstatite	$MgSiO_3$
Bronzite	$(Mg, Fe)SiO_3$
Hypersthene	$(Fe, Mg)SiO_3$

Monoclinic Series

Clinoenstatite	$MgSiO_3$
Diopside	$CaMg(SiO_3)_2$
Hedenbergite	$Ca(Mg, Fe)(SiO_3)_2$
Enstatite Diopside or Magnesium Diopside	$m\text{-}(Mg,Fe)SiO_3.n\text{-}Ca(Mg,Fe)(SiO_3)_2$
Augite	$Ca(Mg,Fe)(SiO_3)_2$ with $(Mg,Fe)SiO_3$ and $(Al,Fe''')_2O_3$
Acmite	$NaFe'''(SiO_3)_2$
Jadeite	$NaAl(SiO_3)_2$
Spodumene	$LiAl(SiO_3)_2$
Wollastonite	$CaSiO_3$
Pectolite	$HNaCa_2(SiO_3)_3$
Rosenbuschite	$Na_2Ca_3[(Si,Zr,Ti)O_3]_4$

Triclinic Series

Rhodonite	$MnSiO_3$
Pyroxmangite	$(FeMn)SiO_3$
Bustamite	$(Ca,Mn)SiO_3$
Babingtonite	$Ca(Fe,Mn)(SiO_3)_2$ with Fe_2O_3 and SiO_2
Sobralite	$CaMgFe_2Mn_4(SiO_3)_8$
Hiortdahlite	$4Ca(Si, Zr)O_3.Na_2ZrO_2F_2$

Many of these species are described under their respective headings, to which reference should be made. Others not so treated are briefly mentioned below. Clinoenstatite, the monoclinic magnesium metasilicate, occurs in meteorites. It is the only stable metasilicate of magnesium prepared in the laboratory. It melts incongruently at 1,557° C. with separation of forsterite. Enstatite diopside or magnesium diopside is an isomorphous mixture of diopside with clinoenstatite, and as such is a characteristic pyroxene of the quartz-dolerite group of igneous rocks. Hedenbergite is a black or dark-green pyroxene characteristic of metasomatically metamorphosed limestones or skarns, and is often associated with andradite garnet. A fluorine-bearing diopside known as mansjöite occurs at Mansjö mountain in Sweden. The manganese- and zinc-bearing monoclinic pyroxenes include schefferite, $Ca(Mg,Fe,Mn)(SiO_3)_2$, and jeffersonite,

$$Ca(Mg,Fe,Mn,Zn),(SiO_3)_2,$$

both occurring at Franklin Furnace, N.J.

Jadeite is a white to gray pyroxene occurring in dense fibrous masses in association with serpentine, glaucophane schists or eclogites in Turkistan, Tibet, Burma and other places. It possesses a distinct ethnographic interest because of its use by prehistoric man in the manufacture of images and utensils. Pectolite occurs as a secondary mineral in the form of radiating fibrous crystals in druses and veins of basic igneous rocks of the triclinic series of minerals classified as pyroxenes; bustamite, fowlerite and pyroxmangite are closely related to rhodonite. The two former occur at Franklin Furnace. Sobralite occurs with manganese-garnet in an eulysite from Södermanland, Swed. According to the most recent analyses, babingtonite contains alkalies and water as essential constituents. The mineral occurs in black crystals on feldspar in the granite of Baveno, It., and also as a product of contact metamorphism in Japan and elsewhere. The rare zirconium-bearing silicates, hiortdahlite, and the monoclinic rosenbuschite occur in the nepheline-rich rocks of southern Norway and of the Los archipelago (Guinea). (C. E. T.)

PYROXENITE, a rock consisting essentially of minerals of the pyroxene group, such as augite and diallage, hypersthene, bronzite or enstatite. Names have been given to members of this group according to their component minerals; *e.g.*, pyroxenite (augite), diallagite (diallage), hypersthenite (hypersthene), bronzitite (bronzite) and websterite (diallage and hypersthene). Closely allied to this group are the hornblendites, consisting essentially of hornblende. The term perknite (Gr. περκνός, dark) has also been used to designate the whole series.

PYRRHO OF ELIS (*c.* 360–270 B.C.), a Greek sceptic philosopher and founder of the school known as Pyrrhonism. Diogenes Laërtius (ix, 61), quoting from Apollodorus, says that he was at first a painter, and that pictures by him were in existence in the gymnasium at Elis. Later he was diverted to philosophy by the works of Democritus. He studied in India under the gymnosophists (*q.v.*) and under the magi in Persia. Returning to Elis, he lived in poor circumstances, but highly honoured by the Elians and also by the Athenians, who gave him the rights of citizenship. His doctrines are known mainly through the satiric writings (Σίλλοι) of his pupil Timon of Phlius (the sillographer). The main principle of his thought is expressed in the word *acatalepsia*, which implies the impossibility of knowing things in their own nature. Pyrrho concludes that, since nothing can be known, the only proper attitude is imperturbability (*ataraxia*). The impossibility of knowledge, even in regard to our own ignorance or doubt, should induce the wise man to withdraw into himself, avoiding the stress and emotion which belong to the contest of vain imaginings. (*See* PHILOSOPHY, HISTORY OF.)

PYRRHOTITE, a mineral species consisting of iron sulphide and crystallizing in the hexagonal system. The formula is Fe_nS_{n+1}, in which n may vary from 5 to 16; such a composition being explained by the "solid solution" of sulphur in ferrous sulphide (troilite). Small amounts of nickel and cobalt are often present; the mineral is of some importance as an ore of gold, and the nickeliferous pyrrhotite of Sudbury, Ont., is by far the most important source of nickel.

Crystals have the form of hexagonal plates bounded at their edges by faces of a hexagonal prism and pyramids, which are deeply striated horizontally. More frequently, however, the mineral is massive, with a laminar or granular structure. It is magnetic, sometimes with polarity, and is therefore often called magnetic pyrites. The colour is bronze yellow, the lustre metallic and the streak grayish black. The hardness is 4 and the specific gravity 4.58–4.64.

Pyrrhotite occurs in metalliferous veins and as grains and plates disseminated through various rocks.

PYRRHUS (*c.* 318–272 B.C.), king of Epirus, son of Aeacides and a member of the royal family of the Molossians. He claimed descent from Pyrrhus, the son of Achilles, and was also connected with the royal family of Macedonia through Olympias, the mother of Alexander the Great. He became king when still a boy, and fought for Demetrius Poliorcetes at Ipsus in 301. He was sent to the court of Ptolemy as a hostage by Demetrius, married Ptolemy's stepdaughter Antigone, and became a thorn in Demetrius' side. For some time he occupied most of Macedonia under the terms of a truce, but in 286 Lysimachus defeated him at Edessa and drove him back into Epirus.

In 281 Tarentum, in southern Italy, asked his assistance against Rome. Pyrrhus went with about 25,000 men, and might, with more wholehearted assistance from the Greek cities, have been a fatal obstacle to the growth of Rome, faced with Etruscans and Gauls in the north as well as this reinforced opposition in the south. Greeks and Romans met at Heraclea, and Pyrrhus, with the advantage gained by his cavalry and elephants, completely defeated the consul M. Valerius Laevinus, but at the cost of very heavy losses. This battle is the origin of the phrase "a Pyrrhic victory." He advanced on Rome through Latium, but the towns were all garrisoned, and though the senate was inclined to agree to terms, the speech of Appius Claudius the censor decided them against it. Cineas, Pyrrhus' minister, was sent back with a refusal to negotiate as long as Pyrrhus' troops were in Italy.

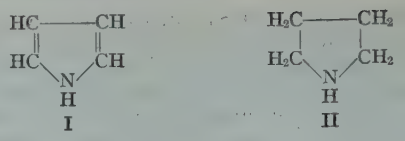
In 279 Pyrrhus won another victory at Asculum in Apulia. He then went to Sicily with the idea of driving the Carthaginians out; his military operations were successful, and Rome and Carthage united in an alliance against him, while his despotic methods alienated the Sicilian cities. He stayed three years in Sicily and then returned to Italy, but the Greek cities now entirely failed to support him and he was completely defeated at Beneventum in 275. He left Italy, saying, "what a battlefield I am leaving to Rome and Carthage"—a remark of some insight. The rest of his life was passed in wars at home, including a victory over Antigonus Gonatas, and an unsuccessful expedition into Sparta at the invitation of Cleonymus in 273. He was killed in 272 in a night skirmish in a street in Argos. Pyrrhus wrote a history of the art of war, which is praised by Cicero and quoted by Dionysius of Halicarnassus and Plutarch.

The chief ancient authority for the life of Pyrrhus is Plutarch; *see* also Polybius xviii, 11, and elsewhere; Dion. Halic. xviii, 1; xix, 6–9; Pausanias i, 13; Justin xviii, 1, 2; xxiii, 3; xxv, 4, 5. Modern monographs by G. F. Hertzberg, "Rom und König Pyrrhus" (popular; in O. Jäger, *Darstellungen aus der römischen Geschichte* [1870]); R. von Scala, *Der Pyrrhische Krieg* (1884), with map of Roman garrison system in 281; R. Schubert, *Geschichte des Pyrrhus* (1894), with full list of authorities; also ROME: *Ancient History*.

PYRROLE. A colourless oil whose existence in coal tar was surmised by the German chemist F. F. Runge in 1834 but which was first isolated and studied by the Scottish chemist Thomas Anderson in 1857. The name is derived from Greek and Latin roots meaning "fiery oil" from the fiery red colour imparted by pyrrole to a wood splint previously moistened with acid. Pyrrole is of great historical interest because of the fact that one of its derivatives, indole (*q.v.*), is the fundamental building block of the regal dye of the ancients, Tyrian purple, as well as of the most important ancient and mediaeval dye, indigo. Pyrrole is also the structural unit of chlorophyll, the green portion of the pigment of leaves; of haeme, the red portion of the pigment of blood; of the pigments of the bile; and of the pigments of numerous types of bacteria, algae and other living organisms. Pyrrole pigments are found in coal, petroleum and similar substances derived from plant and animal sources.

The colouring matters derived from pyrrole are the objects of extensive scientific investigations because their functions in plants and animals are so critically important to life. Atmospheric carbon dioxide, fixed by photosynthesis involving chlorophyll, is the ultimate source of most of our food and fuel, and the efficiency of transportation of oxygen by the blood pigment, haemoglobin, is indispensable to the rapid motions of higher animals. In addition, these pyrrole pigments are probably produced by living organisms in greater tonnage than any other class of pigments. Derivatives of pyrrolidine, which is completely reduced pyrrole, occur in alkaloids, such as cocaine and nicotine, and as building blocks of proteins in the form of the amino acids proline, hydroxyproline and tryptophane.

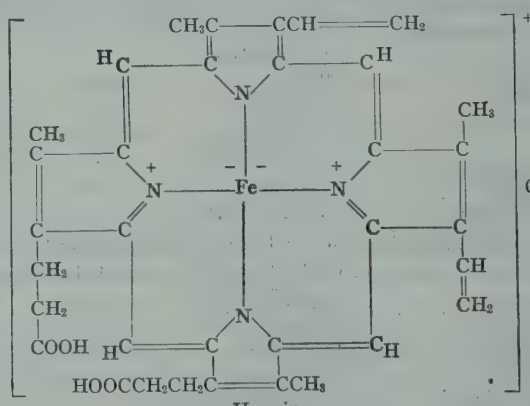
Pyrrole boils at 131° C., is slightly lighter than water (density 0.9669) and has the composition C_4H_5N. It is sparingly soluble in water but dissolves in alcohol, ether and many other solvents. Its structural formula was assigned correctly by the German chemist Adolf von Baeyer in 1870 in the course of his classical investigations on the structure of indigo. It is conventionally represented as in diagram I, while diagram II is the formula of pyrrolidine.



I II

Pyrrole is characterized by great chemical reactivity, being slowly destroyed by air with the formation of a brown pigment. It is also destroyed by strong acids, being partially converted into indole, and it enters into combination with a wide variety of chemical reagents. It has been obtained from bone oil and by destructive heating of proteins but is now available commercially from acetylene, formaldehyde and ammonia. Pyrrole is moderately toxic, acting as a nerve poison. Certain of its derivatives have found a limited application in medicine. Their main use is in organic chemical synthesis for the study of the structure and functions of the naturally occurring pigments.

The most important pyrrole derivatives are the porphyrins (from the Greek for purple) and the chlorins (from the Greek for yellow-green) and their metallic compounds. A typical iron-porphyrin compound is haemin, the oxidized form of the coloured portion of the blood pigment. The chemical formula for this substance was elucidated mainly by researches directed by Wilhelm Küster, Richard Willstätter and especially Hans Fischer; its complete synthesis was accomplished by the latter and his co-workers in 1929. The formula may be conventionally represented as follows:



Haemin

See Hans Fischer and Hans Orth, *Die Chemie des Pyrrols* (Leipzig, 1934–40). (A. H. CN.)

PYRUVIC ACID or PYRORACEMIC ACID is an extremely reactive organic acid which occupies a central place in cellular metabolism. Formed during sugar fermentation, it may be oxidized to acetic acid; or it may be reduced: (1) to lactic acid (glycolysis); (2) to ethyl alcohol (alcohol fermentation) through decarboxylation to acetaldehyde; (3) to malic acid by CO_2 fixation; or (4) to alanine, by NH_3 fixation. The oxidation of pyruvic acid in living cells requires the presence of vitamin B_1 (thiamine), and its concentration in the blood increases in vitamin B_1 deficiency.

Pyruvic acid, $CH_3COCOOH$, is best prepared by heating together a mixture of six parts of fused potassium hydrogen sulphate and four parts of tartaric acid at 210°–220° C. The distillate is fractionated under reduced pressure, the yield being 50%–55%. Pyruvic acid was first obtained by J. J. Berzelius in 1835 by the dry distillation of tartaric acid. It is a liquid boiling at 75°–80° C./25 mm. and at 165° C./760 mm. with partial decomposition; on redistillation at 60° C./10 mm. it forms crystals which melt at 13.6° C. With phenylhydrazine it gives crystalline phenylhydrazone, and it combines additively with prussic acid and with alkali bisulphites. It forms mercaptals with mercaptans, and is oxidized to acetic acid with hydrogen peroxide in neutral and with ceric sulphate in acid solutions. Its most characteristic reaction with aldehydes and aromatic amines (Doebner's reaction) leads to the production of arylcinchonic acids. It can be tested for by reduc-

tion to lactic acid through the action of magnesium and an acid.

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PYRZYCE (Ger. *Pyritz*), a town in the province of Szczecin, Pol., formerly in the Prussian province of Pomerania, Ger., 16 mi. S.W. of Starogród by the railway to Kostrzyn. Pop. (1939) 11,200, (1946) 803. It became a town in 1150 and was surrounded by walls with towers. Near the town was the spring in which Otto, bishop of Bamberg, baptized the first Pomeranian converts to Christianity in 1124.

PYTHAGORAS (6th century B.C.), Greek philosopher, was a native of Samos and flourished about 532 B.C. He is said to have been a pupil of Pherecydes (*q.v.*). In Ionia he had the reputation of a learned and universally informed man. "Of all men," says Heracleitus, "Pythagoras, the son of Mnesarchus, was the most assiduous inquirer." The extensive travels attributed to Pythagoras are no doubt mostly apocryphal, but there is no intrinsic improbability in the statement of Isocrates (*Laud. Busir.*, 28, p. 227 Steph.) that he visited Egypt and other countries of the Mediterranean. The historically important part of the career of Pythagoras begins with his migration to Croton, a Dorian colony in southern Italy, about the year 529. According to tradition, he was driven from Samos by the tyranny of Polycrates. At Croton Pythagoras became the centre of a widespread organization which was, in its origin, a religious brotherhood or an association for the moral reformation of society rather than a philosophical school. The Pythagorean brotherhood had much in common with the Orphic communities which sought by rites and abstinences to purify the believer's soul and enable it to escape from the "wheel of birth." Its aims were those of a religious order rather than a political league. The new order did indeed establish for a time its supremacy over a considerable part of Magna Graecia, but this entanglement with politics led in the end to the dismemberment and suppression of the society. The first reaction against the Pythagoreans, led by Cylon, seems to have taken place in the lifetime of Pythagoras in connection with the victory gained by Croton over Sybaris in 510. Cylon was able to bring about the retirement of Pythagoras to Metapontium, where he remained until his death at the end of the 6th or the beginning of the 5th century. The order appears to have continued powerful in Magna Graecia till the middle of the 5th century when it was violently trampled out. The meetinghouses of the Pythagoreans were everywhere sacked and burned; mention is made in particular of "the house of Milo" in Croton, where 50 or 60 Pythagoreans were surprised and slain. Those who survived took refuge at Thebes and other places. Lysis went to Thebes, where he became the instructor of Epaminondas. Philolaus, too, who according to tradition wrote the first exposition of the Pythagorean system, lived at Thebes at the end of the 5th century. Philolaus, however, and some others were afterward able to return to Italy, and thenceforth Taras (Tarentum) became the chief seat of the school. There Archytas, the friend of Plato, lived; he ruled Taras for years and was never defeated in battle. As a philosophic school the Pythagoreans became extinct about the middle of the 4th century.

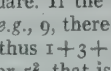
Aristotle in his accounts of Pythagorean doctrines never refers to Pythagoras but always to "the Pythagoreans" or "the so-called Pythagoreans" (οἱ καλούμενοι). Nevertheless certain doctrines may be traced to the founder. Foremost among these is the theory of the immortality and transmigration of the soul (*see* METEMPSYCHOSIS). Pythagoras's teaching on this point is connected with the primitive belief in the kinship of men and beasts, a view which Pythagoras also held. The Pythagorean rule of abstinence from flesh is thus, in its origin, a taboo resting on the blood-brotherhood of men and beasts; and a number of the Pythagorean rules of life which are found embodied in the different traditions appear likewise to be genuine taboos belonging to a similar level of primitive thought. The moral and religious application which Pythagoras gave to the doctrine of transmigration continued to be the teaching of the school. The view of the body (σῶμα) as the tomb (σῆμα) of the soul and the account of philosophy in the *Phaedo* as a meditation of death are expressly connected by Plato with the teaching of Philolaus; and the strain of asceticism and other-worldliness which are met there and elsewhere in Plato is usually traced to Pythagorean influence.

Theory of Numbers.—The scientific doctrines of the Pythagorean school have no apparent connection with the religious mysticism of the society of their rules of living. Their discourses and speculations all connect themselves with the idea of number, and the school holds an important place in the history of mathematical and astronomical science. Aristotle tells us that the Pythagoreans "applied themselves to the study of mathematics and were the first to advance that science; insomuch that, having been brought up in it, they thought that its principles must be the principles of all existing things." Pythagoras is said to have attached supreme importance to arithmetic, which he advanced and took out of the region of commercial utility. He also made geometry a part of a liberal education, examining the principles of the science and treating the theorems from an immaterial and intellectual standpoint.

Pythagoras's greatest discovery was, perhaps, that of the dependence of the musical intervals on certain arithmetical ratios of lengths of string at the same tension, 2:1 giving the octave, 3:2 the fifth and 4:3 the fourth. This discovery could not but have powerfully contributed to the idea that "all things are numbers." According to Aristotle, the theory in its original form regarded numbers, not as relations predicable of things, but as actually constituting their essence or substance. Numbers, he says, seemed to the Pythagoreans to be the first things in the whole of nature, and they supposed the elements of numbers to be the elements of all things, and the whole heaven to be a musical scale and a number (*Metaph.*, A. 986 a). Later, *e.g.*, in the fragments of "Philolaus," things are spoken of, not as *being* numbers, but as *having* number and thereby becoming knowable.

The development of these ideas into a comprehensive metaphysical system was probably the work of Philolaus. The elements of numbers referred to by Aristotle were, according to the Pythagoreans, the odd and the even, which they identified with the limit and the unlimited. The unlimited, and therefore the limit also, was conceived as spatial. Numbers were thus spatially regarded, and "one" was identified with the point, which was thus a unit having position and magnitude; "two" was similarly identified with the line, "three" with surface, and "four" with solid. The odd and even and the limit and unlimited were the first two of a set of ten fundamental oppositions postulated by the Pythagoreans, the remaining eight being: one and many, right and left, male and female, rest and motion, straight and curved, light and darkness, good and evil, square and oblong. To the Pythagoreans the universe was in a sense the realization of these opposites. The further speculations of the Pythagoreans on the subject of number rest mainly on fanciful analogies. Thus "seven" is called πάρθενος and Ἀθήνη because within the decade it has neither factors nor products; "five," on the other hand, is marriage because it is the union of the first masculine and the first feminine number (3+2, unity not being considered a number); "one" is identified with reason because it is unchangeable; "two" with opinion because it is unlimited and indeterminate; "four" with justice because it is the first square number, the product of equals.

Aristotle has the interesting remark that Eurytus, who was a disciple of Philolaus, used to assign numbers to all sorts of things such as horses or men, and imitated their shapes by arranging pebbles after the manner of those who bring numbers into the forms of triangles or squares (*Metaph.*, N. 5, 1092 b 10). This leads to figured numbers and the connection between numbers and geometry. The holy tetractys, by which the later Pythagoreans used to swear, was a figure of this kind representing the triangular number 10 and showing at a glance its composition as 1+2+3+4. To add a row of five dots gives the next triangular number with 5 as the side, and so on, showing that the sum of any number of the series of natural numbers beginning with 1 is a triangular number. The sum of any number of the series of odd numbers beginning with 1 is similarly seen to be

a square; thus 3 and 5 added successively to 1 give a figure of this kind  , and so on. If we take the series of even numbers, we see that the sum of any number of them beginning with 2 makes an oblong number .

The successive odd numbers after 1 were called gnomons because the addition of each of them to the sum of the preceding ones (beginning with 1) makes a square number into the next larger square. If the gnomon added to a square is itself a square number, *e.g.*, 9, there is a square number which is the sum of two squares; thus $1+3+5+7=16$ or 4^2, and the addition of 9 ($=3^2$) gives 25 or 5^2, that is, $3^2+4^2=5^2$. Pythagoras himself is credited with a general formula for finding two square numbers the sum of which is also a square, namely (if m is any odd number), $m^2+\{\frac{1}{2}(m^2-1)\}^2=\{\frac{1}{2}(m^2+1)\}^2$. This connects itself with the theorem of the square on the hypotenuse of a right-angled triangle, which tradition universally associates with the name of Pythagoras. This being a property of all right-angled triangles, consideration would show that, while some such triangles have their sides in the ratio of rational numbers, some, and in particular the isosceles, have not.

In the case of the isosceles right-angled triangle the ratio of the hypotenuse to either of the other sides is what is written as $\sqrt{2}$, which is irrational in the sense that its value cannot be expressed exactly as a ratio between numbers. It was the Pythagoreans who discovered the irrationality of $\sqrt{2}$, and not only so, but they discovered the law of formation of the series of side—and diagonal numbers (as they were called), which satisfy the equations $2x^2-y^2=+1$ and so makes it possible to find, as x and y increase, closer and closer approximations to the value of $\sqrt{2}$. The law depends on the proposition in Eucl. ii, 10 to the effect that $(2x+y)^2-2(x+y)^2=2x^2-y^2$, whence it follows that if x, y satisfy one of the above equations, then $2x+y$, $x+y$ is a solution in higher numbers of the other equation. From this is derived $\frac{1}{1}, \frac{3}{2}, \frac{7}{5}, \frac{17}{12}, \frac{41}{29}$, and so on ad infinitum as approximations to $\sqrt{2}$.

Contributions to Geometry.—Other contributions to geometry by the Pythagoreans comprise the following: (1) Pythagoras, it is said, himself formulated definitions in geometry. (2) The Pythagoreans proved that the sum of the three angles of any triangle is equal to two right angles; there is their proof, which, like Euclid's, uses the property of parallels; hence they knew the theory of parallels. (3) They discovered the powerful method in geometry of the application of areas (*cf.* Eucl., i, 44, 45), including application with excess and defect (*cf.* Eucl., vi, 28, 29) which amounts to the geometrical solution of any quadratic equation in algebra having real roots. (4) Pythagoras himself is said to have discovered the theory of proportion (for when Proclus says that he discovered the theory of irrationals, *τῶν ἀλόγων*, the reading should almost certainly be *τῶν ἀνάλογον*, of proportionals) and of the three means, arithmetic, geometric and harmonic. The arithmetic and harmonic means are shown in the middle terms of the proportion $a: \frac{a+b}{2}=\frac{2ab}{a+b} :b$, a particular case being $12:9=8:6$, from the terms of which the three musical intervals can be obtained. The Pythagorean theory of proportion was arithmetical (after the manner of Euclid, book vii) and did not apply to incommensurable magnitudes; it must not therefore be confused with the general theory due to Eudoxus which is expounded in Euclid v. (5) Proclus also says that Pythagoras discovered the construction of the five regular solids. It was more probably Theaetetus who (as another scholium says) discovered the octahedron and the icosahedron; but the Pythagoreans were clearly acquainted with the pyramid or tetrahedron and the dodecahedron. The construction of the dodecahedron requires that of a regular pentagon, which again depends (as in Eucl., iv, 10, 11) on the problem of Eucl., ii, 11 about the division of a line in extreme and mean ratio, a particular case of the application of areas. The assumption that the Pythagoreans could construct a regular pentagon is confirmed by the fact that the pentagram, the triple interwoven triangle, or the star-pentagon, was used by the Pythagoreans as a symbol of recognition between the members of the school and was called by them health. (6) The Pythagoreans discovered how to construct a rectilineal figure equal to one and similar to another rectilineal figure.

Summing up the Pythagorean geometry, it may be said that it covered the bulk of the subject matter of Euclid's books i, ii, iv, vi (and probably iii), with the qualification that the Pythagorean theory of proportion was inadequate in that it did not apply to incommensurable magnitudes.

Pythagorean Astronomy.—It remains to speak of the Pythagorean astronomy. Pythagoras was one of the first to hold that the earth and the universe are spherical in shape. He realized that the sun, moon and planets have a motion of their own independent of the daily rotation and in the opposite sense. It is improbable that Pythagoras himself was responsible for the astronomical system known as Pythagorean, which deposed the earth from its place in the centre and made it a planet like the sun, the moon and the other planets; for Pythagoras apparently the earth was still at the centre. The later Pythagorean system is attributed alternatively to Philolaus and to Hicetas, a native of Syracuse. The system may be thus described. The universe is spherical in shape and finite in size. Outside it is infinite void which enables the universe to breathe, as it were. At the centre is the central fire, called the hearth of the universe (among other names), wherein is situated the governing principle, the force which directs the movement and activity of the universe. In the universe there revolve around the central fire the following bodies: nearest to the central fire is the counterearth which always accompanies the earth; next in order (reckoning from the centre outward) is the earth, then the moon, then the sun, then the five planets and then, last of all, the sphere of the fixed stars. The counterearth, revolving in a smaller orbit than the earth, is not seen by us because the hemisphere in which we live is always turned away from the counterearth (the analogy of the moon which always turns the same side to us may have suggested this). This part of the theory involves the assumption that the earth rotates about its own axis in the same time as it takes to complete its orbit around the central fire; and as the latter revolution was held to produce day and night, it is a fair inference that the earth was thought to revolve around the central fire in a day and a night, or in 24 hr.

The system amounts to a first step toward an anticipation of the Copernican hypothesis, and Copernicus himself referred to it as such. The curious thing in the system is the introduction of the counterearth. Aristotle in one place says that its object was to bring the number of the revolving bodies up to ten, the perfect number according to the Pythagoreans; but elsewhere he hints at the truer explanation when he says that eclipses of the moon were considered to be sometimes a result of the interposition of the earth, sometimes of the interposition of the counterearth, whence it would appear that the counterearth was invented in order to explain the frequency of lunar eclipses as compared with solar.

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PYTHAGORAS, of Rhegium, a noted Greek sculptor of the 5th century B.C., a contemporary of Myron and Polyclitus, and their rival in making statues of athletes. One of these, that of the boxer Euthymus of Locri, can be dated at 472 B.C. He was born at Samos and migrated in his youth to Rhegium in Italy. He made a statue of Philoctetes notable for the physical expression of pain, an Apollo shooting the Python at Delphi, and a man singing to the lyre. His technical improvements went far to ending archaic stiffness. No existing work can be certainly attributed to him, but the "Apollo on the Omphalos" at Athens and the "Choiseul-Gouffier" Apollo in the British Museum have been identified as copies of his statue of Euthymus.

See Waldstein in *J.H.S.* i, 168; E. A. Gardner, *Handbook of Greek Sculpture* (London, 1915).

PYTHEAS, of Marseille (*Massilia*), Greek navigator and geographer, was probably contemporary with Alexander the Great; his work is lost, and consequently its form and character are not known, but the various titles under which it is quoted (*e.g.*, *Γῆς περίοδος*, or *Τὰ περὶ τοῦ Ὠκεανοῦ*) point to a geographical treatise, in which Pytheas had embodied the results of his observations, rather than to a continuous narrative of his voyage.

Some modern writers supposed Pytheas to have been sent out, at public expense, by the republic of Massilia; but there is no ancient authority for this, and Polybius states that he had undertaken the voyage in a private capacity and with limited means. All that is known concerning the voyage of Pytheas is contained in a brief passage of Polybius cited by Strabo, according to which Pytheas had not only visited Britain, but had "travelled all over it on foot," and estimated its circumference at more than 40,000 stadia (4,000 geographical miles). To this he added the account of Thule (which he placed six days' voyage north of Britain)

and the adjoining regions. After this he visited "the whole of the coasts of Europe" (*i.e.*, those bordering on the ocean) as far as the *Tanais*. Some modern writers suppose that he made two different voyages, but this is improbable; the expressions of Polybius imply that his explorations in both directions, first toward the north and afterward toward the east, formed part of the same voyage.

The countries visited by Pytheas, were previously unknown to the Greeks and were not visited again for two centuries. Thus some of the later Greek geographers altogether disregarded his statements, and treated his voyage as a fiction. In modern times a critical examination has been more favourable and the tendency of modern critics has been to exaggerate the value of Pytheas's work. Speculation has dealt chiefly with his "Thule," believed differently to be Norway, Iceland, or the Shetlands; and "Cassiterides" (Tin islands, perhaps St. Michael's mount in Cornwall).

Pytheas had one special merit; he was a good astronomer, and was one of the first to fix latitudes. His calculations of the length of the longest day at four different points in the neighbourhood of Britain are probably based on native reports. If these figures (16, 17, 18 and 19 hr.) are to be pressed, they would refer to, say, Ushant (48° N.), Flamborough Head (54°), Tarbet Ness in Ross (58°) and the northernmost Shetlands (61°). Pytheas was also the first among the Greeks to arrive at any correct notion of the tides, and to note their connection with the moon, and their periodical fluctuations. Other observations concerning the manners and customs of the inhabitants of remote northern regions prove that he had himself visited them. Among these are the gradual disappearance of various kinds of grain as one advanced northward; the use of fermented liquors made from corn and honey; and the habit of threshing out corn in barns, instead of on open threshing floors as in Greece and Italy.

BIBLIOGRAPHY.—The fragments of Pytheas have been collected by Arvedson (Uppsala, 1824), and by Fuhr (*De Pythea massiliensi*, Darmstadt, 1835). Of the numerous treatises on the subject, *see* Ukert, "Bemerkungen über Pytheas," in vol. i of his *Geog. d. Griechen u. Römer*, pp. 298–309, which contains an excellent summary of all that is known concerning Pytheas; Sir George C. Lewis, *Historical Survey of the Astronomy of the Ancients*, pp. 466–480 (London, 1862); Sir Edward H. Bunbury, *History of Ancient Geography*, vol. i, ch. xv, § 2 (1883); C. I. Elton, *Origins of English History*, *cf.* especially app. i, pp. 400 ff. (1882); Hugo Berger, *Geschichte der wissenschaftlichen Erdkunde der Griechen*, pt. 3, 2nd ed. (Leipzig, 1903). An elaborate investigation of the subject will be found in Müllenhoff, *Deutsche Alterthumskunde*, i, 211–497 (1870). *See* also Sir Clements Markham's paper, "Pytheas, the Discoverer of Britain," in the *Geographical Journal* (June 1893); and H. F. Tozer, *History of Ancient Geography*, pp. 152–164 (Cambridge, 1897).

PYTHIAS, KNIGHTS OF, a fraternal and benevolent order of secret character, founded in Washington, D.C., Feb. 19, 1864, and chartered by a special act of congress. At mid-20th century the order maintained 56 grand lodges or grand domains in the states of the United States and in provinces of Canada. There were also about 3,000 local or subordinate lodges, including lodges in Hawaii. The governing body is the Supreme Lodge. There were four recognized auxiliary bodies, the military department, the Dramatic Order Knights of Khorassan, the Junior Order Princes of Syracuse and the Pythian Sisters which, founded in 1888, was open to all women relatives of members of the Knights of Pythias.

PYTHIS or **PYTHIUS,** one of the most noted Greek architects of the later age. He cultivated the Ionic style, in which he constructed the temple of Athena at Priene. The dedicatory inscription, which is in the British Museum, records that the founder was Alexander the Great. Pythis also made a great marble quadriga which surmounted the mausoleum.

PYTHON, a snake of the family Pythonidae, and more especially any one of the species of the genus *Python*. The snakes of this genus are large, and its various species are found throughout the tropics of the old world. The snakes of the python family are distinguished from the boas (*q.v.*), with which they are often confused, by the presence of the supraorbital bone in the skull. As in the boas, vestiges of the hind limbs are present, visible externally as a pair of claws adjacent to the anal cleft. The teeth are strong and adapted for catching and holding the prey. There is no venom or venom-conducting apparatus.

Killing of the prey is effected by constriction; one or more coils of the body are thrown around the victim, following up the stroke of the head, and pressure is applied by the powerful body muscles. The pressure exerted by a large python must be terrific. The prey is killed, however, by suffocation rather than by any actual crushing of the ribs. During the swallowing process much saliva is secreted, and should the prey be disgorged, as may happen if the snake is disturbed, it will be found to be covered with this secretion. This evidently accounts for the fable that pythons cover their prey with saliva before swallowing it.

There can be no doubt that large pythons are strong enough to kill an animal the size of an ox, but stories of their killing and eating cattle and horses are not to be credited. The prey is swallowed whole, and though the mouth is greatly distensible, it cannot be stretched beyond the calibre of a moderate-sized pig. Authentic accounts of attacks on man are extremely few.

Most pythons are partly arboreal and are likely also to be found in the vicinity of water, in which they lie and soak. Reproduction is by means of leathery-shelled oval eggs, of which there may be a hundred or more in a clutch. The eggs are laid in a heap and are guarded and incubated by the mother, who coils herself around them, and who is known from observation in zoological gardens to have a higher body temperature than the surrounding air while so occupied.

The largest species is the reticulated python (*Python reticulatus*) of the Malay region, which occasionally reaches a length of 30 ft. The Indian python (*P. molurus*) is frequently seen in zoological gardens, as is the African rock python (*P. sebae*). Other members of the python family include the remarkable arboreal green python of New Guinea (*Chondropython viridis*) and various other Australasian types. Two species (*Loxocemus*) inhabit western Mexico, as the only American members of the family. (H. W. P.; K. P. S.)

PYTHON, a huge serpent, nameless and female in the earliest account (*Hymn. Homer* iii, 300 *et seq.*), which was killed by Apollo at Delphi (older name Pytho), either because it would not let him come near the oracle—in one version (Hyginus, *fab.* 140), it used itself to give oracles—or because it persecuted his mother Leto during her pregnancy. It is generally said to be the child of Earth (Hyg., l.c.), and in all probability is to be connected with the reliable tradition (*e.g.*, Aesch., *Eumen.*, 1–8) that there was an oracle of Earth at Delphi before Apollo came.

In Hellenistic belief, a python was a spirit which possessed certain persons and prophesied unknown to them through their mouths (Hesychius, *q.v.*).

See Farnell, *Cults of the Greek States*, iii, 9; iv, 180; also Preller-Robert, i, 239.

PYTHONOMORPHA, the mosasaurs, a group of large marine lizards of Upper Cretaceous age. (*See* REPTILES.)

PYX, a term for various forms of receptacles (Gr. πυξίς, a box or chest). In ecclesiastical usage it is the sacred vase or tabernacle in which the Host is reserved. In the English mint the pyx is the chest in which are placed one coin from every 15 lb. of newly coined gold and one from every 60 lb. of newly coined silver to await the "trial of the pyx" (*see* MINT). This chest was formerly kept in the Chapel of the Pyx in Westminster abbey.

Q THIS letter corresponds to Semitic ϕ (*koph*) and Greek ϙ (*koppa*). The form of the majuscule has been practically identical throughout its known history. In the form found on the Moabite stone the vertical stroke extended to the top of the loop and the same is the case with an early form ϕ from the island of Thera. The Etruscan form was identical with the Greek. The letter did not occur in the Ionic alphabet. The Latin alphabet had two forms Ϙ and Q.

In the minuscule form the stroke has moved to the right side of the letter owing to the speed of writing. This produced the cursive form ϙ occurring in the 6th century A.D. Uncial writing also had the form ϙ and the Carolingian form was practically identical.

In Semitic the sound represented by the letter was an unvoiced guttural pronounced further back than that represented by the letter *kaph*. In Greek the letter was largely redundant, and in the eastern alphabet was entirely superseded by *kappa*.

NAME OF FORM	APPROXIMATE DATE	FORM OF LETTER
PHOENICIAN	B.C. 1,200	ϕ
CRETAN	1,100-900	ϕ
THERAEAN	700-600	ϕ
ARCHAIC LATIN	700-500	Ϙ
ATTIC	600	ϙ
CORINTHIAN	600	ϙ
CHALCIDIAN	600	Ϙ
IONIC	403	Ϙ
ROMAN COLONIAL	PRE-CLASSICAL AND CLASSICAL TIMES	ϙ
URBAN ROMAN		Q
FALISCAN		V Ↄ
OSCAN		? Ↄ
UMBRIAN		? Ↄ
CLASSICAL LATIN AND ONWARDS		Q

THE DEVELOPMENT OF THE LETTER "Q" FROM THE EARLIEST TIMES

In the Chalcidic alphabet it lingered and was taken over from this into Latin, where it became stereotyped for use only before the letter U in words in which the unvoiced labio-velar occurred, represented by the combination of these letters. The combination of these two letters holds to the present day, and in modern English Q is not used unless followed by U, even if, in words such as *oblique*, the sound is a simple velar and not a labio-velar. The most usual position of the sound is initial in words such as *queen, quick*. Q is used apart from U only very rarely in words of foreign origin, especially to represent a Semitic guttural, as in Qabala, 'Iraq. (B. F. C. A.)

QABES: *see* GABES.

QAIN is the administrative headquarters of the very extensive district of Qainat, the southeastern portion of the province of Khurasan in Iran. This district has the province of Kerman on the south and extends eastwards to the frontier of Afghanistan. The region in which Qain is situated consists mainly of a complicated system of hill ranges of mean elevation 4,000 ft. running north to south and sinking down in the south to the Seistan basin. It is without perennial rivers, the drainage flowing westward to the Dasht-i-Lut. The rainfall is greater than that of Kerman province, which has an average fall of 4.7 inches, and the population depend largely on *deimi* crops, *i.e.*, those which are not artificially watered. Great numbers of camels are reared and the principal products are grain, saffron, wool and opium; the asafoetida plant also grows very profusely.

The town of Qain is situated about 200 mi. south of Meshed on the excellent main road to Zahidan (Duzdab), in a broad valley, in 33° 42′ N., 59° 8′ E., at an elevation of 4,500 ft. The population is variously estimated at 5,000–15,000; the town, surrounded by a mud wall with bastions in disrepair, appears to have considerably increased in size and importance in recent years, so that the houses of the wealthier inhabitants are found without the walls. The cultivation of saffron is a specialty of the immediate neighbourhood which supplies nearly the whole of Iran with this commodity. The chief industries are the making of felts and carpets, but the best Qaini carpets are made at Darakhsh northeast of Birjand. Southeast of the town, on the summit of two hills rising 500 ft. above the valley, are the ruins of a great fort about 600 yards in length. Qain is undoubtedly a place of great antiquity and chequered history. The present town was built by Shah Rukh to replace an older town which he is said to have destroyed. After a time the Uzbegs took possession of and held the place until Shah Abbas I (1587–1629) expelled them. In the 18th century it fell under the sway of the Afghans and was a dependency of Herat until 1851.

See P. M. Sykes, "A fourth journey in Persia, 1897–1901," *Geogr. J.* (1902) xix, pp. 119–73; *see* also KHURASAN. (P. Z. C.; X.)

QAIRWĀN (KAIROUAN, KAIRWAN), the sacred city of Tunisia, 36 mi. southwest from Sousse, and about 80 mi. due south from Tunis. Qairwān, in shape an irregular oblong, is surrounded by a crenellated brick wall with towers and bastions and five gates. The city, however, spreads beyond the walls, chiefly to the south and west. Some of the finest treasures of Saracenic art in Tunisia are in Qairwān. The chief buildings are the mosques, which are open to Christians, Qairwān being the only town where this privilege is granted. It is served by a branch of the metre-gauge railroad from Kasserine to Sousse.

In the northern quarter stands the great mosque founded by Sidi 'Oqba ibn Nafi, containing his shrine and the tombs of many Tunisian rulers. It was several times rebuilt; that which subsists dates from the period of the Aghlabites (3rd century of the Hegira, 9th century of the Christian era). Like the primitive mosques of Islam, it consists of a rectangular hypostylar hall preceded by a courtyard surrounded by porticoes on all sides. The gateway on the N.E., named the gate of Lella Rejana, is preceded by a beautiful square porch, decorated with ancient columns. In the middle of the northern side of the courtyard rises a massive square minaret.

The Mosque of Sidi 'Oqba is the prototype of many other notable mosques. (*See* MOSQUE.) Of greater external beauty than that of Sidi 'Oqba is the Mosque of the Three Gates. Cufic inscriptions on the façade record its erection in the 9th and its restoration in the 15th century A.D. Internally, the mosque is a single chamber, supported by 16 Roman columns. One of the finest specimens of Moorish architecture in Qairwān is the *zawia* of Sidi Abid-el-Ghariani (d. *c.* A.D. 1400), one of the Almoravides, in whose family is the hereditary governorship of the city. The entrance, a door in a false arcade of black and white marble, leads

into a court whose arches support an upper colonnade. The Mosque of the Companion (*i.e.*, of the Prophet), outside the walls to the northwest, is also important. This mosque is specially sacred as possessing what are said to be three hairs of the Prophet's beard, buried with the saint, who was one of the companions of Mohammed. (This legend gives credence to the belief that the tomb contained the remains of Mohammed's barber.) The mosque consists of several courts and chambers, and contains some beautiful stained glass.

The town is the centre of fairly active trade and industry, especially in leather goods and carpets. Its suks are interesting but less important than those of Tunis. The town in 1936 had a population of 22,991, of whom 21,902 were Moslems.

The legend says that 'Oqba in A.D. 671 (A.H. 50) determined to found a city as a rallying point for the followers of Mohammed in Africa. He led his companions into the desert and, having exhorted the serpents and wild beasts, in the name of the Prophet, to retire, he struck his spear into the ground exclaiming "Here is your Qairwān" (resting place), so naming the city. In the 8th century Qairwān was the capital of the province of Ifrikia. Later it became the capital of the Aghlabite princes, thereafter following the fortunes of the successive rulers of the country. (*See* TUNISIA: *History.*) After Mecca and Medina, Qairwān is the most sacred city in the eyes of the Mohammedans of Africa, and constant pilgrimages are made to its shrines.

In World War II, the axis took over, in Nov. 1942, the railway and important adjacent airfields which were subjected to Allied bombing. The British 1st army, re-enforced by U.S. troops, took the city on April 11, 1943.

See Murray's *Handbook to Algeria and Tunis,* by Sir R. L. Playfair (1895); H. Saladin, *Tunis et Kairouan* (1908); Georges Marcais, *Manuel d'art Mussulman,* Tome I (1926). (P. W. I.)

QAIS, an island in the Persian gulf lying about 10 m. off the mainland of Iran in 54° E.; it is the site of a trade emporium of great importance in former times. The island measuring 10 m. by 5 m., rises 120 ft. above sea level to a plateau and is bare of vegetation except for small patches of cultivation and a few date groves and stunted herbage. It is surrounded by a reef and pearl banks. The normal population is estimated at about 2,000 chiefly Arabs of the Al Ali tribe, who largely engage in pearl fishing.

Qais is an arabicized form of the Persian Kish; and is the Kataia of Arrian. In the Mohammedan period it formed a part of the province of Fars, but it was only in the later middle ages that the place attained importance, when a prince of South Arabian origin obtained possession of it, built a fleet there, and gradually extended his power. He captured Siraf (modern Tahiri 27° 40′ N., 52° 20′ E.) which was then the principal emporium of the Persian-Indian-Chinese trade. Siraf gradually—in the first half of the 11th century—became more and more deserted under the suzerainty of the princes of Qais, as they diverted the very considerable trade from the captured Persian sea-port to their own island, and finally Qais supplanted Siraf.

At its period of greatest power, the dynasty of Qais also ruled over the district of Oman on the opposite Arabian shore. The Rabbi Benjamin of Tudela visited Qais between A.D. 1164–73, and noted the rich market of the island whose chief business was the exchange of Persian, Mesopotamian, Arabian and Indian manufactures and produce. The site of the old city is marked by the ruins known as Harira on the north coast. Qais in turn lost its importance—for what reason is not precisely known—somewhere in the 14th century, and its trade passed to Hormuz.

See W. Ouseley, *Travels in various countries of the East,* vol. i. (1819); A. W. Stiffe, "Ancient trading centres of the Persian Gulf. Kais." *Geogr. J.,* 1896, VII.; A. T. Wilson, *The Persian Gulf* (1928). (P. Z. C.)

QARAITES or **KARAITES** (Hebr. *Benē Miqrā',* sons of the Scripture), a mediaeval Jewish sect claiming to return to primitive Judaism by restoring the Scriptures to their rightful place now usurped by tradition (the Oral Law). Neither historically nor spiritually have they any connection with the Sadducees, the Samaritans or with Schechter's Jewish Sectaries of Damascus. Karaism was an anti-Rabbinic religious innovation prompted by politics, but the Karaites have always endeavoured to prove their antiquity and to trace their origin to former sects that had existed and decayed before Karaism arose. The founder, Anan ben David of Baghdad, in 760 claimed to succeed Isaac Iskawi his uncle as Exilarch, but the *Geōnim* (*see* GĀON) ultimately chose Anan's younger brother Josiah, whose appointment was confirmed by the Caliph al-Manṣūr. Anan proclaimed himself as anti-exilarch and succeeded in enlisting the support of various sects such as the Isawites, the Yudganites and the Shadganites. This act on the part of a *dhimmi* in Islam was treasonable. In 767 Anan was arrested but saved from execution by the advice of a fellow-prisoner, the famous Abu Hanifa. Anan pleaded that his was a new religion which venerated Islam and followed Muslim law in many ways, *e.g.,* in fixing the calendar by observation instead of by calculation. In 770 he published his code (*Ṣēfer ham-Miṣwōth*). Ultimately he led his followers to Jerusalem, whence they spread over Egypt, Syria and S. Russia. They have never been numerous and now number about 14,000.

The chief points of difference with the Rabbanites were the calendar, Sabbath and marriage laws. Karaism had a great effect on the body of Judaism: polemics stimulated learning. Sa'adya of Fayyum was one of the notable scholars who challenged Karaite exegesis. The Karaites possessed a number of scholars of considerable distinction, especially in the direction of Hebrew philology, biblical exegesis (*e.g.,* Yepheth ibn 'Ali) and philosophy of religion (*e.g.,* Isaac b. Abraham Troki, 1533–1594, author of the *Ḥizzūq 'emūnah*). Their liturgy is jejune, being composed almost entirely of scriptural excerpts and possessing practically no hymns. Nevertheless this constitutes no general reflection on Karaite intellectualism. No movement can be considered barren from the literary standpoint that has produced writers such as Benjamin Nahawandi (*c.* 850), Abu Yusuf al-Qirqisani (tenth cent.) and his contemporaries Sahl ibn Maṣliaḥ, Solomon ibn Yeroḥam, Yusuf ibn Nuḥ, Aaron ben Elijah of Nicomedia (b. 1300), Elijah ben Moses Bashyazi (1420–90), Caleb Afendopoulo (end of 15 cent.) and, latterly, Abraham Firkovitch (1786–1874). The latter dimmed his splendid reputation for scholarship and lowered the value of his enormous archaeological activity by partisan conduct. He discovered in the Crimea very many mss. and tombstones of considerable antiquity but he tampered with the dates and colophons to prove the age of the Karaites and their claims to represent true Judaism. Largely owing to his efforts, the Karaites were exempt from the religious persecution from which the Russian Jews (Rabbanites) suffered. A notable controversy arose in consequence of his discoveries, which were more or less categorically impugned by H. L. Strack and A. Harkavy (lit. *s.v.* Firkovitch in *Jew. Enc.*) but upheld (with reservations) by D. Chwolson (*Corp. Inscrip. Hebr.,* St. Petersburg, 1882). The recent Masoretic researches of Paul Kahle (e.g., *Masoreten d. Westens,* Stuttgart, 1927: *Hebr. Bibelhandschriften aus Babylonien,* Giessen, 1928) incline to the latter view.

BIBLIOGRAPHY.—*See* the various articles in *Jew. Enc.* and Hastings' *E.R.E.* and articles in *Jew. Quart. Rev.*

QARO (or CARO), **JOSEPH BEN EPHRAIM** (1488–1575), codifier of Jewish law, whose code is still authoritative with the mass of Jews, was born in 1488. As a child he shared in the expulsion from Spain (1492), and like most prominent Jews of the period was forced to migrate from place to place. In 1535 he settled in Safed, Palestine, where he spent the rest of his life. Safed was then the headquarters of Jewish mysticism. Qaro's mysticism did not take the form of a revolt against authority, but was rather the spiritual flower of pietism. It is, however, as a legalist that Qaro is best known. In learning and critical power he was second only to Maimonides in the realm of Jewish law. He was the author of two great works. In the earlier and greater book, in the form of a commentary (entitled *Beth Yoseph*) on the *Turim* (*see* 'ASHER BEN YEHIEL) designed exclusively for specialists, Qaro shows an astounding mastery over the Talmud and the legalistic literature of the middle ages. He felt called upon to systematize the laws and customs of Judaism in face of the disintegration caused by the Spanish expulsion. But the *Beth Yoseph* is by no means systematic. Qaro's real aim was

effected by his second work, the *Shulḥan 'Arukh* ("Table Prepared"). Finished in 1555, this code was published in four parts in 1565. The work gradually became the almost unquestioned authority of the whole Jewish world. Its influence was to some extent evil. It "put Judaism into a strait-jacket." Independence of judgment was inhibited, and the code stood in the way of progressive adaptation of Jewish life to the life of Europe. But its good effects far outweighed the bad. It was a bond of union, a bar to latitudinarianism, an accessible guide to ritual, ethics and law. It sanctified the home, it dignified common pursuits. When, however, the era of reform dawned in the 19th century, the new Judaism assumed an attitude of hostility to Qaro's code.

See Graetz, *Geschichte der Juden*, vol. ix. (English trans. vol. iv.); Ginzberg, in *Jewish Encyclopedia*, arts. "Caro" and "Codification"; Schechter, *Studies in Judaism*, second series, pp. 202 *seq.*

QENA, a town of Upper Egypt on a canal about a mile E. of the Nile and 380 mi. S.S.E. of Cairo by rail. Pop. (1937) 34,431. Qena, the capital of a province of the same name, was called by the Greeks Caene in distinction from Coptos, 15 m. S., to whose trade it eventually succeeded. That its modern name should be derived from a purely Greek word seems to point to Qena having originated in a foreign settlement in connection with the Red Sea trade. It is a flourishing town, specially noted for the manufacture of the porous water jars and bottles used throughout Egypt. Its trade in grain and dates with Arabia is all that is left of the extensive commerce formerly maintained between Upper Egypt and India and Arabia.

QISHM, styled by the Arabs as *Jazirat-at-Tawilah* or Long Island, the Oarakta of the ancients, the largest island in the Persian gulf, is in the Strait of Ormuz and separated from the mainland of Iran by Clarence strait, 2 to 15 mi. in width. The island has an extreme length of 68 mi. and average breadth of 10 mi. and is composed of table-topped hills rising to 560 ft. with one peak attaining 1,300 ft. The range on the south is largely composed of rock salt, which is quarried at Namakdan and other places and forms one of the main products. In general aspect the island is parched and barren, but there are fertile patches of cultivation near the villages, producing grain, grapes, dates and melons. The climate is trying to Europeans from May to October.

The total population, mainly of Arab origin, is estimated at 15,000. The chief town is Qishm (pop. 3,000) on the northeastern point, a well-built Arab village which was partially destroyed by earthquake in 1898. It carries on a small coasting trade which (including that of Hanjam island) amounted to 6,300 tons in 1925–26, mainly in fish, fruit and salt. Borings for oil were made by the Anglo-Persian Oil Company during the years 1914–1922 but without result. A light buoy with a flashing light is moored about a mile east of the Portuguese fort, now in ruins. The administration is in the hands of a *shaikh*, an Arab of the Bani Ma'in, who has executive powers under the Iranian authorities.

Basidu, known to British sailors as "Bassadore" is on the northwestern extremity of Qishm, exposed to all winds. The site was ceded to the British Crown in 1817, having been selected, after the suppression of piracy, as a base for the naval squadron responsible for keeping order in the Persian gulf and protecting trade. The station was abandoned in 1823.

QOSEIR, EL, a port on the west coast of the Red sea, just north of latitude 26° north. Not only is this place opposite the region in which the Nile comes nearest to the Red sea but between the Nile and El Qoseir is the Wadi Hammamat, with more water than have the valleys farther south. This district (anciently Rohanu) is rich in diorite, which was quarried for building the great monuments of ancient Egypt and, at least from the days of the 18th dynasty, a caravan route (about 120 m.) left the Nile at Qubti (Coptos), afterwards superseded by Qus and then by Qena, north of Thebes, making for the Red sea where the port of Tuâu (the old El Qoseir) was in use at first, but was later superseded by Sav (El Qoseir) 3 m. to the south-east. It was thence that Egypt sent its ships to Punt for spices, perfumes, gold, incense, ivory, skins, scented woods and precious stones. The town stands on a beach with a coral reef in front giving shelter to small craft; larger ships have to anchor outside.

QUACKERY, the pretensions or practice of a boastful pretender to skill which he does not possess, especially medical skill. Although this dictionary definition does not attach the condition that the quack practises for gain, such is usually the fact.

The existence of quackery pre-supposes four factors (1) an evil, usually an obstinate disease, (2) a sufferer from such an evil, (3) a person—the quack—who claims special knowledge or power to cure the particular evil, (4) a person—the orthodox medical practitioner—who holds out little or no hope of cure. Inasmuch as the sufferer has no knowledge whether the quack or the orthodox practitioner is more justified in his statement and is anxious to leave no stone unturned to be rid of his trouble, there is small cause for wonder that the quack has a great following. Other factors play a part, the desire for cheapness, for the quack medicine or treatment can be obtained—at all events in the first instance—at a relatively low price; rebellion against authority especially when authority gives an unpleasant decision; the hope which, as in the old fable, lies at the bottom of Pandora's box of human ills; the element of mystery which the quack usually employs; the natural repugnance to surgical operation when such is the only remedy recognized by the orthodox practitioner; the desire for secrecy particularly in respect of venereal disorders. It may be imagined from the foregoing that such diseases as cancer, venereal diseases, kidney and bladder complaints, diseases of the skin and respiratory tract, chronic rheumatism, chronic indigestion supply the largest proportion of the quack's clientèle; still, no common disease is free from a fringe of quackery.

The agents employed by quacks in various ages repeat themselves. In the case of cancer, the same chemical substances, the same corrosives have been employed, the same articles of diet have been inculpated over and over again. And though the agents have been shown repeatedly to be useless—even injurious—they come daily under the notice of those whose duty it is to investigate suggested cures and causes of cancer. Other agents are vegetable substances often derived from distant and little occupied parts of the world, called by local names, and for the most part unrecognizable by botanists. The tendency to repetition is unjustifiably taken by the public as a sign of their efficacy in the face of medical antagonism, whereas the truth is that the agents lend themselves to the secrecy which is one of the characteristics of the cancer curer and to the production of a medicine or ointment which can be sold at a price. It is a common story that the "cure" has been handed down from parent to child through many generations and often that it has been imparted to the present owner in return for some remarkable service.

Besides the use of chemical and vegetable substances the quack often turns to profitable account the current scientific tendency of the day. With the advance in knowledge of electricity he builds up what he terms a special form of electrical treatment and though his apparatus may be of the crudest kind and unable to generate electricity in appreciable quantity, the mystery attaching to his method of treatment and the pseudo-scientific language which he employs are not without effect upon the mind of the patient who is already more than half convinced in his favour. Similarly, with the discovery of radium, so-called radium treatments were devised for many complaints in which the amount of radium concerned was in the region of the limit of detectability. In the case of chronic rheumatism "magnetic belts," which give no more than a barely detectable electric current, have been recommended widely, as well as radium plasters which in all contained perhaps a thousandth of a milligram of radium. When it is recognized that the commercial value of such an amount of radium at current prices would be under twopence, the profitable side of such a variety of treatment becomes obvious.

The quack relies largely upon advertisement in newspapers and magazines and most publications of repute exercise scrupulous care in the admission or total exclusion of such advertisements. He is aided, too, by the reluctance of those who have consulted him with disadvantage to acknowledge their action and by the magnification of his successes or apparent successes. Moreover, his powers of diagnosis are negligible and upon strict examination a case of cancer, for example, reported to have been cured always

fails because there is no evidence, either that the case was truly cancer or else that it was truly cured. The one requires microscopical evidence, the other the lapse, according to medical standards, of a period of years—three, five or more.

Quackery flourishes in certain parts more than others. In respect of cancer the mining districts of Northumberland, Durham and South Wales, South Africa, Australia and to a less extent Canada are the source of the greater number of so-called "cancer cures" met with in England, but the proportion is trivial compared with what occurs in Prussia, where it is said that there is one quack to every three orthodox medical practitioners. Recourse to quackery is not the foible of any particular class of society and is compatible with a high level of general intellect. In the case of the wealthy and intelligent it is difficult to feel sympathy for the sufferer in his action, but for the poor and ill-educated who often waste time and money only to find themselves at the end in a hopeless condition, sympathy is great. Yet it is difficult to see how they can be safeguarded. Legislation with regard to quacks and their medicines varies in different countries. In England they are liable if they hold themselves out to be recognized medical practitioners or if death occurs in a person whom they are treating. On the other hand the law considers that a person consults a quack at his own risk; it does not actually forbid the quack from giving advice though he cannot charge for that advice; as a result the financial side is represented by the sale of ointments, apparatus, etc. Elsewhere (*e.g.* in Prussia) legislation has been tried and has failed. The real remedy lies in advancement of medical knowledge and in education.

A word may be said on patent medicines the sale of which is great in all countries. In England they pay a duty but otherwise their sale is unrestricted though limits are imposed upon their composition. The British Medical Association for years has made a practice of analysing patent medicines and attaching to the report of their composition a statement as to the cost of the ingredients; all return to the proprietor a very large margin of profit. Copies of the reports issued from time to time are published under the authority of the Association. Many of these patent medicines are harmless, some are useful; actual fraud, as a rule, is absent. This cannot be said for the quack and his wares.

(W. S. L.-B.)

In the United States the outstanding quacks are located in the large cities; mail-order quackery, like the mail-order house has grown tremendously and it requires a large staff of agents of the post office to make even the slightest inroads on this form of fraud. After some four years of battling in the courts the post office may issue a fraud order against such concerns denying them the use of mails, whereupon they dispose of their wares over the counters of drug stores, and promote them through advertising in the press. Although leading newspapers refuse to carry fraudulent advertisements of cancer and tuberculosis cures, they still carry all sorts of nostrum advertising for coughs, colds, rheumatism and similar complaints.

The use of the testimonial is fundamental to quackery and its advertising. Testimonials, obtainable at a price, have become a current feature in the trade.

In the headquarters of the American Medical Association is a bureau of investigation which carefully investigates the claims made for all new methods of medical treatment. Here is a card index containing 125,000 cards cross-indexing the various forms of quackery practised in the United States. In each of the 48 States there are different laws regulating the practice of medicine; hence quackery varies in each State according to the limits permitted by law. In some States quackery is limited almost entirely to the sale of medicines of secret composition and with claims not justified by the content. In other States quackery is rampant, including not only the sale of patent medicines but the operation of healing institutions conducted by quack doctors, all of the 40 or 50 forms of religious and faith healing, healing by conjuring and by charms, the practice of systems of healing such as chiropractic, naturopathy, naprapathy and similar methods. (M. Fr.)

QUACK-GRASS (*Agropyron repens*), a perennial grass of the barley tribe (Hordeae), called also couch-grass or quitch-grass. It is native to Europe, common in northern Europe and widely naturalized in North America. Quack-grass has bright-green, smooth, stiffly erect stems, 1 to 4 ft. high; leaves with flat or inrolled blades; and terminal flowering spikes, 2 to 6 in. long, composed of numerous, usually five-flowered spikelets, which often bear short awns. Sometimes it is grown for forage, but it is better known as a troublesome weed in cultivated fields, especially on rich soil, spreading rapidly by its extensively creeping greenish-yellow rootstocks. The best method to eradicate it is to plow the land, after it has been left in sod two or more years, just after the flowers appear and harrow at weekly intervals for about 6 weeks.

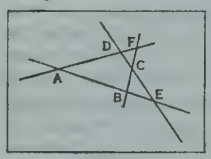
BY COURTESY OF THE IOWA GEOLOGICAL SURVEY

QUACK-GRASS (AGROPYRON REPENS)

QUADRATRIX: *see* CURVES, SPECIAL.

QUADRATURE (from Lat. *quadratura*, a making square), in astronomy, that aspect of a heavenly body in which it makes a right angle with the direction of the sun; applied especially to the apparent position of a planet, or of the moon at first and last quarters. In mathematics, quadrature is the determination of a square equal to the area of a curve or other figure. Integration by quadratures means calculation by a step-by-step process when no analytical expression for the integral is available.

QUADRILATERAL, in geometry, a figure formed by four straight lines. It is said to be plane or skew according as the four lines do or do not lie in one plane. Quadrilateral is also a military term applied to a combination of four fortresses mutually supporting each other. The most famous military quadrilateral was that of the four fortified towns of north Italy—Mantua and Peschiera on the Mincio, and Verona and Legnago on the Adige. This quadrilateral gave Austria a firm hold on Lombardy.



Let us consider the plane figure bounded by four lines terminated at the vertices. A line joining a pair of opposite vertices is called a diagonal. The area of such a quadrilateral is half the product of the length of one diagonal by the sum of the perpendiculars drawn to this diagonal from the other two angular points. The sum of the squares of the four sides of such a quadrilateral is equal to the sum of the squares of its diagonals increased by four times the square of the line joining the midpoints of the diagonals. If the vertices of such a quadrilateral lie on a circle, the product of the diagonals is equal to the sum of the products of the opposite sides.

It is in projective geometry that the quadrilateral plays its most interesting rôle. If *A, B, C, D* are four points in a plane no three of which are collinear, then the lines *AB, BC, CD, DA*, each taken to be of indefinite extent, form a quadrilateral. These sides intersect in pairs not only in the four given points (called vertices) but also in a point *E* on both *AB* and *CD*, and in a point *F* on both *BC* and *AD*. The points *E* and *F* are also called vertices. Then each side of the quadrilateral contains three vertices. Two vertices not on the same side are called opposite. A line joining two opposite vertices is called a diagonal. The configuration so described is called a complete quadrilateral. The dual figure is called a complete quadrangle. These figures are of fundamental importance in projective geometry (*q.v.*).

QUADRILLE, the name of a game of cards and of a dance. The game, played by four persons with a pack of forty cards, was a variation of the Spanish game of ombre and superseded it in popularity about 1725, to give way in turn to whist. The dance is of French origin and is usually danced by four couples in square. In the 18th century the *contredanse* was introduced into the ballet,

and groups of four, eight or twelve dancers dressed alike performed different figures; these were first called *quadrilles des contredanses*, later shortened to *quadrilles*. Later the dance became popular outside the ballet, and its figures, five in number, with a finale, bore the names of the different *contredanses, Le Pantalon, l'Été, La Poule, La Trénitz, La Pastourelle.*

QUAESTOR (Lat. *quaerere*, to investigate), a Roman magistrate whose functions, in the later times of the republic, were principally financial, although he was originally concerned with criminal jurisdiction. The quaestorship was probably instituted in 509 B.C. simultaneously with the consulship. The number of quaestors, originally two, was successively increased until Julius Caesar raised it to 40 (45 B.C.); Augustus reduced it to 20, which remained the regular number under the empire. When the number was raised from two to four in 421 B.C., the office was thrown open to the plebeians.

The quaestorship was the lowest of the great offices of State, and hence it was the first sought by aspirants to a political career (*cursus honorum*). The candidate was bound to have completed his 30th year before he entered office, but Augustus lowered the age to 25. Quaestors were elected by the *comitia tributa* (*see* COMITIA) under the presidency of a consul or another of the higher magistrates. They held office for one year, but, like the consuls and praetors, they were often continued in office. Indeed, it was a rule that the quaestor attached to a higher magistrate should hold office as long as his superior; hence, when a consul presided over the city for one year and afterwards as proconsul governed a province for another year, his quaestor also held office for two years. A peculiar burden laid on the quaestors, as a sort of fee exacted from all who entered on the political career, was the paving of the high roads, for which the Emperor Claudius substituted the exhibition of gladiatorial games.

Various classes of quaestors may be distinguished:—

The Urban Quaestors.—Originally the duties of the quaestors, like those of the consuls, were undefined; the consuls were the superior magistrates of the republic, the quaestors their assistants. From a very early time, however, the quaestors possessed criminal jurisdiction; political crimes only seem to have been excepted. The criminal jurisdiction of the quaestors appears to have terminated only when trial by permanent courts (*quaestiones perpetuae*) was extended to criminal cases.

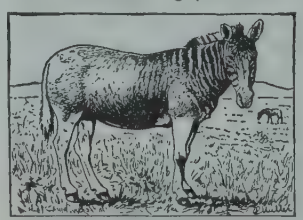
The quaestors had also charge of the public Treasury (*aerarium*, q.v.) in the temple of Saturn, and this was in later times their most important function. They kept the keys of the Treasury and had charge of its contents, the coin and bullion, the military standards, and a large number of public documents, which comprised all the laws as well as the decrees of the senate. Their functions as keepers of the Treasury were withdrawn from urban quaestors by Augustus and transferred to other magistrates.

The Military Quaestors.—These were instituted in 421 B.C. and were clearly distinguished from the urban quaestors by the fact that a non-urban quaestor was assigned as an assistant or adjutant to every general in command, whose name or title the quaestor usually added to his own. Originally they were the adjutants of the consuls only, afterwards of the provincial praetors, and still later of the proconsuls and propraetors. The governor of Sicily had two quaestors; all other governors and commanders had but one. Between the quaestor and his superior, a close personal relation existed, and was not severed when their official connexion ceased. The duties of the military quaestor, like those of the Treasury quaestor, were primarily financial. Moneys due to a provincial governor from the State Treasury were often, perhaps regularly, received and disbursed by the quaestor; the magazines seem to have been under his charge; he coined money, on which not infrequently his name appears alone. But, though his duties were primarily financial, the quaestor was the chief assistant or adjutant of his superior in command, and invested with a certain degree of military power. When the general left his province before the arrival of his successor, he usually committed it to the care of his quaestor, and, if he died or was incapacitated from naming his successor, the quaestor acted as his representative.

The Italian Quaestors.—The subjugation of Italy occasioned the institution (267 B.C.) of four new quaestors, who appear to have been called *quaestores classici* because they were originally intended to superintend the building of the fleet (*classis*); their functions, however, are very imperfectly known.

See Mommsen, *Staatsrecht;* A. H. J. Greenidge, *Roman Public Life* (1901); J. E. Sandys, *Companion to Latin Studies* (1921); W. E. Heitland, *The Roman Republic* (1923).

QUAGGA, an animal of the genus *Equus* (*E. quagga*), allied to Burchell's zebra, formerly met with in vast herds on the great plains of South Africa between the Cape Colony and the Vaal river, but now extinct. The colour of the head, neck and upper parts of the body was reddish-brown, irregularly banded and marked with dark brown stripes, stronger on the head and neck, and gradually becoming fainter until lost behind the shoulder. There was a broad dark median dorsal stripe. The under surface of the body, the legs and tail were nearly white, without stripes. The crest was high, surmounted by a standing mane, banded brown and white.



THE QUAGGA (EQUUS QUAGGA), OF SOUTH AFRICA CLOSELY ALLIED TO THE ZEBRA; NOW EXTINCT

The name is an imitation of the shrill barking neigh of the animal. (*See* ZEBRA.)

QUAHOG: *see* CLAM.

QUAIL, a bird well known throughout Europe, Asia and Africa. The common quail (*Coturnix coturnix*) is variable in colour, but in general is reddish-brown above, marked with dark brown and buff and pale buff below, passing into white on the belly. Essentially migratory, quails breed on the ground, laying 9 to 15 yellowish white eggs, spotted with dark brown. They are very good table birds and immense numbers are netted during the autumn migration across the Mediterranean. Quail is now very rare in Britain, but the numbers fluctuate. It is much the smallest British game bird. It feeds largely on weed seeds, but also eats insects, and is decidedly a beneficial species. Allied species include the rain-quail (*C. coromandelica*) of India; the Australian stubble-quail (*C. pectoralis*); the North American "Bob White" (*Colinus virginianus*); and the Californian tufted quail (*Lophortyx californica*).

The button-quails (*Turnix*) are a somewhat different group, lacking the hind toe in most species. One, *T. sylvatica*, inhabits Barbary and southern Spain; all are confined to the Old World.

QUAIN, SIR RICHARD, BART (1816–1898), Irish physician was born at Mallow-on-the-Blackwater, Co. Cork, on Oct. 30, 1816. After a brilliant career as a student at University college, London, he became assistant physician at the Brompton hospital for diseases of the chest. He served this hospital until his death (March 13, 1898) as full physician (1855–75), and then as consultant. He became physician-extraordinary to Queen Victoria in 1890, and was created a baronet in the following year. Quain's name is remembered by the *Dictionary of Medicine*, the preparation of which occupied him from 1875 to 1882 (3rd ed., 1902).

QUAKERS, originally a cant name applied in derision to the members of the Society of Friends, but now used without any contemptuous significance. It was used as early as 1647, and arose from the physical manifestations of religious emotion characteristic of many early Friends. (*See* FRIENDS, SOCIETY OF.)

QUAKERTOWN, a borough of Bucks county, Pennsylvania, U.S., 38 mi. N. of Philadelphia; served by the Quakertown and Bethlehem and the Reading railways. Pop. (1950) 5,673; it was 5,150 in 1940. It is an agricultural region, and has a number of factories making stoves, hosiery, silk and clothing.

QUALITIES. Primary qualities of matter are, mainly, the spatio-temporal ones, such as shape or motion; secondary ones are the sensible qualities, such as colour or smell. "Tertiary qualities" is a new and convenient term, introduced by Bosanquet, among others, to designate what are commonly called the ultimate values, beauty, goodness, truth.

Primary and Secondary Qualities.—The distinction between primary and secondary qualities is given officially for

British philosophy by Locke (*Essay*, Bk. ii., ch. viii. secs. 9, 10). "Qualities thus considered in bodies are First, such as are utterly inseparable from the body in what estate soever it be; such as, in all the alterations and changes it suffers, all the force can be used on it, it constantly keeps; and such as sense constantly finds in every particle of matter which has bulk enough to be perceived, and the mind finds inseparable from every particle of matter, though less than to make itself singly be perceived by our senses." Locke enumerates: "solidity, extension, figure, motion or rest and number." Secondly, "Such qualities, which in truth are nothing in the objects themselves, but powers to produce various sensations in us by their primary qualities, *i.e.*, the bulk, figure, texture and motion of their insensible parts, as colours, sounds, tastes, etc., these I call secondary qualities." Locke adds that there is a third set of qualities, which are powers to produce changes in other bodies, not merely sensations in us. The distinction of primary and secondary qualities does not originate with Locke. It occurs in Greek philosophy in the doctrine of Democritus: "Sweet and bitter exist by law or convention" (that is, are relative to us); "what exists in reality are the atoms and the void." The atoms, which possess shape and other "primary" qualities, themselves by their density account for such qualities as heavy or hard; but other qualities are the effect upon us of the atoms. Aristotle makes the distinction on a quite different basis, and probably the more valuable one. He distinguishes (*De Anima*, ii., 5) the special sensibles, like colour or taste, which are apprehended by only one sense, from the common sensibles, apprehended by all the senses alike, motion, rest, etc. For modern philosophy, the distinction of primary qualities from secondary ones, in much the same form as Locke's, begins with Galileo, who goes so far even as to say that secondary qualities are but names which we give to things because they excite certain sensations in us (Hoeffding, *Hist. Phil.*, vol. i., p. 183). Locke derived his statement of the distinction from Descartes who, in a famous passage of the *Meditations*, points out how a piece of melting wax changes its colour but always retains extension. Extension he therefore regarded as an essential quality of matter, the sensible qualities being due to us or subjective. Locke puts the matter naïvely in the form, that ideas of figure or motion exactly resemble their original in real things, whereas colour and taste have nothing like themselves in things, and are the work of the mind. As thus drawn, the distinction corresponds to the practice of science and the tradition of the so-called mechanical theory of the world, which has been of such enormous practical value for scientific procedure.

Locke's statement implies that the primary qualities are real and the secondary ones subjective or mental, that is, have no existence apart from the mind; and secondly that the primary qualities are prior in the order of importance and fact to the secondary ones, for the secondary qualities are due to the impingement, however indirect, upon our sense-organs of the primary qualities of the microscopic constituents of matter. Two fundamental questions are therefore raised for philosophy: the relation of the two sets of qualities in respect of reality; are they unequally real, the one independent of the mind and the other dependent on the mind; and secondly their relative status, which of the two is prior in rank in the world of ideas to which they both belong. It is not strange, therefore, that the formulation of the difference between them raises vital questions of philosophy as a whole.

The first question was the immediate interest of Locke's successor, Berkeley, who declared them both to be upon the same level of reality, both being dependent on the mind, or being ideas, that is mental objects. Berkeley had little difficulty in showing first of all that the primary qualities are as much subject to variation with the condition of the observer as the secondary ones; and secondly that the primary ones cannot be experienced apart from the secondary ones—extension must be seen or touched to be experienced. If, then, the secondary ones are mental, so also are the primary ones. Berkeley's contention that both sets are on the same level of reality has been generally accepted by all who have been content to regard both of them as sensible objects. When, as with Kant, a distinction has been readmitted it has been on the ground that extension, for instance, is not a sensible but an *a priori* form of all external sensibles. Granted, however, that they are both on the same level of reality, the primary qualities may still be the more important. But the significance of Berkeley's result for present philosophy lies in this that it leads directly to the question, are the two sets of qualities alike because both are dependent on mind, or because both are equally independent of mind? Now suppose, as simple realism supposes, that what the mind directly experiences is not its ideas but real objects themselves; that instead of holding its objects to be ideas we hold the so-called ideas to be objects themselves; it is still true that primary and secondary qualities are equally real, this time because both are equally independent of mind.

The general metaphysical difficulties of such an idealism as Berkeley's cannot be fully discussed here. But the idealism which has replaced his still declares that reality is experience and even sentient experience (Bradley); and accordingly there is some impatience expressed in either camp when it is asked if secondary qualities are not real. The question still remains whether they are both dependent on mind, or both independent of it. That secondaries are still dependent upon us is maintained even by those realists who urge that, at any rate, they depend if not upon our minds at least upon our bodies, that there would not be colours except there were eyes. The answer made by those realists who maintain that secondaries are as much as primaries independent of mind, is that the bodily organs are instrumental to perception, but are not constitutive, even in part, of the perceived. It is one thing to hold that objects cannot be known without a mind to know them, and another to hold that they owe their existence to mind. The doctrine of behaviourism, which has acquired such strength in American psychology, rests upon the belief that what are called mental acts are nothing but bodily reactions of certain specific sorts to stimulation from objects, and are thus instances of the wider field of organic vital reactions. And some, like the present writer, have expressed the situation for philosophy by saying that in sensation a bodily reaction which is conscious takes place in response to a physical object and that in such action an object or sensum, *e.g.*, a colour, is revealed to the mind. What the exact character of the object in question is may for the moment be deferred.

According to this, secondary and primary qualities alike are independent of mind. An entirely different complexion is put upon the matter in the theory of "neutral monism" advocated by several present philosophers both American (*e.g.*, Holt) and English (*e.g.*, Bertrand Russell). Upon this view the stuff of things is neither material nor mental but neutral; as Bertrand Russell puts it, the mental is more like matter and the material more like mind than is commonly supposed. This doctrine descends from William James who said that physical objects and the ideas of them are but the same thing considered in different relations as, for instance, the same fire may physically destroy a house and mentally suggest the danger of its inhabitants. It is plain that secondary qualities are real on such a view, and that there is no point in asking if they are subjective or objective. Into the grounds of this doctrine there is no space to enter. We may note, however, that it is far closer in its general tendency to idealism as represented by Bradley than it is to any realism which declares that we apprehend objects directly and that we discover what they are in virtue of the specific reactions which the body-mind makes towards them. Without examining neutral monism further we may observe that it stands or falls with its initial statement of experience. When we see a patch of red, it is held that the experience is completely described in the words, a red patch occurs. Is this exact, or must we rather say, I am aware, or there is awareness, of a red patch?

This question must be left, in order to turn to the second question of the order of priority between primary and secondary qualities. No one has ever suggested that the two sets of qualities are upon the same level in this respect. But it is noticeable that in the more recent English philosophy the old priority of the primaries seems to give way to the priority of the secondaries.

Granted that both are equally real, different ways have been adopted of stating their difference. One way is that of G. F. Stout (*Proceedings of the Aristotelian Society,* N.S. vol. iv., 1903–4, p. 153) that "the difference lies in their respective relation to the interaction of material things." The executive order of the material world can be expressed only in terms of the primary and not in terms of the secondary properties of matter. In Bergson's doctrine (*Matter and Memory,* ch. iv.) red differs from the corresponding vibrations in the *tempo* at which the experience is taken by the mind: what at a slower rhythm of *durée* may be apprehended as mechanical vibrations at a faster rhythm is condensed into colour.

But in the important recent philosophy of A. N. Whitehead, although the relative position of the two sets is not discussed as such, the traditional priority of the primaries would seem almost to be reversed in favour of the secondaries. The secondaries are, of course, real. In a happy phrase Whitehead has effectually destroyed the "representationism" inherited from Locke and Descartes by "protesting against the bifurcation of nature into two systems of reality," the one physical, which is not directly known, and the other "which is the byplay of the mind" (*Concept of Nature,* 1920). The world in this philosophy is a world of events, and the simplest events into which the total event which is "the passage of nature" can be resolved are described as "situations" into which "eternal objects," like red or sweet, which are not events, make "ingression." The perception of sense-objects implies a multiple relation into which enter the "percipient event" which is a bodily state, the "situation," the "eternal object" and the surrounding conditions (p. 152). (Compare his *Science and the Modern World,* pp. 99–102.)

The reality of secondary qualities is here not in doubt. The relative position of the primaries and secondaries is not so clear. For space and time on this doctrine are relational, relations between events as thus fully qualified by ingression of eternal objects; and accordingly constructions are framed to describe in terms of concrete events such conceptions as points, areas, volumes, etc.; and the great merit of this procedure is that it starts from concrete events instead of from conceptual entities like points. It is possible thus to define a point by means of all the sets of concrete extensions (*e.g.,* red patches) by which we can approach it. Now, to come to the present question, since space and time are relations between events, they are logically posterior in rank to the events themselves; and it would seem to follow that primary qualities such as geometrical figures, which are enumerated under the head of eternal objects (*Science and the Modern World,* p. 146), are posterior to the secondary qualities which are situated in the events. At least the two sets of qualities appear to be on a different footing. This is, however, not the author's statement but an inference of the writer's, which may be mistaken. We may add that the omission of any analysis or explanation of the vague conception of "relation" makes the whole subject obscure.

A different though allied doctrine, that of the writer (*Space, Time and Deity*), leaves the primary qualities with their traditional priority, while at the same time raising difficulties of its own. According to this view the stuff of the world is space-time itself, that is, pure events, and the qualities or objects, which on Whitehead's doctrine are ingredient into events from the beginning, are said to emerge historically as the web of events within the whole space-time assumes certain complexities of configuration. Primary qualities, such as shapes or numbers, arise within space-time at the earliest level of existence. Subsequently these spatio-temporal configurations assume a certain complexity and we have matter or at least sub-matter. At a higher level of complexity there "emerge" certain material or submaterial configurations, complexes in the end of space-time, which are those conditions of bodies of which we have become aware as colour or taste. The notion of Emergence (*q.v.*) indicates the fact that at certain critical points in the development of the spatio-temporal world, new qualities appear, which are based upon the lower level of existence, and while also equivalent to the lower-level complex are qualified by a new character. So, to take an example from a higher stage of history, a certain complex of chemical and mechanical processes is endowed with the quality life; in the same way as a certain complex of purely spatio-temporal configurations becomes submaterial. Emergence is a term applied by this writer to the large critical novelties only; by Lloyd Morgan it is applied more freely to any change that can be called a change of character. (Whitehead uses the term differently. Since events from the outset are characterized by qualities through the ingression of objects, he speaks naturally of the emergence not of a new quality or "eternal object" but of a new thing through the ingression of a fresh complex of eternal objects.) On this second view, then, secondary qualities emerge from primary ones when those primary qualities, as in material or submaterial things, reach a certain degree and kind of complexity—*e.g.,* when certain motions occur in the body which are propagated in the form of light waves. The grave difficulties, which need not be concealed, in this general doctrine lie in its basis, in its use of the notion of pure event without quality, and its assumption without investigation of geometrical ideas such as point and line.

The Tertiary Qualities or Values raise similar problems, but it may well be doubted whether it is altogether happy to suggest, as the name does, that values belong to things in the same sense as the primary and secondary qualities do. Beauty is the only one of them which belongs directly to things; for truth attaches to propositions, and goodness to actions; and it will be convenient to speak principally of it. It has been held that beauty belongs to the beautiful object itself, a statement which, plausible enough when made of works of art, seems at first only the obvious one to make of a beautiful sunset or any form of natural beauty. Beauty, according to this view, is real and objective like shape or colour. In like manner goodness is held by some to belong to the person or act which is good; and it may be noted that even a writer like Kant treats good as objective though belonging to the intelligible or supra-phenomenal world. The statement that beautiful things have beauty apart from mind is, however, difficult to accept, because in a work of art beauty depends so largely on characters imputed to the work by the artist or the spectator. Thus dead marble looks alive and full of character, or in a picture stable forms are seen, aesthetically, to be in motion, for instance, to be dancing; and in a poem, the words are chosen not merely to describe but to endow: "two voices are there, one is of the sea, one of the mountains," though neither sea nor mountains have voices. There is so far always an element of illusion in art, a character being imputed to the material which it does not possess of itself. Even in natural beauty, the beauty may be seen to depend on selection on our part, or it may be addition; for instance, we may select in the sunset the shades which harmonize, or in the landscape the features which suit our own mood.

It would seem to follow that beauty is really dependent on the mind, and would not exist either in art or nature except for our interference. And it is not difficult to carry this line of reflection further and maintain that goodness and truth are human constructions, as, with respect to goodness, was held by Spinoza. Truth is not so obviously a human invention, but it is, in fact, different from reality itself, though it is guided and controlled by reality. Truth as in science is really a semi-artistic product in which the seeker blends himself with reality and does so by selection. His difference from the artist is that, though he imputes and interprets, he imputes nothing that he cannot verify in the reality. The artist introduces himself into his art giving the work characters which it only has so far as seen with the aesthetic eye. The enquirer who attains truth possesses reality for himself, but he keeps his human imputations out of the product.

The same thing may be concluded from observing that beauty satisfies a specially human impulse which has to make the object which is to satisfy it. Animals, including men, live by using the food which they find; but the impulse to beauty is a creative impulse, which the present writer (*Art and Instinct,* 1927) identifies as the impulse of constructiveness (such as animals and bees

or ants also have) but used without regard to a practical purpose. In the same way truth appeals to an impulse of curiosity, and goodness to a social impulse. The values accordingly possess value because they satisfy these special impulses, and bring a peculiar satisfaction.

Such a conception of beauty and the other values has been held by some critics to be inconsistent with the view that the secondary qualities are independent of mind. If beauty is so dependent, why not colour? The question is really irrelevant, for the same explanation does not necessarily apply to situations which may seem superficially similar. And, as has been indicated, the action in virtue of which we discover colour is entirely different from the creative action by which we become aware of beauty and goodness and truth.

The values therefore rest on a different basis from primary and secondary qualities. Men produce works of art and good societies and true knowledge. But these products have these qualities only on sufferance from their makers. Remove men, and beauty would disappear. But red would remain; though, unless there are creatures with the appropriate organs, it would not be perceived.

At the same time in declaring the values to be qualities only of the new realities which are held upon human tenure, we do not declare them to be mere figments of men. On the contrary, goodness belongs, in the sense described, to acts which bring out what is best in human nature, and true knowledge, being controlled throughout by reality, admits us to the secrets of that reality. And art embodies, in stone or sound, the constructive visions of men and reveals the deeper relations between us and nature.

The separation of tertiary qualities from those which do not depend on human interference helps us to set in a clearer light the quality of things which is their "worshipfulness" and becomes, when considered as abiding in them, the object of religion. It is commonly spoken of as a value along with beauty, goodness, and truth, and may consistently be so regarded, if value is thought to be inherent in what is valuable. If, however, the above considerations are valid, it would be treated, whether under the name of deity, or worshipfulness, or as Otto calls it (in *The Idea of the Holy*, Eng. trans., 1923), "numinousness," not as a value or tertiary quality at all, but, just because it belongs to its possessor intrinsically, without need of human intervention, as a quality, on the line of the primary and secondary qualities, independent of man and actually belonging to the world of things, which world includes, of course, man and man-made values. This topic is, however, raised here only for completeness, and it falls beyond the scope of this article to examine further the nature of deity and its possessor. (S. A.)

QUANTICS, the study of homogeneous algebraic functions of two or more variables which generally contain only positive integral powers of the variables. *See* ALGEBRAIC FORMS.

QUANTITY THEORY OF MONEY. A summary form of expression for two allied but distinct propositions relating to the causes of changes in the value of money. The broader proposition referred to is that, other things being equal, changes in the value of money are dependent upon changes in the quantity of money. The narrower proposition is that changes in the value of money, other things being equal, are *directly* proportional to changes in the quantity of money: so that, if, say, the quantity of money is either halved or doubled, all other things remaining the same, the value of money will be doubled or halved; that is (since the price level is an expression of changes in the value of money) prices will rise or fall in strict proportion to a given change in the quantity of money, all other things being supposed to remain unchanged. It will be clear from what has been said that the narrower proposition cannot be true if the broader proposition is not, but that it by no means follows that the untruth of the broader proposition can be proved by disproving the truth of the narrower.

The controversies to which these propositions have given rise are amongst the most celebrated in political economy. Before approaching them, it must be pointed out that the issues involved are irrelevant for any theory of money which asserts that money is only a symbol *expressing* values, but itself incapable of *possessing* value. Any such theory must reject not only the quantity theory in any form, but also the view (which historically is very important) that the value of money is based upon the cost of production of the precious metals. It must reject the latter alternative by arguing that, though the given form of money may be made from gold or silver, which may possess value, it is not *this* fact which is relevant in deciding whether the coin so made is money or not; the important fact is the denomination of units of value expressed and these are independent of the material out of which money is made. But, though some "symbolistic" theories of money reject the quantity theory, others are so worded as to admit of some form of it; and, in any case, the "quantity theory" and the "cost of production theory" are capable of reconciliation; for it may be argued, as, for example, by J. S. Mill, that "cost of production would have no effect on value if it could have none on supply." Thus a lowering of the cost of production of gold lowers the value of gold and therefore raises prices, because under these circumstances more gold will be produced.

It must be pointed out, further, that the truth of any form of the quantity theory cannot be established purely by an appeal to facts. This is so, not merely because, in practice, other things never are equal—so that, in the real world, changes in the quantity of money are always accompanied by changes, not only in the price level, but in other things—but also because mathematical or statistical equivalences between quantities are incapable of throwing any light upon causal sequence. In other words, assuming that changes in the price level always do accompany changes in the quantity of money, this fact, if it is a fact, does not tell us which change depends upon which. It must be shown, if any form of the quantity theory is true, why changes in the price level are dependent upon changes in the quantity of money. Otherwise it might be argued that changes in the quantity of money are dependent upon changes in the price level, or that changes in the price level and changes in the quantity of money are co-effects of remoter causes.

Though the truth of the quantity theory is not denied by a majority of economists, the formulation of the theory has undergone profound modifications. A distinction must be drawn between the "older" and the "newer" quantity theories. In what follows we shall deal first with the older and traditional theory, and then with its formulation in recent years.

The Older Theory.—The older view, which received its most complete expression at the hands of Irving Fisher in his *Purchasing Power of Money* before the World War (1911), ultimately rests upon the following assumptions. The dynamic consequences of the theory flow from the fact that additional supplies of money *constitute an incentive to additional spending*. Additional supplies of money drive prices up, because (the supply of goods being assumed constant) there will be more to spend and competition among spenders is a cause of rising prices. The additional supplies of money, secondly, *will be spent* because money possesses no intrinsic power of yielding satisfactions; the satisfactions arising from the possession of money can be realized only by acquiring goods and services which possess a direct power of satisfying wants. Now, given these two assumptions, it follows almost as a matter of course not only that prices will rise as the quantity of money rises, but that the price-rise will be in proportion to the increase in the quantity of money. For, given a certain increase in the volume of money and a *disproportionate* alteration of prices, disequilibrium will prevail until the price level is in direct relation to the new total quantity of money. If prices have risen less than in proportion to money, goods will seem unusually cheap to consumers and this will stimulate further consumption of them. If prices have risen more than in proportion to the increased quantity of money, consumers will, in spite of additional quantities of money, find prices unusually high and will check their consumption, with the result that prices will fall. If, but only if, prices alter in exact correspondence to changes in the quantity of money, everyone will find himself in the same position as formerly, with the same real income of satisfaction, but with higher prices on the one hand, and larger money supplies available on the other.

The quantity theory, in the course of its evolution, gradually acquired complexity of exposition. Three separate points have to

be noted in this connection. The first is the modification introduced when changes in the volume of goods are taken into account. Changes in production may be increasing the supply of goods contemporaneously with the increased monetary supply and the latter may even exert some stimulating effect upon production. Other things in this case will not be equal, so that the price level will be forced upwards or downwards according as the influence of increased supplies of money or of goods exerts the preponderating influence; so that the quantity theory is usually expressed in the form that prices move directly with the supply of money and inversely with the supply of goods. Further, it is not the volume of physical goods but the volume of goods *and services* which must be contrasted with the supply of money: an increase in the number of *separate transactions* associated with production works, in this connection, as a price reducing factor, because, in fact, transactions represent services rendered in connection with physical supply. Next, the theory has to take account of the fact that, during a given period of time, each unit of money, passing from hand to hand, necessarily plays a part in the number of transactions, the number depending upon the rapidity of its circulation. Given a certain number of monetary units, an increase in their *velocity of circulation* is equivalent in effect to increasing the supply of units acting as money during the period of time considered, so that an increase in the velocity of circulation, other things being equal, raises prices, whilst a decrease in the velocity reduces prices. Lastly, the quantity theory has to take account of credit instruments of various kinds. Here two solutions are possible. One is to treat these instruments as *additional* to the supply of metallic money and bank and government notes, so that an increase in the supply of credit instruments raises prices in exactly the same way as an increase of money would have done. The second alternative is to regard credit instruments as a *substitute* for ordinary forms of money, which are replaced in a certain number of transactions by credit instruments, so that, *in relation to transactions*, the supply of money rises and prices rise in correspondence.

The New Formulation of the Quantity Theory.—The theory fashionable in pre-war days had two great defects. By contrasting money as a whole with transactions as a whole, it was unable adequately to take account of the individual process of revaluation which is implied in a change in the price level. Secondly, the facts of inflation during the war threw grave doubt on the view that prices were altered proportionately to changes in the quantity of money, the fact being that prices rose much more rapidly in the later stages of inflation, and appreciably less rapidly in the early stages of inflation, than the theory warranted. The new formulations have no difficulty in dealing with these points.

The modern quantity theory starts from the fact that each independent individual or other economic unit requires to keep on hand at all times a certain stock of money. At any moment, of course, money may be passing out of one stock into another, but this does not invalidate the fact that considerations of convenience and habit dictate the keeping of a certain stock on hand. This stock of money on hand or, as Hawtrey calls it, "The unspent margin," is as much required as a stock of clothes or a stock of food, if the economic system is to function adequately. The aggregate demand for money, then, is derived from the sum of individual demands for stocks, just as the demand for houses is derived from the individual demands of those who desire to occupy them. An increase in demand for money is equivalent to an unwillingness to reduce the stock actually held and a desire to add to it. If the supply of money is fixed, this must mean that money acquires a higher value, that is, prices will fall, because people can add to their stocks only by parting with goods or services in order to increase the stock they hold and, since the total stock of money is assumed to be fixed, this can only be at the expense of other stocks held by other individuals. If there is a general desire to decrease stocks on hand, prices must rise, in spite of the total supply of money being fixed, because if there is a general alteration in the desire to hold money, holders can only get rid of what they have by offering it more cheaply, that is, at a lower price in goods to the taker. But this is equivalent to a rise of prices.

When the supply of money alters, the effect produced upon prices depends upon the effect alterations in the supply have upon the willingness to hold stocks. At first the effects of increasing supplies upon the price level, when spent by the issuer, are not in any case likely to be very great. If, at such a time, people's willingness to increase their stocks extends, the rise in the price level will not be in proportion to the increase in the output of money. But if this output increases continuously, the rise in the price level will tend to be more and more rapid and to outstrip the increase in the quantity of money, and that for two reasons. The larger the stock already held, the lower must be the price at which additional amounts must be offered to holders in order to induce them to take more. It may be argued that, as prices rise, individual holders need to hold more, because otherwise the stock held will be inconveniently small in view of the new price level. This is so, but it by no means follows that in the course of the process of adaptation, individuals have not altered their ideas as to what a convenient stock is; in fact, the rise of prices shows that they must have done so. In any case, if the supply of money goes on increasing and prices go on rising, anticipation of the future value of money begins to play an important part. Just as individuals will refuse to add to their stocks of cotton at a time when they believe that cotton will continue to fall in value, so they will refuse to add to their stocks of money at a time when that is falling in value, and unwillingness to add to their stocks is in itself a cause why the fall in the value of money should proceed more rapidly.

It makes no essential difference to the new formulation whether credit is regarded as a form of money or not. If it is so regarded, then the demand for stocks must be regarded as a demand for so much cash plus so much credit. It is thus that the position is treated by Keynes and Hawtrey. If credit is regarded as a substitute for cash, as it is by Cannan, then the demand for cash will fall off if credit arrangements are regarded as more convenient, and in the absence of appropriate arrangements for withdrawing superfluous cash, prices will rise, since part of the stock of cash will have become redundant.

See also INFLATION AND DEFLATION; MONEY; BANKING AND CREDIT; CURRENCY. (T. E. G.)

QUANTUM MECHANICS. Throughout the 19th century most physicists regarded Newton's dynamical laws as sacrosanct. During the 20th century it has, however, become increasingly clear that many phenomena, especially those connected with radiation, defy explanation on Newtonian principles. It is well recognized that two major innovations are essential. One of these is the introduction of the principle of relativity. The relativistic corrections are important only for bodies moving with velocities comparable with that of light, and as a result experimental confirmation is possible only in very special types of laboratory experiments or in the cosmological field. The other innovation is quantum mechanics. Although rather less publicized than relativity, the quantum concepts have equally drastic philosophical implications, and furnish richer and more diversified fields for investigation in the laboratory.

Quantum mechanics is the mechanics governing phenomena which are so small-scaled that they cannot be described in classical terms. Thus, quantum rather than Newtonian dynamics must be used in dealing with the motions of electrons or nuclei inside atoms and molecules. In the equations of quantum mechanics, Max K. E. L. Planck's element of action, $h = 6.62 \times 10^{-27}$ erg sec., plays a central role. This constant, which is one of the most important in all of physics, has the dimensions mass$\times$length^2/time. The term "small-scale" used to delineate the domain of quantum mechanics should not be literally interpreted as relating necessarily to extent in space. A more precise criterion as to whether quantum modifications of the Newtonian laws are of importance is whether or not the phenomenon in question is characterized by an "action" (time integral of the kinetic energy) which is large compared to Planck's constant. Thus, if a great many quanta are involved, the Planck idea that there is a discrete, indivisible quantum unit loses importance, just as to a millionaire it would make little difference whether the smallest unit of currency is the cent or the dollar. This fact explains why our ordinary physical processes appear to be so fully in accord with the laws of

Newton. Planck's element of action is, for example, far too fine-grained to have any bearing on the driving of an automobile. Since ultimately all matter is built out of atomic or small-scale ingredients, it must be possible to describe the properties of even large-scale bodies by means of quantum mechanics. In other words, Newtonian dynamics must represent a special case of quantum dynamics appropriate to cases where the action is very large compared to the elementary quantum. This is indeed true; it should, however, be emphasized that quantum mechanics is really an extension of classical statistical mechanics rather than of the deterministic laws of Newton. As a result, one of the most important philosophical implications of quantum mechanics concerns the apparent breakdown of the causality principle in atomic phenomena. (*See* UNCERTAINTY PRINCIPLE, THE.)

The history of quantum mechanics may be divided into three main periods. The first of these began with Planck's theory of black body radiation in 1900, and may be described as the period in which the reality of Planck's constant of action was demonstrated, but its real meaning was rather obscure. The second period began with the Bohr theory in 1913. Niels Bohr's ideas gave the correct formula for the frequency of spectral lines in many cases, and were an enormous help in the codification and understanding of spectra. Still they did not represent a consistent, unified theory, as he himself recognized, but rather a sort of patchwork affair in which classical mechanics was subjected to a rather extraneous set of so-called "quantum conditions," which restrict the constants of integration to certain particular values. The true quantum mechanics appeared in 1926, reaching fruition almost simultaneously in a variety of forms, *viz.*, the matrix theory of Max Born and Werner Heisenberg, the wave mechanics of Louis V. de Broglie and Erwin Schrödinger, and the transformation theory of Paul A. M. Dirac and Pascual Jordan. These different formulations are in no sense alternative theories, but rather different aspects of a consistent body of law.

Since the laws of atomic physics were but imperfectly understood prior to 1926, previous editions of this encyclopaedia contained articles on "quantum theory" rather than "quantum mechanics." By 1946, however, the status could be aptly described by quoting a sentence or two, as follows (from Dirac in *Proceedings of the Royal Society* A, vol. 123): "The general theory of quantum mechanics is now almost complete, the imperfections that still remain being in connection with the exact fitting in of the theory with relativity ideas. These give rise to difficulties only when high-speed particles are involved, and are therefore of no importance in the consideration of atomic and molecular structure, and ordinary chemical reactions. . . . The underlying laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known, and the difficulty is only that the exact solution of these laws leads to equations much too complicated to be soluble." We ought perhaps to add that quantum mechanics made no pretense, as of 1946, of describing completely what goes on inside the nucleus. In other words, we do not know the details of the short-range dynamics of the neutrons, protons, etc., of which the nucleus is composed, although quantum mechanics has been a help in understanding many nuclear phenomena, such as the emission of alpha particles and photo-disintegration. In short, close to the mid-20th century the theory of nuclear physics was in a more or less embryonic stage comparable, say, with extra-nuclear quantum theory in its early days. Thus, quantum mechanics gave us the appropriate laws of nature down to distances of the order 10^{-10} cm., but we still did not know the rules in detail when we sought to probe below nuclear radii of the order 10^{-12} cm.

QUANTUM THEORY PRIOR TO THE BOHR ATOM

First, let us describe the earlier investigations in quantum theory which anteceded the discovery of the true quantum mechanics in 1926. This procedure is not merely an attempt to preserve historical order, but is also advisable because some of the primitive theories describe some subjects fairly well and help in the visualization of the later more recondite developments.

Black Body Radiation.—The quantum of action had its birth in the studies of black body radiation in 1900 by Planck, professor of physics at the University of Berlin. All black, *i.e.* perfectly absorbing, bodies heated to a given temperature should emit radiation having the same spectrum. The latter can be shown to be identical with the spectral distribution of energy in a so-called "hohlraum," *i.e.* a cavity whose radiation is in thermal equilibrium with matter. (*See* BLACK BODY.) According to classical physics, the density of radiant energy should be proportional to the square of the frequency, and so increase without limit as the wavelength is made progressively shorter. This prediction is sometimes called the "ultra-violet catastrophe," and the corresponding analytical formula for the energy density is called the Rayleigh-Jeans law. It yields the dashed curve of fig. 1. The observed distribution is that indicated by the solid curve, which Planck was able to deduce theoretically by making a quantum hypothesis.

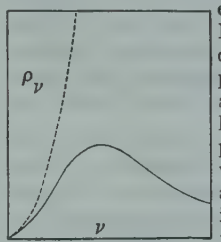


FIG. 1.—THE ENERGY DENSITY OF BLACK BODY RADIATION AS A FUNCTION OF FREQUENCY. CLASSICAL AND QUANTUM THEORIES GIVE RESPECTIVELY THE DASHED AND SOLID CURVES

We shall now indicate how the Rayleigh-Jeans and Planck radiation laws can be derived and shall formulate them mathematically. The method which we sketch is a well-known but rather formal one. It may be characterized as the application of classical equipartition or of classical statistics to the degrees of freedom of the ether. We do not mean to presume that a material ether really exists; we use this term merely to indicate that the standing electromagnetic waves in an enclosure are handled by the same type of statistical procedure as those of a material medium. The first step is the enumeration of the different types of standing waves or modes of vibration of the ether in a rectangular parallelopiped of volume V. Just as a rope with fixed ends can vibrate only in certain ways, represented by the fundamental and the various harmonics, so also in the three-dimensional case only certain modes of oscillation are compatible with the boundary conditions. If the edges of the parallelopiped are large compared to the wave length, the number of possible vibrations in the frequency interval ν, $\nu+d\nu$ can be shown to be

$$(8\pi\nu^2V/c^3)\cdot d\nu, \tag{1}$$

where c is the velocity of light. Let the mean energy of an oscillation of frequency ν be denoted by ϵ_ν. Then the density of radiant energy in the frequency range ν, $\nu+d\nu$ is $\rho_\nu d\nu$ with

$$\rho_\nu=\epsilon_\nu\cdot(8\pi\nu^2/c^3). \tag{2}$$

It is now necessary to evaluate ϵ_ν. This is done by treating each characteristic mode of vibration as a harmonic oscillator. According to classical statistical mechanics, we have

$$\epsilon_\nu=kT, \tag{3}$$

where k is Boltzmann's constant 1.38×10^{-16} erg/degree. Equation (3) is a direct consequence of the classical theory of equipartition. The latter demands that the mean kinetic energy per degree of freedom be $\frac{1}{2}kT$, and a harmonic oscillator has equal mean kinetic and potential energies, so that the total energy is kT. Substitution of (3) in (2) yields the Rayleigh-Jeans law

$$\rho_\nu=8\pi\nu^2kT/c^3. \tag{4}$$

The fact that ρ_ν increases without limit when ν is made arbitrarily large is the ultra-violet catastrophe already mentioned.

In quantum theory, however, the mean energy of a harmonic oscillator is taken to be

$$\epsilon_\nu=\frac{h\nu}{e^{h\nu/kT}-1}. \tag{5}$$

This formula is obtained by assuming that the energy of a harmonic oscillator is restricted to the "quantized" values 0, $h\nu$, $2h\nu$, $3h\nu$, $\cdots$. The mean energy is calculated by weighting these values in accordance with the usual Boltzmann factor, so that

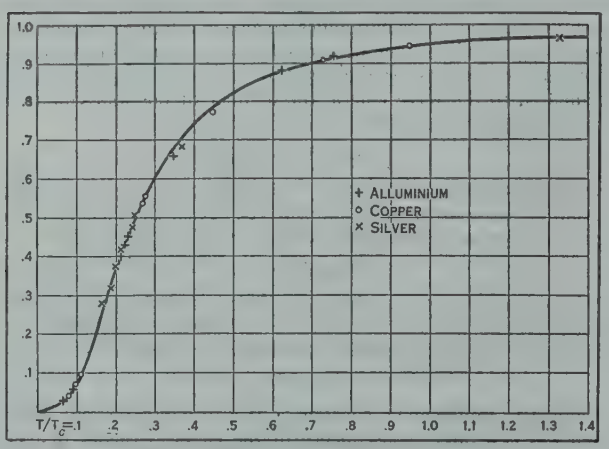
$$\epsilon_\nu=\frac{h\nu e^{-h\nu/kT}+2h\nu e^{-2h\nu/kT}+\cdots}{1+e^{-h\nu/kT}+e^{-2h\nu/kT}+\cdots} \tag{6}$$

The series in the numerator and denominator of (6) are readily summed, and the result is (5). Substitution of (5) in (2) gives

$$\rho_\nu = \frac{8\pi h\nu^3}{c^3} \cdot \frac{1}{e^{h\nu/kT}-1}. \qquad (7)$$

This is the celebrated Planck radiation formula. We have presented essentially one approach used by Planck. He also had other ways of obtaining his formula, but most of these have now been discarded. The best present derivation of the Planck radiation formula is probably one due to Albert Einstein in 1916, which is based on so-called detailed balancing for a system of matter and radiation.

Specific Heats.—Another early success of quantum theory was in the field of specific heats, where it explained the deviations from the law of Pierre L. Dulong and Alexis T. Petit. This law states that the specific heat per gram atom is very nearly the same, about six calories, for many solid elements. However, there are many exceptions. Also, if the temperature is lowered sufficiently, the specific heat approaches zero, instead of remaining constant, as predicted by the law. The behaviour of three metals, for instance, is shown in fig. 2. The law of Dulong and Petit is a direct consequence of the classical theory of equipartition, provided we apply the latter to the atom as a whole and arbitrarily do not attempt to apply classical statistics to the motion of the electrons inside the atom. The specific heat is then independent of temperature, and so in fig. 2 would be represented by a horizontal straight line of unit height in the scale employed there. Debye's quantum model, on the other hand, yields the solid curve, which is in good agreement with experiment. This curve approaches unity if the temperature is raised sufficiently. More generally, all classical and quantum theories of specific heats agree asymptotically at high temperatures. On the other hand, the vanishing of the specific heat at the absolute zero is a characteristic quantum phenomenon.



ADAPTED FROM T. PRESTON, "THEORY OF HEAT" (MACMILLAN)

FIG. 2.—THE SPECIFIC HEAT OF A MONATOMIC SOLID AS A FUNCTION OF TEMPERATURE. THE CURVE IS CALCULATED FROM DEBYE'S QUANTUM THEORY. THE SCALE OF ORDINATES IS SO CHOSEN THAT CLASSICAL THEORY GIVES UNITY

In the mathematical analysis the difference between the classical and quantum theories of the specific heats of solids parallels closely that between the proofs of the Rayleigh-Jeans and Planck laws for radiation. Instead of considering the electromagnetic vibrations of the ether, we have to deal with the vibrations of the atoms composing the solid with respect to each other. If the forces binding the atoms to their equilibrium positions obey Hooke's law, the vibrations are simple harmonic. The dynamical system represented by the aggregate of atoms constituting the solid obviously is exceedingly complicated, but, in principle, modes of vibration can be sorted out according to frequency. Let there be $n_\nu d\nu$ such modes in the interval ν, $\nu+d\nu$. Let the mean energy of a harmonic vibration be denoted by ϵ_ν, which, as before, has the value (3) or (5) according as we use classical or quantum theory. The total energy is obtained by integrating over all frequencies, and the specific heat c_V is the temperature derivative of the energy. Hence

$$c_V = \frac{d}{dT}\left[\int_0^\infty n_\nu \epsilon_\nu d\nu\right]. \qquad (8)$$

The determination of the factor n_ν specifying the distribution of vibration frequencies represents an exceedingly difficult problem, as n_ν is no longer given by the simple expression (1) which applied in the radiative case. However, if the classical result $\epsilon_\nu = kT$ is employed, it is not necessary to determine n_ν, as kT is merely a constant factor, which can be taken outside the integration. The integral can then be immediately evaluated from the relation

$$\int_0^\infty n_\nu d\nu = 3N, \qquad (9)$$

which states that the total number of independent modes of oscillation, or in other words the total number of degrees of freedom, must be three times the total number of atoms N. Hence, according to classical equipartition we have

$$c_V = 3Nk. \qquad (10)$$

This is essentially the law of Dulong and Petit. If we take an amount of material equal to a gram atom, so that N becomes the Avogadro number, and if we express the specific heat in calories rather than in ergs, then (10) gives a specific heat of 5.96 calories per degree.

In quantum theory, on the other hand, it is necessary to evaluate n_ν. Peter J. W. Debye assumed a distribution law for n_ν analogous to that (1) for the radiative case, but with allowance for transverse and longitudinal vibrations with different velocities of propagation, which can be calculated from the elastic constants of the material. There is then no limit to the high-frequency end of the spectrum, and the integrals in (8) and (9) diverge. To avoid this difficulty the upper limit in (8) and (9) is rather artificially taken to be ν_c rather than ∞, where ν_c is a "cut-off frequency" so chosen as to satisfy (9) and thus make the total number of vibrations equal to $3N$. With this model, Debye found $c_V = f(T/T_c)$, where $f(T/T_c)$ is a universal function of a "reduced temperature" T/T_c, which is the ratio of the ordinary temperature to a "characteristic temperature" T_c calculable from the elastic properties of the material. This reduced temperature is used for the abscissa in fig. 2. Debye's method for obtaining n_ν originally appeared somewhat artificial, but Born and Karmen showed that it had some dynamical basis. The Debye model applies only to simple monatomic solids. When the solid is composed of molecules, one must consider the vibrations not only of molecules with respect to each other, but also the vibrations of atoms inside the molecules. As emphasized by Einstein, the latter effect gives sharp maxima of n_ν at certain frequencies. In recent years, improved methods of calculating n_ν have been developed, and the theory correspondingly refined.

We have spoken so far only of solids. There is also considerable literature on the specific heats of gases. Here again, quantum theory explains deviations from the classical theory of equipartition, especially at low temperatures, which are particularly pronounced for hydrogen.

Photoelectricity.—Nowhere, perhaps, is the inadequacy of classical theory revealed more strikingly than in the subject of photoelectricity, which is concerned with emission of electrons by an illuminated body. (*See* PHOTOELECTRICITY.) Photoelectric phenomena exhibit two main features: (1) no emission occurs at all unless the frequency ν of the incident radiation exceeds a certain critical value, called the threshold frequency, and (2) the kinetic energy of the ejected electrons depends on the frequency of this radiation, and not on its intensity. In other words, if a light source is removed farther and farther from the body which it illuminates, the emitted electrons are undiminished in their velocity of escape, but are decreased in number. Such a state of affairs was a complete conundrum at the turn of the century, since in classical electromagnetic theory, diminished incident in-

tensity implies a lowering of the energy traversing the absorbing "target area," and as a result of the lower energy flow, the velocity imparted to the electron should be decreased, contrary to experiment. In 1905 Einstein showed that the observed behaviour could be explained if in the emission of the electron, a quantum of energy $h\nu$ is picked up by matter from the radiation, regardless of the latter's intensity. The process merely becomes less likely when the intensity is low. Just how such a corpuscular model was to be reconciled with the undulatory features of light, such as interference, was something not understood for two decades or so, but was finally clarified by the Heisenberg uncertainty principle, and by Bohr's theory of complementarity. From the less sophisticated outlook of 1905, Einstein showed that if we ignored the conflict with the wave viewpoint, his picture did indeed account for the salient factors of photoelectricity. The kinetic energy of escape of the electron will not in general be the same as the quantum $h\nu$ absorbed from the radiation inasmuch as part of the energy is consumed in liberating the electron from the metal. This portion is called the thermionic work function, and will be denoted by the letter ϕ. Einstein's equation for determining the velocity of escape v of an electron is thus

$$\tfrac{1}{2}mv^2 = h\nu - \phi. \qquad (11)$$

Since the kinetic energy $\frac{1}{2}mv^2$ is necessarily positive, emission is possible only if $\nu > \phi/h$. Hence ϕ/h is the threshold frequency.

Closely related to the photoelectric effect is the Compton effect (*q.v.*), which also reveals the need of the quantum hypothesis.

THE BOHR ATOM

A signal advance in quantum theory was achieved when a Danish physicist, Niels Bohr, propounded his theory of the spectrum of hydrogen, in 1913. By that time there was no doubt as to the validity of the Rutherford picture of the atom as a miniature solar system, with the nucleus and electrons playing respectively the role of the sun and the planets. (*See* ATOM.) The number of electrons in the neutral atom is the same as the chemists' atomic number, one for hydrogen, two for helium, etc. Therefore, the dynamics of the orbits of the electrons in the various atoms will be very complex except in the hydrogenic case, for the mathematical difficulties associated with even a three-body problem (*e.g.*, neutral helium, with one nucleus and two valence electrons) are enormous. By a hydrogenic atom we do not mean necessarily a hydrogen atom, but any other atom which has been stripped of all but one valence electron as a result of ionization. Examples are singly ionized helium, doubly ionized lithium, etc. Clearly, the study of the spectrum of hydrogen, because of its comparative simplicity, should be the most likely starting point of any attempt to decipher the complexities of atomic spectra.

The Balmer Formula.—It has long been known that there are some remarkable regularities in the spectrum of hydrogen. As early as 1885, Johann J. Balmer showed that the wave lengths λ of many lines are well represented by the empirical formula

$$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n'^2} - \frac{1}{n''^2}\right], \qquad (12)$$

in which n', n'' are integers, and R is a constant, the so-called Rydberg one. If, for instance, one takes $n'=2$ and $n''=n'+1$, $n'+2$, $\cdots$, the expression (12) gives the wave lengths of the lines in what is called the Balmer series. The choices $n'=1$, 3, 4, and 5 yield respectively the Lyman, Paschen, Brackett and Pfund series, which were discovered later. Since the atomic number Z is unity for hydrogen, the factor Z^2 in (12) is unnecessary for present purposes, but is included to permit later extension to atoms of higher nuclear charge.

The Postulates of the Bohr Theory.—For many years, the *raison d'être* for the formula (12) was completely obscure. It is not surprising that the subject of line spectra was a closed book to the classical physicist. As some one has said, the task of constructing a model of the atom merely from knowledge of its spectra radiated under violent electrical or thermal excitation is comparable with trying to learn about a piano merely from the noise emitted when it is dropped downstairs. Bohr, however, showed that the behaviour (12) could be explained by means of two postulates, as follows:

(1) The existence of stationary states: In every atom there is a discrete succession of states, in any one of which the electrons can move without appreciable radiation, and which can be identified by a set of integers, usually called quantum numbers. The designation of these states as stationary refers to the absence of radiation from the orbits, in contravention of classical electrodynamics, and does not imply a static atom. Except for omission of the radiation corrections, the motion of the electrons in the stationary states is assumed to conform to the laws of classical mechanics.

(2) The Bohr frequency condition: It is assumed that an electron can sometimes pass discontinuously from one allowed orbit to another. In such a transition, the initial and final states will have different amounts of mechanical energy E″ and E′. To secure conservation of energy, the change in the mechanical energy must be counterbalanced by the absorption or emission of a light quantum, whose energy is $h\nu$ if the frequency is ν. This requirement yields the so-called Bohr frequency condition

$$h\nu = \mathrm{E}'' - \mathrm{E}'. \qquad (13)$$

The analogy to Einstein's photoelectric equation (11) is obvious.

In connection with the first postulate it is necessary to formulate the quantum conditions which restrict the energies of the atoms to certain particular values. The easiest case to handle is that of a simply periodic system, where the orbit repeats itself after a given interval of time τ. Here the quantization is effected by the relation

$$\overline{T} = \tfrac{1}{2}nh\nu_0, \qquad (14)$$

in which n is an integer, $\overline{T}$ is the mean kinetic energy of the system, *i.e.* the average of the kinetic energy T over a period, and $\nu_0 = 1/\tau$ is the frequency with which the orbit repeats itself. It is to be emphasized that the orbital frequency ν_0 is in general not the same as that ν given by the Bohr frequency condition (13). This nonidentity of the orbital and radiated frequencies is a celebrated paradox of the Bohr atom, as according to classical mechanics or actual observations on large-scale phenomena there is no distinction between the frequencies of motion of a system and those of the waves which it radiates. It should be mentioned, however, that in the Bohr theory there is an asymptotic agreement of the two frequencies for large quantum numbers, which is usually termed the "correspondence principle for frequencies."

Derivation of the Balmer Formula from the Bohr Theory.—We shall now show that the Balmer expression (12) is a consequence of the quantum condition (14) and the Bohr frequency condition. This derivation is such a simple and classic one that it seems worth giving, even though in a sense it is outmoded by more recent, but more intricate, calculations by means of wave mechanics, which also yield the result (12) with identically the same value of the Rydberg constant R as that obtained from the Bohr theory.

To simplify the calculations, we shall assume that the orbit is circular, but it can be shown that the energy levels are no different in the general case of ellipses. Let the mass of the nucleus and electron be denoted by M and m respectively, and let the nuclear and electronic charges be Ze and $-e$. Here e has the value 4.80×10^{-10} in electrostatic units, and Z is the atomic number. The centre of gravity, which may be supposed stationary, divides the line connecting the two particles in the inverse ratio of their masses. Hence, the electron and nucleus revolve around this centre in circles of radii $Ma/(m+M)$ and $ma/(m+M)$ respectively, where a is the distance from the nucleus to the electron. Since the angular velocity is $2\pi\nu_0$, the kinetic energy is

$$T = \tfrac{1}{2}\left[m\left(\frac{M}{m+M}\right)^2 + M\left(\frac{m}{m+M}\right)^2\right](2\pi\nu_0)^2a^2, \qquad (15)$$

This equation can also be written as

$$T=\tfrac{1}{2}\mu(2\pi\nu_0)^2a^2, \tag{16}$$

where μ is the so-called reduced mass, given by

$$\mu=mM/(m+M) \tag{17}$$

As T is constant in time, there is no distinction between T and $\overline{T}$. Thus application of the quantum condition (14) gives

$$(2\pi\nu_0)\mu a^2=nh/2\pi. \tag{18}$$

In other words, the angular momentum of the system is an integral multiple of $h/2\pi$. The equality between the centrifugal force on the electron and the Coulomb attraction due to the nucleus yields a further relation

$$\mu a(2\pi\nu_0)^2=Ze^2/a^2. \tag{19}$$

When equations (18) and (19) are solved for a and ν_0, the result is

$$a=n^2h^2/4\pi^2Ze^2\mu, \qquad \nu_0=4\pi^2\mu Z^2e^4/n^3h^3. \tag{20}$$

The first relation of (20) shows that the allowed or "quantized" values of the radius of the atom form a progression of the form $a_0, 4a_0, 9a_0, \cdots$, where a_0 is a fundamental unit $h^2/4\pi^2\mu Ze^2$ called the Bohr radius, and having the numerical value 0.53×10^{-8} cm. if Z=1 (hydrogen). Substitution of (20) in (16) gives

$$T=2\pi^2\mu Z^2e^4/n^2h^2,$$

while the potential energy is

$$V=-Ze^2/a=-4\pi^2\mu Z^2e^4/n^2h^2.$$

Hence the total energy E=T+V is

$$E=-2\pi^2\mu Z^2e^4/n^2h^2. \tag{21}$$

When we substitute this value of E in the Bohr frequency condition (13) and remember that $\lambda=c/\nu$, we have indeed the Balmer formula (12), provided the Rydberg constant R has the value

$$R=2\pi^2\mu e^4/ch^3. \tag{22}$$

One immediately asks whether (22) yields a value of R in agreement with the optical measurements, when the numerical values of the constants e, h, μ, c are substituted. The answer is that there is certainly agreement within the precision with which these constants are known, for e, h, μ are known only to one part in a thousand or so. On the other hand, since optical wave lengths are known so very accurately, the Rydberg constant R can be determined to within less than one part in a million. A valuable cross-check on the values of the various atomic constants is thus provided: namely, use of (22) along with the spectroscopic determination of R permits us to determine one of the four quantities e, h, μ, c if the other three are known. It is thus possible to increase the accuracy with which we know the value of the particular one of the four constants, viz. h, which otherwise cannot be as precisely determined as the other three.

Correction for the Motion of the Nucleus, and the Spectroscopic Determination of e/m.—If we neglect the motion of the nucleus, or in other words consider the mass M of the nucleus to be infinite, then equation (17) shows that the reduced mass becomes identical with the mass m of the electron. When allowance is made for the finite mass of the nucleus, μ will differ slightly from m. The neutral hydrogen atom and ionized helium atom resemble each other in having only one electron, so that formula (22) should be applicable to either. However, the different masses of the hydrogen and helium nuclei will make the Rydberg constant slightly different for the two. Just this state of affairs is found experimentally: the best spectroscopic value of the Rydberg constant for hydrogen is $R_H=109677.58$ cm.$^{-1}$, while that for helium is $R_{He}=109722.26$ cm.$^{-1}$ (Birge's figures). The corresponding value for a hydrogenic atom of infinite nuclear mass is $R\infty=109737.30$ cm.$^{-1}$.

Equation (22) shows that the ratio of the Rydberg constants for hydrogen and ionized helium is equal to the ratio of the reduced masses, the other constants cancelling out. When (17) is used, we can write

$$\frac{R_{He}}{R_H}=\frac{1+m/M_H}{1+m/xM_H}, \tag{23}$$

where x is the ratio M_{He}/M_H of the mass of the helium nucleus to that of hydrogen. This ratio can be regarded as known from determinations of atomic weights, since practically all of the atom's mass arises from the nucleus. Hence, by means of (23) and the spectroscopic determinations of R_H, R_{He}, it is possible to evaluate the ratio m/M_H of electronic to protonic mass. Furthermore, one can go a step farther and determine e/m spectroscopically, inasmuch as one has $e/m=(e/M_H)(M_H/m)$ and as the value of e/M_H is known from electrolysis, *i.e.* from the so-called electrochemical equivalent. In this way, the shift between the Rydberg constants for hydrogen and ionized helium furnishes perhaps the most accurate means of determining e/m. In the early 1930s there appeared to be a discrepancy between the values of e/m determined spectroscopically and by more direct deflection methods. This difficulty has now disappeared, and the generally accepted value of e/m is 1.759×10^7 e.m.u.

During the first years of Bohr's theory, the only known hydrogenic atoms, *i.e.* those with one valence electron, were H and He^+. Subsequently, X-ray measurements at Uppsala have revealed lines due to Li^{2+}, Be^{3+}, B^{4+} and C^{5+}. These lines are particularly useful because they furnish wave-length standards in the X-ray region. Another subsequent development was the discovery of the hydrogen isotope deuterium, which has about double the value of M for ordinary hydrogen and hence a slightly different Rydberg constant. This difference, in fact, historically furnished the means of initially demonstrating the existence of deuterium with certainty.

The Relativity Fine Structure.—A great triumph of the Bohr atom was the theory of the relativity fine structure in hydrogen, which was developed by Arnold Sommerfeld in 1916. In the preceding discussion, the problem was treated by means of Newtonian mechanics. When the relativity corrections are introduced, the orbits cease to be periodic, and the quantization becomes more complicated. It is necessary to introduce two quantum conditions, mathematical details of which we shall omit except for mentioning that they restrict the values of certain so-called "phase integrals" to integral multiples of Planck's constant. If the nuclear mass is treated as infinite, the formula for the energy can be shown to be

$$E=mc^2\left\{\left[1+\left(\frac{\alpha Z}{n-k+g}\right)^2\right]^{-\frac{1}{2}}-1\right\}, \tag{24}$$

where

$$\alpha=2\pi e^2/hc, \qquad g=(k^2-Z^2\alpha^2)^{\frac{1}{2}}, \tag{25}$$

If (24) be expanded as a power series in α^2, and terms beyond α^4 are disregarded, the expression for E takes the form

$$E=-\frac{2\pi^2mZ^2e^4}{n^2h^2}\left[1+\frac{\alpha^2Z^2}{n^2}\left(\frac{n}{k}-\frac{3}{4}\right)+\cdots\right]. \tag{26}$$

Since $m=\mu$ if $M=\infty$, the first term of (26) is the same as the Newtonian result (21), and involves only the principal quantum number n. The remainder of (26) is due to the relativity corrections, and involves a second quantum number k, which is the so-called azimuthal quantum number. Its physical significance is that the angular momentum is $kh/2\pi$, and the range of values for k is $1, 2, \cdots n$. The dependence of the energy on k is only a minor effect because of the smallness of α (=1/137.0), but it causes lines which would otherwise coincide to be slightly separated so as to form the components of a multiplet. A decomposition is indeed found experimentally, and on the whole the observed spacing of the components agrees well with theory.

The Stark Effect.—Still another quantitative success of the Bohr theory of the hydrogen spectrum is provided by the Stark effect, or splitting of the energy levels and hence of the spectral lines by means of an electric field. The separation and number of the components accords with theory in a remarkable fashion. The formulas for the displacement in frequency involve Planck's constant h, and so classical theory was powerless to explain any of the features of the Stark effect. On the other hand, in the

alternative phenomenon of the Zeeman effect (separation of lines in a magnetic field), Planck's h cancels out of the final formula for the shift in frequency, and so classical and quantum theories give identical results for the normal Zeeman effect (*q.v.*).

Moseley's Relation.—When one seeks to apply the Bohr concepts to nonhydrogenic atoms, the mathematical complexities are so great that the permitted energy levels or frequencies cannot be exactly determined. Nevertheless, certain successes of the theory should be stressed. One of these is the explanation of Moseley's relation in X-ray spectra, wherein the frequencies of the K lines, *i.e.* the hardest lines (lines of shortest wave length or highest frequency) are proportional approximately to the square of the atomic number. This is simply an expression of the factor Z^2 in (21). The result (21) applies approximately to an interior electron of a nonhydrogenic atom if the screening of the nucleus by the other electrons is so poor that the field is substantially that of the bare nucleus. This approximation will be a good one only for electrons which are deep-seated in the atom, such as are responsible for the emission of X-rays.

Relation between Critical Potentials and Spectral Frequencies.—By electron bombardment it is possible to "excite" an atom from one stationary state, say of energy E', to another of higher energy E''. To be able to do this, the impinging electron must have at least a kinetic energy equal to $E''-E'$, as otherwise conservation of energy cannot be secured. The energy which an electron acquires in falling through a difference of potential V is Ve. Hence, the minimum or "critical" accelerating potential required for the excitation is given by $Ve=E''-E'$. Alternatively, the Bohr frequency condition states that $h\nu=E''-E'$. Thus, we have $Ve=h\nu$, and this relation holds as a useful consequence of the theory, even though the mechanics of the many-body problem is so intricate that one cannot calculate theoretically the energy levels E', E''.

The Stern-Gerlach Effect.—The application of the quantum conditions to an atom in a magnetic field shows that its component of angular momentum in the direction of the field should be "quantized" and equal to an integral multiple of $h/2\pi$. The corresponding magnetic moment, which is proportional to the angular momentum, should hence likewise acquire only discrete values. Stern and Gerlach verified this prediction by observing the deflections of atoms in an inhomogeneous magnetic field. We cannot overemphasize how beautifully the existence of only certain particular deflections in their experiments demonstrates the reality of the quantized positions which are the essence of quantum theory. It is true that the explanation of the precise quantitative values of the deflections found by Stern and Gerlach requires inclusion of electron spin and the refinements of quantum mechanics in certain cases. However, the broad outlines of the phenomenon were clear even in the days of the Bohr theory, especially the complete contradiction between the classical continuous distribution of orientations and quantum discreteness. The Stern-Gerlach experiment decided unequivocably in favour of the latter.

The Harmonic Oscillator and the Rotator—Molecular Spectra.—There are two very simple schematic models which are particularly easy to quantize and which are rich in physical applications. They are the harmonic oscillator and the rigid rotator or "rotating dumbbell."

For a particle which is harmonically bound, *i.e.* subject to a linear restoring force, the mean kinetic energy is equal to the mean potential energy. Hence the total energy, which is the sum of the kinetic and potential, is equal to twice the mean kinetic energy. Furthermore, the frequency ν_0 of a harmonic oscillator is independent of the initial conditions. Therefore, application of (14) immediately yields the result

$$E=nh\nu_0. \tag{27}$$

The quantized values of the energy of a harmonic system given in (27) are the same as those which we previously used in discussing black-body radiation and specific heats.

For a rigid rotator, there is no potential energy, and the kinetic energy has the constant value $\frac{1}{2}I(2\pi\nu_0)^2$, where I is the moment of inertia, and ν_0 is the rotation frequency. The quantum condition (14) yields $2\pi\nu_0 I=nh/2\pi$. The quantization thus consists in equating the angular momentum to an integral multiple of $h/2\pi$. The corresponding quantized value of the energy is, since $E=T$,

$$E=n^2h^2/8\pi^2I. \tag{28}$$

These formulas have a direct application to the spectrum of a diatomic molecule such as HCl. As a first approximation, the energy of the molecule can be divided into contributions from (a) the electronic motion relative to the two nuclei regarded as fixed attracting centres, (b) the vibration of the two nuclei along the line connecting them, and (c) "end-over-end" rotation of the molecule as a whole. Effects (b) and (c) are respectively portrayed by the harmonic oscillator and the rotator. The quantum numbers associated with (b) and (c) are not, of course, the same, and so we use the letters v, J for them instead of n. The total energy of the molecule is thus

$$E=E_e+vh\nu_0+J^2h^2/8\pi^2I. \tag{29}$$

The electronic term E_e will be a function of numerous quantum numbers other than v, J, but is too difficult to compute explicitly because of the complexities of the many-body problem. The dependence on the rotational and vibrational quantum numbers v, J predicted by (29) agrees nicely with experiment (*see* BAND SPECTRUM).

Intensities and Transition Probabilities in the Bohr Theory.—The theory that we have so far presented is one-sided, as it tells us how to calculate the frequency, but nothing about the intensity. In order to have information about the latter, it is necessary to know the transition probability. It is a fundamental concept of the Bohr theory that radiation takes place sporadically and discontinuously, when an electron passes from one stationary state to another, rather than continuously as in classical theory. The transitions between states are governed by the statistics of random processes, like radioactive decay. Thus, if an electron is initially in a state l, there is a certain probability $A_{l\to m}$ that it will pass to another state m. Let us denote by $\nu(lm)$ the frequency associated with this transition, which by (13) is the same as $(E_l-E_m)/h$. Since an amount of energy $h\nu(lm)$ is radiated in each transition, the total rate at which energy is radiated in the frequency $\nu(lm)$ is

$$I_{l\to m}=h\nu(lm)A_{l\to m}N_l, \tag{30}$$

where N_l is the number of atoms in the state l.

Part of the contribution to $A_{l\to m}$ in the case of emission, and all in the case of absorption, will come from transitions induced by a radiation field. Even in the absence of the latter, however, there is a certain probability of "spontaneous radiation," provided the energy E_m of the final state is less than that E_l of the initial one. For simplicity, we shall consider only the spontaneous effect.

The problem is now to calculate the transition probability in the absence of a radiation field. Here the Bohr theory gave no clear-cut answer. The best that could be done was to make an approximate estimate by means of the so-called correspondence principle, which has been described as a "magic wand which enables one to borrow the results of classical theory for quantum theory." According to classical electrodynamics, an electron moving in a periodic orbit described by Fourier series such as

$$x=\sum_{\tau=-\infty}^{\infty} x_\tau e^{2\pi i\tau\nu_0 t}$$

radiates energy in the harmonic $\tau\nu_0$ at a rate

$$(4e^2/3c^3)(2\pi\tau\nu_0)^4[|x_\tau|^2+|y_\tau|^2+|z_\tau|^2].$$

The correspondence principle for frequencies shows that if the difference in quantum number between the initial and final states is τ, the quantum frequency $\nu(lm)$ approaches asymptotically the classical overtone $\tau\nu_0$ if the quantum number is large. Hence, a formula by which the transition probability can be estimated qualitatively or asymptotically is

$$A_{l\to m}=(4e^2/3hc^3)(2\pi)^4\nu(lm)^3[|x_{l-m}|^2+|y_{l-m}|^2+|z_{l-m}|^2]. \quad (31)$$

It is to be emphasized that (31) never gives a clear-cut and unambiguous answer, as there is no way of telling whether the Fourier coefficients should be evaluated for the initial or the final orbit of the transition, or should represent some sort of compromise between the two.

ADVENT OF THE TRUE QUANTUM MECHANICS

Although the Bohr theory had the many triumphs that we have indicated, still as time progressed, especially in the early 1920s, it became increasingly apparent that it was not adequate. With much labour one could determine the energy levels of the neutral helium atom, a three-body problem, and these did not accord with experiment. Unjustifiable half-quantum numbers, *i.e.* half rather than whole integers, kept appearing in the empirical description of band spectra. Numerous other difficulties could be recited. It was clear that the trouble was simply that the "old" or Bohr quantum theory was a patchwork doctoring of classical mechanics, wherein the quantum conditions were added in a rather artificial way. What was needed was a rational, self-consistent quantum mechanics, which started afresh and evolved a mathematical framework and philosophy all its own. This was discovered in 1926, which was thus an epoch-making year in the history of quantum theory.

This remarkable new mechanics cannot be regarded as the product of any one man, and was instead the result of the impact of mind on mind among the leading theoretical physicists of the time. It was developed in a diversity of mathematical forms, which present a rather confusing array to the student beginning the subject. However, these various formulations, though different in superficial mathematical structure, are basically in harmony with each other. The three main mathematical forms are the following: (1) the matrix theory of Born, Heisenberg and Jordan, (2) Schrödinger's wave mechanics, the outgrowth of De Broglie's concept of "phase waves" and (3) the so-called transformation theory, based on kinetical indeterminism, developed by Dirac and Jordan, and interpreted by Heisenberg.

WAVE MECHANICS

The Hamiltonian Analogy and De Broglie Waves.—We shall begin with the "wave" formulation, as this is the version most universally used, and perhaps the easiest to understand. The impetus to the development of this form of quantum mechanics was furnished by De Broglie's interpretation of the classical Hamiltonian analogy between optics and dynamics. This analogy, which is readily demonstrated from Fermat's principle in optics and the principle of least action in mechanics, establishes a formal similarity between the path of a particle in a mechanical system and a hypothetical optical system in which the refractive index is correlated in a rather arbitrary way with the potential energy $V(x, y, z)$ in the mechanical problem. This comparison always seemed highly artificial because the velocity in the optical system was different from that in the mechanical one. However, if somehow it is possible to introduce the concept of wave length into the analogy, so that it is meaningful to talk about dispersion, then besides the phase velocity there is also a group velocity, which is the velocity with which signals or modulations are propagated. De Broglie showed that although the velocity of the mechanical particle differed from the phase velocity, it became identical with the group velocity, provided the wave length has the value

$$\lambda=\frac{h}{\sqrt{2m(E-V)}}=\frac{h}{mv}. \quad (32)$$

The second form of (32) is obtained by noting that the energy constant E is the sum of the kinetic energy $\frac{1}{2}mv^2$ and the potential energy $V(x, y, z)$. Formula (32) gives the celebrated De Broglie wave length which occurs so characteristically in quantum-mechanical diffraction problems. When De Broglie first propounded his ideas in 1925, it was not clear whether they had much physical significance, but in only a year or so after his paper, the existence of the De Broglie wave length was confirmed in a most striking fashion in the experiments of Clinton J. Davisson and Lester H. Germer on the diffraction of electrons by a crystal. They showed that beams of electrons passing through a crystal were diffracted in many ways like X-rays, but with the wave length given by the formula $\lambda=h/mv$.

The Schrödinger Wave Equation.—Prior, however, to the Davisson-Germer experiments, Schrödinger recognized the great portent of the De Broglie wave length, and by means of it was led to the fundamental equation of wave mechanics, usually called "the wave equation." Schrödinger conjectured that true quantum mechanics stands in the same relation to ordinary classical mechanics that physical optics does to geometrical optics. Just as the ray-tracing characteristic of the latter is unable to explain the phenomena of diffraction and interference, so, Schrödinger reasoned, ordinary mechanics could not explain atomic phenomena, the reason in each case being that the dimensions are not large compared to the wave length. Hence he sought to establish a procedure analogous to that used in physical optics. Now the fundamental "wave equation" of the latter is

$$\frac{\partial^2 f}{\partial x^2}+\frac{\partial^2 f}{\partial y^2}+\frac{\partial^2 f}{\partial z^2}=\frac{1}{u^2}\frac{\partial^2 f}{\partial t^2}. \quad (33)$$

Here the phase velocity u may be a function of x, y, z. In the monochromatic, or periodic, case, the solutions can be written in the form $f=\psi(x, y, z)e^{2\pi i\nu t}$, where the space factor ψ satisfies the equation

$$\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}=\frac{4\pi^2}{\lambda^2}\psi, \quad (34)$$

with $\lambda=u/\nu$. For the wave length λ, Schrödinger inserted the De Broglie value (32). Then (34) becomes

$$\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi^2 m}{h^2}(E-V)\psi=0. \quad (35)$$

This is the Schrödinger wave equation. One immediately wonders how quantized phenomena can be extracted from (35), as a partial differential equation suggests things continuous rather than discrete. The answer is that one must confine one's attention to the "physically admissible," or, colloquially, "civilized" solutions of (35), which meet certain requirements of continuity, single-valuedness, etc. Solutions which fulfil these demands are called "characteristic functions," "proper functions" or "eigenfunctions." The precise conditions that these physically admissible solutions need to meet vary somewhat with the physical nature of the problem. It is usually sufficient that ψ be single-valued, continuous, together with its first derivatives, and finite, except perhaps at a few points at which ψ becomes infinite in such a way that $\iiint|\psi|^2dv$ and $\iiint\left\{\left|\frac{\partial\psi}{\partial x}\right|^2+\left|\frac{\partial\psi}{\partial y}\right|^2+\left|\frac{\partial\psi}{\partial z}\right|^2\right\}dv$ exist. Also, ψ must vanish at infinity. Now, to be sure, (35) possesses an infinity of solutions, since the latter involve arbitrary constants of integration and even arbitrary functions. Nevertheless, it often happens that not one of these solutions has the properties demanded of a characteristic function. Instead, an admissible solution is usually obtained only if E is given certain particular values, called "characteristic values," "proper values" or "eigenvalues." These values of E are those which are to be substituted into the Bohr frequency condition (13).

The Rotator and the Harmonic Oscillator.—A simple illustration of how the condition that the solution be physically admissible limits the parameter E is provided by the two-dimensional rotator, *i.e.* the rotating dumbbell whose motion is confined to a plane. Here the wave equation analogous to (35) is

$$\frac{\partial^2\psi}{\partial\varphi^2}+\frac{8\pi^2 IE}{h^2}\psi=0, \quad (36)$$

as is seen by specializing (35) to one co-ordinate, with $V=0$, and noting that in a rotational problem the moment of inertia I

and angle φ replace the mass and a linear displacement. The solution of (36) is

$$\psi = A\cos[(8\pi^2 IE/h^2)^{\frac{1}{2}}\varphi - \epsilon], \qquad (37)$$

where A and ϵ are arbitrary constants. The requirement of single-valuedness as a function of position on the circular path of rotation demands that $\psi(\varphi+2\pi)=\psi(\varphi)$. This is possible only if the coefficient of φ in the argument of the cosine is an integer n. Thus

$$E = n^2h^2/8\pi^2 I. \qquad (38)$$

This is exactly the same formula for the energy of a rotator as that (cf. equation (28)) obtained with the old quantum theory. It would thus at first appear that the new quantum mechanics did not remove the difficulty that half rather than whole integers are required to obtain agreement with experiment on rotational energy levels. Actually, however, the end-over-end rotation of a molecule should be represented by a rotator not confined to a particular plane, and so associated with a three rather than two-dimensional space. When this extra degree of freedom is added, it is found that the factor n^2 in (38) is replaced by $(n+\frac{1}{2})^2-\frac{1}{4}$, so that, apart from an unimportant additive constant, the result is the same as though half quantum numbers were used in the Bohr theory. We omit the details of the analysis, but it is essentially the same as that in classical potential theory where it is shown that the characteristic values of the differential equation for surface harmonics are proportional to $n(n+1)$.

Of course, in most problems the mathematical analysis is more complicated than in our purposely simple illustration of the rotator. When exact, closed expressions are obtained for the characteristic values of a system with one degree of freedom, they are usually derivable by the so-called polynomial method. In this, the solution is expressed as a power series, and it is shown that if the series does not terminate, the solution is not physically admissible. The termination condition then usually restricts the energy parameter E to certain particular or "characteristic" values.

The polynomial method may be illustrated by the one-dimensional harmonic oscillator. Here the wave equation (35) takes the form

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}(E-\tfrac{1}{2}ax^2)\psi = 0. \qquad (39)$$

On the introduction of the following abbreviations and changes of variable,

$$A = \frac{4\pi E}{h}\left(\frac{m}{a}\right)^{\frac{1}{2}}, \qquad u = \frac{m^{\frac{1}{4}}a^{\frac{1}{4}}(2\pi)^{\frac{1}{2}}}{h^{\frac{1}{2}}}x, \quad \psi = e^{-u^2/2}g \qquad (40)$$

equation (39) becomes

$$\frac{d^2g}{du^2} - 2u\frac{dg}{du} + (A-1)g = 0 \qquad (41)$$

We assume a series solution

$$g = c_k u^k + c_{k+2}u^{k+2} + c_{k+4}u^{k+4} + \cdots. \qquad (42)$$

After the indicated operations are performed, the entire left side of (41) can be expressed in the form of a series. The coefficient of each power of u in the latter must vanish if (41) is satisfied. The vanishing of the coefficient of the lowest power, *viz.* u^{k-2}, requires either $k=0$ or $k=1$. On equating to zero the coefficient of u^n, one obtains the recurrence formula

$$\frac{c_{n+2}}{c_n} = \frac{2n+1-A}{(n+1)(n+2)}$$

for determining the ratio c_{n+2}/c_n. The series (42) will terminate at the term $c_n u^n$ if $A=2n+1$ or, in other words, by (40) if

$$E = (n+\tfrac{1}{2})h\nu_0, \quad \text{with} \quad \nu_0 = \frac{1}{2\pi}\left(\frac{a}{m}\right)^{\frac{1}{2}}. \qquad (43)$$

It can be shown that if the series does not terminate, then ψ increases without limit as x becomes arbitrarily large, and the solution is not physically admissible. Hence, the only characteristic values of the harmonic oscillator are those given by (43). Comparison with (27) shows that the new quantum mechanics gives the same energy levels for the harmonic oscillator as does the old Bohr theory, except for an additive constant which is equivalent to the use of half quantum numbers in (27). Usually it is unimportant whether the extra term $\frac{1}{2}h\nu_0$ is included, but by study of the shift between the electronic spectra of diatomic molecules differing only in being composed of different isotopes, it is possible to decide experimentally between (27) and (43), and the results unequivocably favour the latter.

The Hydrogen Atom.—The focal point of the old Bohr theory was its success with the hydrogen atom, and one is naturally anxious to know whether these triumphs are reproduced by wave mechanics. It turns out that the Schrödinger theory usually gives exactly the same energy levels for a hydrogenic atom as did that of Bohr. This remarkable coincidence holds even inclusive of the corrections for the motion of the nucleus, and in the first order Stark effect. Thus, all the standard achievements of the old Bohr theory regarding the Rydberg constant, hydrogen-helium shift, spectroscopic determination of e/m, etc., are reproduced with wave mechanics. When second powers of the electric field are included in the Stark effect, the results are slightly different with wave mechanics, and the experimental results favour the new formula, though observation of the effect of the second-order corrections requires such high field strengths that precision is difficult. We shall not give the details of the mathematical analysis, but shall cite a few salient points. The calculation for hydrogen is unlike the illustrations of the rotator and oscillator which we have given, inasmuch as there are three degrees of freedom rather than only one. A problem involving more than one co-ordinate is exactly soluble in wave mechanics as a rule only if the variables are separable, *i.e.*, if co-ordinates can be found such that the wave equation admits a solution which can be resolved into products of factors, each of which involves only one co-ordinate. Fortunately such a decomposition is possible for the hydrogen atom. Variables can be separated by using polar co-ordinates, and the wave function then takes the form

$$\psi = AR_{nl}(r)P_l^{|m_l|}(\cos\theta)e^{im_l\varphi} \qquad (44)$$

Here $P_l^{|m_l|}$ is an associated Legendre function (in which $|m_l|$ is the absolute value of m_l), and R_{nl} is the product of an exponential factor and a polynomial in r (a derivative of the so-called Laguerre polynomial). The constant A is arbitrary, while n, l, m_l are integers. The mathematical problem is very similar to the familiar one of the solution of Laplace's equation in polar co-ordinates, except that the differential equation satisfied by the radial factor is different, no longer admitting a solution in the form of a simple power of r as in the Laplacian case. For the Stark effect, the separation of variables is achieved by using parabolic rather than polar co-ordinate. Both of these types of co-ordinates are special cases of elliptical co-ordinates, and Eisenhart has shown generally that if the Schrödinger equation for a single particle admits separation at all, it must be with elliptical co-ordinates.

Continuous Spectra.—So far we have given the impression that the characteristic values form a discrete rather than continuous manifold. However, there are certain ranges within which any value of the energy is allowable. The simplest example is furnished by the hydrogen atom. Here, in addition to any of the discrete negative values (21), any positive value of the energy is allowable. The reason for this distinction is the following. The differential equation satisfied by the radial factor of the wave function for the hydrogen atom has two singular points, *viz.*, the origin and the point at infinity. There is always one solution which is regular at the origin, but it will in general increase without limit at infinity if $E<0$. Only certain special negative values of E avoid this catastrophe, and these are the characteristic values. When, however, the energy constant E is positive, all solutions vanish at infinity, and so the solution which behaves properly at the origin also necessarily does the same at infinity. Hence any positive value of E is a characteris-

tic value. This remark applies even to nonhydrogenic atoms if the origin of the energy is chosen at ionization. The existence of this continuous manifold of positive energy values is reflected experimentally in the continuous absorption beyond the series limit. In fig. 3 the transitions from a fixed lower state to upper states with larger and larger values of n give rise to lines which crowd closer and closer together. Because there can also be transitions to states in the continuum there is a continuous spectrum beyond the limit corresponding to $n=\infty$. There can also be transitions between two values of the energy in the continuous domain, and it is by this mechanism that the continuous X-ray spectrum is emitted from the anode of an X-ray tube.

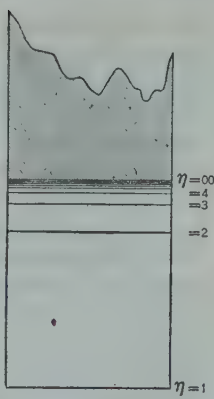


FIG. 3.—DISCRETE AND CONTINUOUS ENERGY LEVELS OF A HYDROGENIC ATOM

More General Form of the Wave Equation.—So far, in (35), we have given the form of the wave equation for a conservative system consisting of a single particle and having a definite energy. We need a rule for forming the wave equation in other cases, involving either more than one particle or an indefinite energy, or both. In classical theory a conservative system necessarily has a definite, constant energy, but in quantum mechanics this need not be so, as will be discussed later more fully in connection with the Heisenberg uncertainty principle. As a result, it is no longer redundant to say that a conservative system has a definite energy. The more general scheme for forming the wave equation which we now give also applies to the nonconservative case in which the potential energy V contains the time explicitly.

The procedure is as follows. First of all, the Hamiltonian technique is to be used, *i.e.*, the system is to have associated with it a classical Hamiltonian function $H(q_1, \cdots, q_f, p_1, \cdots, p_f, t)$, which is a function of the co-ordinates and momenta. We replace p_k by the operator $\frac{h}{2\pi i}\frac{\partial}{\partial q_k}$, and in this fashion we can form a linear differential equation

$$\left[H\left(q_1,\cdots,q_f,\frac{h}{2\pi i}\frac{\partial}{\partial q_1},\cdots,\frac{h}{2\pi i}\frac{\partial}{\partial q_f},t\right)+\frac{h}{2\pi i}\frac{\partial}{\partial t}\right]\Psi=0. \quad (45)$$

This is the general wave equation. One is led to it primarily by comparison with other forms of quantum mechanics, especially transformation theory, rather than through the De Broglie and Schrödinger interpretation of the Hamiltonian analogy.

In case the system is conservative, so that t does not enter explicitly, (45) will admit a solution of the form

$$\Psi=e^{-2\pi iE_mt/h}\psi_m(q_1,\cdots,q_f), \quad (46)$$

where ψ_m is independent of t and satisfies the equation

$$\left[H\left(q_1,\cdots,q_f,\frac{h}{2\pi i}\frac{\partial}{\partial q_1},\cdots,\frac{h}{2\pi i}\frac{\partial}{\partial q_f}\right)-E_m\right]\psi_m=0. \quad (47)$$

However, (46) does not represent the most general solution of (45) for a conservative system, which is

$$\Psi=\Sigma_m c_m e^{-2\pi iE_mt/h}\psi_m, \quad (48)$$

where the summation is over all the characteristic values E_m and where the c_m are arbitrary constants. The expression (46) presupposes that the energy has a definite value, whereas (48) does not involve this restriction.

Equation (47) reduces to (35) for a one-particle system, where the classical Hamiltonian function is $(p_x^2+p_y^2+p_z^2)/2m+V$. To include the correction for the motion of the nucleus, we must add to this Hamiltonian function an extra term $(p_\xi^2+p_\eta^2+p_\zeta^2)/2M$, where M and p_ξ, p_η, p_ζ are respectively the mass and components of momentum of the nucleus. It is, of course, then necessary to use the general equation (47) rather than (35). It can be shown that the variables can be separated by changing them from $x, y, z, \xi, \eta, \zeta$ to $X, Y, Z, r, \theta, \varphi$ where X, Y, Z are the Cartesian co-ordinates of the center of gravity, and r, θ, φ are polar co-ordinates with origin at the nucleus. The solution of the wave equation takes a form similar to (44) except that there is an extra factor $e^{ik_1X}e^{ik_2Y}e^{ik_3Z}$ which allows for the motion of the centre of gravity of the system, and in which k_1, k_2, k_3 are arbitrary constants. The differential equation satisfied by the "internal" part of the wave function, *i.e.* the part depending on r, θ, φ can be shown to be the same as for the one-body problem, in which the nuclear motion is disregarded, except that the reduced mass (17) appears in place of the electronic mass m. The total energy, *i.e.*, the characteristic value of (47), is the sum of the internal energy given by (21) and an extra term $(k_1^2+k_2^2+k_3^2)h^2/8^2\pi(m+M)$ which represents the translational kinetic energy of the centre of gravity of the system. In our discussion of the Bohr theory we omitted this translational energy, but its inclusion in the Bohr frequency condition introduces a correction to the frequency which is essentially the quantum analogue of the classical Doppler effect, and yields results substantially equivalent to the latter.

An important property of (47) is that its solutions can be shown to be orthogonal, provided the operator is of the so-called "self-adjoint type." This condition is one which can practically always be met. If, in addition, the arbitrary proportionality constants in the wave function are so chosen that they are normalized to unity, one has the relation

$$\int\psi_l^*\psi_m d\tau=\delta_m^l, \quad (49)$$

where $d\tau$ is a volume element embracing the co-ordinate space of all the particles (of dimensionality $3n$ if there are n particles), and where the integration is over all the co-ordinates. The expression δ_m^l is the usual Kronecker delta, and has the meaning that $\delta_m^m=1$ and that $\delta_m^l=0$ $(l\neq m)$. The asterisk is used here and elsewhere to denote the complex conjugate. It is necessary to distinguish between ψ_m and its conjugate ψ_m^*, because the solutions of the Schrödinger wave equation are not necessarily real. In (49) the case $l\neq m$ expresses the orthogonality, and $l=m$ embodies the normalization.

THE MATRIX FORM OF QUANTUM MECHANICS

A few months prior to Schrödinger's discovery of wave mechanics, another, superficially very different approach to quantum mechanics was developed by Born and Heisenberg. The impetus to this other approach was Born's repeated emphasis to his colleagues at Göttingen that the reason the old quantum theory was then (1925) failing was that it sought to use the same kinematical concepts of space and time within the atom as in ordinary measurable large-scale events. After all, the concepts of space and time have a meaning only when we tell how they can be measured, and obviously at atomic distances we cannot use ordinary measuring rods or clocks. Guided by this philosophy based on the so-called operational viewpoint, Heisenberg discovered his matrix mechanics. He did not, however, originally recognize his formulation as a matrix one, and Born was the first to see that Heisenberg's equations were best interpreted in the language of matrices.

The basic idea of the matrix mechanics is that the co-ordinates and momenta associated with the electrons in the atom are to be treated as matrices rather than as quantities having a definite numerical value. A matrix is an array of the form

$$a=\begin{Bmatrix} a(11) & a(12) & a(13) & \cdots \\ a(21) & a(22) & a(23) & \cdots \\ a(31) & a(32) & a(33) & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & a(nn) \end{Bmatrix}$$

The matrices involved in quantum mechanics are infinite ones, *i.e.*, have an infinite number of rows and columns.

The Heisenberg matrix elements are quantities which are intimately connected with the concept of the transition probability in the old quantum theory, and alternatively with Fourier co-

efficients in classical mechanics. For simplicity, consider a system with only one degree of freedom. Then the matrix index can be identified with the quantum number, and a matrix element $a(lm)$ is correlated with a transition between states of quantum numbers l and m. The exact matrix expression replacing (31) is

$$A_{l\to m}=(4e^2/3hc^3)(2\pi)^4\nu(lm)^3[|x(lm)|^2+|y(lm)|^2+|z(lm)|^2]. \quad (50)$$

Here $x(lm)$ refers to an element of the x co-ordinate matrix, etc., and is the quantum analogue of the Fourier coefficient x_{l-m} involved in the rough formula (31) arrived at by means of the correspondence principle. As we have presented it, and as Heisenberg reasoned historically, (50) is obtained by analogy with classical theory, but it should be mentioned that (50) can also be derived independently from the Dirac radiation theory, which applies quantum mechanics to the degrees of freedom of the ether. By means of (50) the intensity of a line can be calculated if the Heisenberg matrices are known.

In order to compute the matrix elements needed for use in (50), one must transcribe atomic mechanics into the mysterious matrix language, and for this a matrix algebra and calculus are necessary. The sum of two matrices is formed by adding corresponding elements, so that $(a+b)(lm)=a(lm)+b(lm)$. Matrices are multiplied together in the same way as determinants, *i.e.*

$$(ab)(lm)=\Sigma_n a(ln)b(nm). \quad (51)$$

There is, however, the difference that whereas a determinant has a numerical value, a numerical meaning is attached only to the individual entries of a matrix and not to its entirety. This loss of numerical value corresponds to the abandonment of ordinary kinematical relationships within the atom. The multiplication is in general noncommutative, *i.e.* $(ab)(lm)\neq(ba)(lm)$ or more symbolically $ab\neq ba$, if boldface type is used to designate the entire matrix rather than a single entry.

By repeated additions and multiplications one can construct functions of matrices which are in turn matrices, and thus develop a matrix algebra. In order to transcribe atomic mechanics into the mysterious matrix language, it is necessary to have some sort of rule for constructing the derivative of one matrix with respect to another. A consistent mathematical framework is obtained if one defines the derivatives of a function $f(q_1, \cdots, q_f, p_1, \cdots, p_f)$ in the following way:

$$\frac{\partial f}{\partial p_k}=\frac{2\pi i}{h}(fq_k-q_kf), \frac{\partial f}{\partial q_k}=-\frac{2\pi i}{h}(fp_k-p_kf). \quad (52)$$

The special cases $f=p_j$ or q_j yield the so-called quantum conditions

$$p_kq_k-q_kp_k=(h/2\pi i)1, \qquad p_kq_j-q_jp_k=0 \quad (k\neq j)$$
$$p_kp_j-p_jp_k=0, \qquad q_kq_j-q_jq_k=0. \quad (53)$$

A diagonal matrix is one which has vanishing entries except down the principal diagonal, *i.e.* $a(lm)=0$, $l\neq m$, while a unit matrix has the additional property $1(ll)=1$. A diagonal matrix is the quantum analogue of a Fourier series which contains nothing but a single constant term. Hence, in a conservative system with a definite energy, the energy matrix must be a diagonal one.

It should be pointed out that the Heisenberg matrices are infinite ones in the sense that they involve an infinite number of rows of columns. Namely, each index (number of row or column) is correlated with a stationary state, and there is an infinite number of such states. Furthermore, in connection with fig. 3 we have seen that often the permitted stationary states form a continuous rather than discrete manifold. In the continuous region one has to introduce the rather recondite concept of a matrix with continuously varying indices, so that it cannot then even be tabulated in terms of rows and columns. When there is a continuum, the summation in (51) must be replaced by an integration. Similarly, in the expansion (48) the summations are to be construed as including integrations over the continua when these are present.

Relation of the Matrix and Wave Theories.—It is possible to work out the energy levels of the harmonic oscillator, rotator, hydrogen atom, etc., by means of pure matrix theory, and the results are always the same as those obtained with wave mechanics. One immediately suspects that the two approaches are interrelated. This is indeed the case. If the Schrödinger wave functions are known, the Heisenberg matrix elements can be computed by a straightforward integration. Suppose that we desire the matrix elements of a function $f(q_1, \cdots, q_f, p_1, \cdots, p_f)$ of the co-ordinates and momenta. Then the appropriate formula is

$$f(lm)=\int\psi_m^*f(q_1, \cdots, q_f, \frac{h}{2\pi i}\frac{\partial}{\partial q_1}, \cdots, \frac{h}{2\pi i}\frac{\partial}{\partial q_f})\,\psi_l d\tau, \quad (54)$$

where the integrand contains an operator f formed by replacing each p_k by $\frac{h}{2\pi i}\frac{\partial}{\partial q_k}$. We shall not attempt to prove (54) but shall note one or two simple consequences. In the first place, the quantum conditions (53) are satisfied. For instance, if $f=p_kq_k-q_kp_k$, then

$$f\psi_m=\frac{h}{2\pi i}\left[\frac{\partial}{\partial q_k}(q_k\psi_m)-q_k\frac{\partial\psi_m}{\partial q_k}\right]=\frac{h}{2\pi i}\psi_m,$$

and except for a factor $h/2\pi i$, the integral (54) becomes identical with (49), so that we have $f(lm)=(h/2\pi i)\delta_m^l$. This result agrees with the first relation of (53), since the elements of a unit matrix are equivalent to a Kronecker delta. The remaining relations of (53) are obviously satisfied. The third relation, for instance, follows since $\partial^2\psi/\partial q_j\partial q_k=\partial^2\psi/\partial q_k\partial q_j$.

Satisfaction of the wave equation (47) for a conservative system with definite energy is tantamount to making the energy a diagonal matrix. To see this we note that by (47) the operator H is equivalent to multiplication by a constant E_m. Hence, if f in (54) is taken to be the Hamiltonian operator H, the integral differs from (49) merely by a constant factor and so has the value $E_m\delta_m^l$.

If one is wedded to the extreme matrix viewpoint, one regards the wave functions merely as mathematical auxiliaries used to compute the Heisenberg matrix elements by means of the "matrix computing machine" (54). Such a viewpoint is undoubtedly too one-sided, and is offensive to physicists who take comfort from the parallelism of wave mechanics to classical mathematical physics, and to optics, in particular.

The Intensities and Polarizations of Spectral Lines.—By combining (54) (as applied to $f=x, y, z$) with (50), it is possible to compute the intensities of spectral lines. Furthermore, by examination of the relative magnitudes and phases of the corresponding x, y, and z components involved in (50), predictions can also be made regarding the polarization behaviour. In this fashion, for example, the intensities in the various components in the Stark effect for hydrogen can be calculated. Also, and even more important, it is possible to derive the various so-called "selection rules," which forbid certain quantum numbers changing except by a specified number of units. It can be demonstrated, for instance, that the quantum number for a harmonic oscillator cannot change by more than one unit. With the restriction $n''-n'=\pm 1$, the quantum-mechanical frequency ν obtained by substituting (43) in (13) becomes identical with the classical frequency ν_0. Without the restriction, ν could be any multiple of ν_0, a highly unreasonable situation since classically overtones are always absent for a simple harmonic system.

A particularly important case of the selection principle is that for the so-called azimuthal quantum number l, which is involved in the relativistic hydrogen atom and especially in Newtonian nonhydrogenic atoms with one valence electron. By means of (54) one can prove that l cannot change except by one unit. The quantum number l plays a vital role in interpreting the spectra of alkali atoms. (*See* SPECTROSCOPY.) An energy level is classified of the s, p, d, f character according as $l=0, 1, 2, 3$. The selection principle $l'-l''=\pm 1$ materially limits the "combinations" of the terms, *i.e.* the possible transitions between the different energy states. The predictions are strikingly confirmed by experiment.

THE STATISTICAL SIGNIFICANCE OF QUANTUM MECHANICS

Interpretation of the Wave Function.—We have not as yet given sufficient emphasis to the physical meaning of the solution of the Schrödinger wave equation, in distinction from its relation to the matrix formalism. The wave function satisfying the general equation (45) has an important physical interpretation. The square of its modulus is proportional to what may be called a statistical charge density. Let us consider first a system with only one particle. Then the probability that the particle will be in the volume element $dxdydz$ at time t may be taken to be

$$|\Psi|^2dxdydz, \quad (55)$$

provided the total probability is normalized to unity, *i.e.*

$$\iiint|\Psi|^2dxdydz=1. \quad (56)$$

This scheme of interpretation is a consistent one, as it can be shown that it is a consequence of the differential equation (45) that the integral on the left-hand side of (56) is independent of time. Otherwise the normalization condition (56) could not be imposed. Similarly, when there are n particles, $|\Psi|^2$ determines the probability in a $3n$ dimensional

space whose volume element $d\tau$ is $dx_1, \cdots, dz_n$.

It is to be emphasized that the density given by (55) is inherently statistical in character. We do not say that the particle is in the element $dxdydz$ at time t, but merely that there is a certain probability of the particle being there. In the particular case of a conservative system in a definite stationary state, the relation $|\Psi|^2=|\psi_m|^2$ is satisfied by virtue of (46), and then the probability becomes independent of time. The places where $|\Psi|$ or $|\psi_m|$ is large are those where the particle is likely to be located, but we can never say when it is there. The situation may be compared to the information obtainable from the time exposure of a firefly on a dark night. Where the photographic plate reveals the most brightness is where the firefly has spent most of the time, but one cannot infer just when the insect was at a particular spot. Similarly in quantum mechanics, the information about particles is inherently restricted because of its statistical nature.

When quantum mechanics was first discovered, there was considerable controversy as to whether it was necessarily statistical in character. For a while many physicists maintained that a deterministic picture was possible, in which the electron was considered to be a fluidlike affair whose density distribution is governed by (55). It is now, however, generally conceded that such attempts are untenable and involve the same fallacy as reasoning from the time exposure of the firefly that the latter is a luminous fluid rather than a discrete insect. It should be regarded as an advantage rather than a drawback that quantum mechanics must be interpreted statistically. When atomic experiments are analyzed from the "operational" viewpoint, it is found that the measurements always involve statistical features inasmuch as some of the parameters are distributed over a range of values and are not determined with complete precision. It is not the co-ordinates alone which must be statistically interpreted, but also other dynamical quantities, such as energy, momentum, etc.

Probability Distribution in Momentum Space.—Again confining our attention to one particle, we may, for instance, inquire concerning the probability that its components of momentum fall within a certain range at time t. The symmetrical roles of co-ordinates and momenta in the Hamiltonian technique suggest that there is a function χ such that

$$|\chi(p_x, p_y, p_z, t)|^2 dp_x dp_y dp_z \tag{57}$$

determines the probability that the momenta are in the element $dp_x dp_y dp_z$ at time t. There is indeed such a function, and the relation between the two functions Ψ, χ is similar to that between a function and its Fourier transform. Namely, it can be shown that

$$\Psi = h^{-3/2} \iiint \chi(p_x, p_y, p_z, t) e^{2\pi i(p_x x + p_y y + p_z z)/h} dp_x dp_y dp_z, \tag{58}$$

$$\chi = h^{-3/2} \iiint \Psi(x, y, z, t) e^{-2\pi i(p_x x + p_y y + p_z z)/h} dx dy dz. \tag{59}$$

Equation (58) has intuitively a very reasonable form, as it is natural to regard any disturbance as being built up of a superposition of De Broglie waves, each of the structure $e^{2\pi i p x/h}$ in one dimension or $e^{2\pi i(p_x x + p_y y + p_z z)/h}$ in three. In any principle of superposition in physics, the square of the amplitude governs the intensity, and so it is natural to assume that $|\chi|^2$ gives the probability. It can be shown from the mathematical theory of Fourier transforms (Plancherel's theorem) that

$$\iiint |\Psi|^2 dx dy dz = \iiint |\chi|^2 dp_x dp_y dp_z. \tag{60}$$

If (60) were not satisfied, the physical interpretation given Ψ, χ would lack consistency, for it is necessary that the total probability for either co-ordinate or momentum distribution be unity; or in other words, the normalization (49) in co-ordinate space must imply a corresponding normalization in momentum space. Another relation which can be established, and which shows the intimate relation between momentum and the operator $\frac{h}{2\pi i}\frac{\partial}{\partial x}$ is

$$\iiint p_x^n |\chi|^2 dp_x dp_y dp_z = \iiint \Psi^* \left(\frac{h}{2\pi i}\frac{\partial}{\partial x}\right)^n \Psi dx dy dz, \tag{61}$$

where n is an integer. Also there is a symmetrical relation

$$\iiint x^n |\Psi|^2 dx dy dz = \iiint \chi^* \left(-\frac{h}{2\pi i}\frac{\partial}{\partial p_x}\right)^n \chi dp_x dp_y dp_z. \tag{62}$$

Clearly (62) and (61) give respectively the mean value of the nth power of the x-component of displacement and of momentum.

Interference of Probability Amplitudes.—In ordinary probability theory, probabilities are compounded in accordance with the law

$$P(b) = \int P(b, a) P(a) da, \tag{63}$$

where $P(a)$ is the probability of occurrence of a, and $P(b, a)$ is the probability of occurrence of b when a is given. On the other hand, since $|\Psi|^2$ or $|\chi|^2$ is the density in position or momentum space, the functions involved in the compounding relation (58) are the square roots of probabilities and are spoken of as "probability amplitudes." The function $e^{2\pi i(x p_x + y p_y + z p_z)/h}$ is essentially a De Broglie wave and is called the probability amplitude connecting co-ordinates and momenta. The fact that in quantum mechanics we have a compounding relation analogous to (63) with $P^{\frac{1}{2}}$ rather than P is sometimes called the phenomenon of the "interference of probability amplitudes." Although no logical inconsistencies are ultimately involved, still this somewhat curious way of associating probabilities leads to many paradoxes which look rather strange from the standpoint of large-scale statistical mechanics. There is a certain amount of parallelism to the unintelligibility of interference phenomena in optics, wherein amplitudes rather than intensities are added, to a person who has been versed only in geometrical optics, ray tracing, and perhaps the corpuscular theory of light. It is now well recognized that radiation has both corpuscular and undulatory aspects. The former, for instance, stands out clearly in the photoelectric effect. As emphasized in Bohr's principle of complimentarity, the two aspects are not contradictory but instead play complimentary roles. So also, matter has both corpuscular and undulatory features. The type of compounding involved in (58) implies use of the wave amplitude in much the same way as in optics. It is well known that interference phenomena in the latter must be treated by superposing wave amplitudes rather than intensities or the number of corpuscular light quanta.

Transformation Theory.—The general interpretation of quantum mechanics as essentially a theory of probability amplitudes has been developed particularly by Jordan and by Dirac. The details of this so-called "transformation theory" are too intricate and abstract for us to treat here, but their formulation of quantum mechanics has elegance, generality and a unifying influence on the interpretation of the various other viewpoints. The Schrödinger wave equation, from the standpoint of transformation theory, may be regarded as an equation for finding the probability amplitude for distribution-in-position when the energy is known. One might ask for the probability amplitude for the distribution of other functions than positional co-ordinates—for instance, momenta—and the known quantity might not necessarily be the energy, as certain experiments correspond to fixation of other quantities than the energy. Such more general problems can be solved by means of transformation theory.

The Uncertainty Principle.—It is to be noticed that in (55) or (57) we have given expressions for the probability of the particle being in an element of volume $dxdydz$ of position space, or in an element of momentum space, but we have not a probability function for a concurrent occurrence of given values of position and momentum associated with a volume element $dxdydzdp_x dp_y dp_z$. This fact takes us to the heart of the Heisenberg uncertainty principle. The latter limits the accuracy with which it is possible to specify simultaneously the values of a co-ordinate and its canonically conjugate momentum. If Δp_x and Δx be the limits of precision within which p_x and x can simultaneously be determined, there exists the inequality

$$\Delta x \Delta p_x \geq h/4\pi. \tag{64}$$

For illustrations of this concept, and its philosophical implications, *see* UNCERTAINTY PRINCIPLE, THE. In virtue of the latter, it is meaningless to talk about the probability of a simultaneous occurrence of a given value of a co-ordinate and its conjugate momentum, for by (64) there is infinite uncertainty in a momentum if the position is known with complete precision, or vice versa.

The uncertainty principle should not be regarded as an additional hypothesis artificially injected into quantum mechanics. Instead, it is something which can be proved as a consequence of the latter, along the following lines. By proper choice of the origin for position and velocity, the mean position and velocity can be made zero; in other words, $I_{61}^{(1)}=I_{62}^{(1)}=0$, where $I_{61}^{(n)}$, $I_{62}^{(n)}$ denote respectively the integrals (61) and (62). The uncertainty in position and momenta can then be regarded as measured by the root mean square displacement and momentum, so that we can take $\Delta p_x^2=I_{61}^{(2)}$, $\Delta x^2=I_{62}^{(2)}$ provided Ψ is normalized in accordance with (56). Now it can be shown by pure mathematics, largely by the aid of the so-called Schwarz inequality, that any function Ψ normalized in accordance with (56) and satisfying the requirements of continuity, etc. required of a physically admissible wave function satisfies the identity $I_{61}^{(2)} I_{62}^{(2)} \geq (h/4\pi)^2$. The uncertainty principle is hence proved for the type of system under consideration. The equality sign in (64) corresponds to the minimum possible value of the product of the two errors, and this is achieved only when the probability functions have a Gaussian distribution.

It can be shown that the time is canonically conjugate to the energy. Hence, if we make an experiment whose span in time is limited, as is always the case, the energy cannot be known with complete precision, and so the appropriate wave function is (48), in which there is a dispersion of energy values, rather than (46), in which it is supposed that the energy is completely determinate. Wave functions of the general form (48), in which a number of stationary states are superposed and thus coexist, are sometimes spoken of as "wave pockets." It is through the construction of the latter that classical and quantum theories merge when the amount of action is large.

ELECTRON SPIN

A very important development practically concomitant with the advent of the true quantum mechanics was the discovery of electron spin. The basic idea of the latter is that the electron has an extra degree of freedom which may be likened to the spin of a top about an axis. Or,

if the electron moving about the nucleus is compared to the earth in the solar system, then there is an obvious analogy of the spin of the electron to the diurnal rotation of the earth about its own axis. The important features of the spinning electron were first presented by two young Dutch physicists, George E. Uhlenbeck and Samuel A. Goudsmit, in 1925, although some of the earlier literature did contain suggestions of a rotating electron in rather different connections.

The various dilemmas of spectroscopic theory and magnetism which are resolved by the introduction of electron spin are many. One of them is the existence of multiplets in molecular spectra. The simplest and most familiar example of a multiplet is provided by the two components of the *D* lines of sodium, which arise because the energy level of the upper state is double, *i.e.* consists really of two stationary states. A single level, however, is obtained if one uses the ordinary theory of a point electron. It is hence necessary to introduce a fourth quantum number, whose values subdivide the energy levels more than if one introduced merely the quantum numbers associated with the external degrees of freedom of the electron.

If one uses an electron model without spin, then there are three quantum numbers per electron. If the force field is dominantly central, as is usually the case even in nonhydrogenic atoms, then these three can be interpreted as the principal quantum number n, the azimuthal quantum number l, and the "magnetic" or "equatorial" quantum number m_l. The range of values of l is $0, \cdots, n-1$, and that of m_l is $-l, \cdots, +l$. The azimuthal quantum number l has the physical significance of specifying the angular momentum of the electron, in multiples of $h/2\pi$, while m_l fixes the component in a particular direction. The mathematical significance in terms of the indices of Tesseral harmonics involved in the wave function is that revealed in equation (44).

The Pauli Exclusion Principle.—Wolfgang Pauli proposed that besides n, l, m_l there be a fourth quantum number, or index m_s, which can take on the values $\pm\frac{1}{2}$. He then (1925) introduced his famous exclusion principle, for which he was awarded the Nobel prize in 1945. This principle states that no two electrons can have all four quantum numbers n, l, m_l, m_s the same. From this, the properties of the chemists' periodic table flow out automatically, including the existence of the "long" periods containing the iron, platinum and palladium groups, and of 14 rare earths. For instance, the choice $n=1$ for the principal quantum number corresponds to the first or hydrogen-helium period, which has two elements, and $n=2$ to the second or lithium-neon period. Namely, if $n=1$, we can have $l=0, m_l=0, m_s=\pm\frac{1}{2}$, two possibilities in all, whereas if $n=2$, we can have $l=0, m_l=0, m_s=\pm\frac{1}{2}$ and also $l=1, m_l=1, m_s=\pm\frac{1}{2}$; $l=1, m_l=0, m_s=\pm\frac{1}{2}$; $l=1, m_l=-1, m_s=\pm\frac{1}{2}$ giving eight possibilities all told. In this general fashion the numbers of elements in the different rows of the periodic table are deduced by a simple enumerative process.

When Pauli published his celebrated paper in 1925, the significance of the fourth quantum number was a complete mystery. The great contribution of the theory of Uhlenbeck and Goudsmit, which appeared less than a year later, was to show how naturally the spinning electron accounts for the Pauli formalism. The two choices $m_s=\pm\frac{1}{2}$ are interpreted as determining the two possible orientations of the spin angular momentum relative to the axis of quantization. In order that there be two choices, and no more, it is necessary to postulate that the electron has a "half quantum" $\frac{1}{2}(h/2\pi)$ of spin angular momentum.

Interpretation of the Exclusion Principle in Terms of Antisymmetric Wave Functions.—The spin hypothesis of Uhlenbeck and Goudsmit furnished an explanation of the fourth quantum number. It did not, however, give any indication of why it is that no two electrons have all four quantum numbers the same. Heisenberg was the first to point out that the Pauli exclusion principle has a rudimentary interpretation in terms of the symmetry properties of wave functions. When one solves the wave equation for a system of several like particles, their identity introduces special properties of symmetry, and permits classification of the solution according to symmetry characteristics, the precise codification of which involves complicated group theory. For the very simple special case of only two identical particles, for instance, the solutions are either symmetric or antisymmetric, as regards interchange of the corresponding co-ordinates of the two particles. In other words, the wave function is either invariant or reverses sign when the electrons are permuted. When there are more than two electrons, there are many types of symmetry intermediate between the symmetric and antisymmetric cases, which represent two extremes but which still have a meaning. Furthermore, the antisymmetric solution can never be constructed when the electrons are in identical states, *i.e.* have all four quantum numbers the same, for then the wave function would have to reverse sign as a result of an operation which does not change the arguments, an obvious impossibility. Hence, the Pauli principle is an automatic consequence of the formalism of quantum mechanics if we postulate that only those solutions of the Schrödinger equation which are antisymmetric under permutation of the electron co-ordinates are physically realizable. In other words, nature somehow has a penchant for antisymmetric wave functions. In this connection it is to be understood that all four co-ordinates are to be permuted, *i.e.* the spin co-ordinate as well as the three ordinary orbital ones x, y, z. The spin co-ordinate, unlike the variables x, y, z, which are continuous, assumes only the two values which correspond to the two possible orientations of the spin angular momentum relative to the axis of quantization. The wave function, on the other hand, need not be antisymmetric with respect to permutation of the orbital co-ordinates alone. In fact, no rigorous delineation of symmetry types under purely orbital permutation is possible, although it can be shown that symmetry characteristics associated with the orbital part of the problem determine the multiplicity of a spectral term, *i.e.* whether it is a singlet, doublet, triplet, etc. The purely orbital forms of the wave equation which we have given in (35) or (45) do not take cognizance of the spin. Inclusion of the latter introduces certain small magnetic interaction terms involving spin operators in the Hamiltonian function, and requires that the arguments of the wave function include spin variables as well as the ordinary orbital co-ordinates $q_1, \cdots, q_f$.

Electron Spin and Magnetism.—Electron spin plays a leading role in the theoretical interpretation of magnetic phenomena. A fuller description will be found in the article on MAGNETISM, and we shall mention only two points. One is that ferromagnetism arises almost entirely from spin rather than from orbital magnetic moment, for in the solid state the crystalline electric fields usually quench the orbital contributions to the magnetic moment. The other is that in the Uhlenbeck-Goudsmit model of electron spin the ratio of magnetic moment to angular momentum is taken to be e/mc, whereas the classical value of the ratio which applies to the orbit is $e/2mc$. In other words, the so-called gyromagnetic ratio has an anomalous factor 2 when applied to the spin. This anomaly is confirmed not only by measurements on the gyromagnetic effect (rotation of a body by magnetization, or magnetization by rotation), but also by those on the anomalous Zeeman effect. In the latter the so-called Landé g-factor expresses the fact that part of the contribution to the magnetic moment is of the normal orbital type, and part of the anomalous spin variety. *See* ZEEMAN EFFECT.

THE DIRAC ELECTRON

In the Uhlenbeck-Goudsmit theory, the half quantum of spin angular momentum and the anomalous factor 2 in the gyromagnetic ratio are introduced in a purely *ad hoc* fashion. Another approach, which avoids this arbitrariness, was developed by Dirac in 1928. In the original Schrödinger theory without spin, the behaviour of an electron was described by a single second-order differential equation. The spin properties assumed by Uhlenbeck and Goudsmit involved two different possible settings of space-quantized spin angular momentum, and were interpreted by means of the matrix theory. Pauli, however, soon showed how the Schrödinger wave theory could be generalized to include the spin, by introducing two wave functions, ψ_1, ψ_2 which satisfy two simultaneous second-order differential equations. Dirac had the revolutionary idea that the electron be described by four wave functions ψ_1, ψ_2, ψ_3, ψ_4 which satisfy four simultaneous first-order differential equations. If the electron is subject to an electrostatic potential $\varphi(x, y, z)$ and vector potential A, these equations are as follows:

$$(p_0+mc)\psi_1+(p_1-ip_2)\psi_4+p_3\psi_3=0,\ (p_0+mc)\psi_2+(p_1+ip_2)\psi_3-p_3\psi_4=0,$$
$$(p_0-mc)\psi_3+(p_1-ip_2)\psi_2+p_3\psi_1=0,\ (p_0-mc)\psi_4+(p_1+ip_2)\psi_1-p_3\psi_2=0 \tag{65}$$

where

$$p_0=-\frac{h}{2\pi ic}\frac{\partial}{\partial t}+\frac{e}{c}\varphi, \qquad p_1=\frac{h}{2\pi i}\frac{\partial}{\partial x}+\frac{e}{c}A_x,$$
$$p_2=\frac{h}{2\pi i}\frac{\partial}{\partial y}+\frac{e}{c}A_y, \qquad p_3=\frac{h}{2\pi i}\frac{\partial}{\partial z}+\frac{e}{c}A_z.$$

When first viewed, these equations certainly look arbitrary and artificial. Space will not permit description of how, to the first approximation in the dimensionless constant $(2\pi e^2/hc)^2$, they are equivalent to the more conventional theory based on second-order differential equations. It was this equivalence that first led Dirac to hit upon the equations of the structure (65). If the solutions are normalized to unity in the sense that

$$\iiint[|\psi_1|^2+|\psi_2|^2+|\psi_3|^2+|\psi_4|^2]dxdydz=1$$

then $(|\psi_1|^2+|\psi_3|^2)dxdydz$ and $(|\psi_2|^2+|\psi_4|^2)dxdydz$ are respectively the probabilities that the electron be in the volume element $dxdydz$ with spin parallel or antiparallel to the axis of quantization. It can further be shown that the simultaneous equations (65) have the proper invariance under a Lorentz transformation, so that the requirements of the special theory of relativity are satisfied. This is not true of the simple Schrödinger equation (35), which is essentially Newtonian in character. The relativistic transformation properties of ψ_1, ψ_2, ψ_3, ψ_4 are those appropriate to a pair of spinors, each of which has two components. This result is rather surprising, as one's first conjecture would be that the ψ's would transform like the components of a four-vector.

All the properties of electron spin, including the proper amount of angular momentum, relativistic fine structure, and even the gyromagnetic ratio, flow out of the Dirac formalism in an almost miraculous fashion suggestive of a magician's extraction of rabbits from a silk hat. Of course, some mathematical calculation, which we omit, is required to demonstrate that these various properties are indeed implied in (65), but we would like to emphasize particularly that when (65) is used, no additional postulates are necessary as in the original theory of Uhlenbeck and Goudsmit. Thus (65) can be regarded as the basis of a relativistic electron, with spin as a by-

product. In fact, the discovery of (65) and related methodology must be regarded as one of the most brilliant achievements in the whole history of mathematical physics.

When the Dirac equations (65) are used, the expressions for the energy levels of a hydrogenic atom have exactly the same form (24) as in the original relativistic Bohr-Sommerfeld theory. This identity of results must be regarded as one of the strangest coincidences in all of physics. In other words, the new quantum mechanics with spin is equivalent to the old theory without spin. Unless the spin is included in some form, either explicitly through the Uhlenbeck-Goudsmit model (which, however, is reliable only to the approximation (26)) or implicitly through the more refined Dirac equations, relativistic wave mechanics gives results different from (24) and not in accord with experiment. There is an important difference between the new and old interpretations of (24). The integer k no longer has the significance of being the azimuthal quantum number, as in the old quantum theory, but rather is equal to $j+\frac{1}{2}$, where j is the so-called inner quantum number which takes on half-integral values. The selection principles allow transitions in which the inner quantum number is unaltered as well as those in which it changes by ± 1, whereas only the ± 1 changes are allowed for the azimuthal quantum number. Hence, even though the energy levels are exactly the same, more spectral lines are allowed in the new than in the old interpretation of the relativistic fine structure. The extra components are confirmed experimentally, although the resolution is generally inadequate to detect them except as satellites of other lines.

Another success of the Dirac model is that it yields the so-called Klein-Nishina formula for the scattering of X-rays, which, unlike previous expressions, agrees well with experiment.

Negative Energy States and the Positron.—Hitherto we have stressed only the triumphs of the Dirac theory. Some of its difficulties should also be mentioned. One is that it is uncertain how the relativistic theory should be extended to include the interaction between electrons found in nonhydrogenic atoms. A more serious trouble is the existence of the so-called negative energy states. It is convenient and hence customary in relativity to include, as we shall henceforth, the so-called rest energy mc^2 of the electron in the total energy. This inclusion is equivalent to omitting the term -1 from the brace in (24), and with this modification the energy levels given by (24) are all positive. The dividing line between the discrete and continuous levels in fig. 3 then comes at $E=mc^2$. The equivalence of energy levels in the old and new theories mentioned above applies only as long as we confine our attention to states of positive energy. The old quantum theory gave no negative ones. However, it can be shown that with the Dirac equations (65) there is a continuum of states of negative energy, filling the entire range of energies below $-mc^2$. The rest energy mc^2 is enormously greater than the binding energy of the hydrogen atom, represented by the span of the discrete levels in fig. 3. The interval between the lowest positive state and the highest negative one is thus very approximately $2mc^2$, or about 1,000,000 electron-volts. To show even the highest negative energy level, it would be necessary to extend fig. 3 about two miles below the bottom of the page, the intervening interval being void, and from there down to minus infinity the figure should be shaded to indicate a continuum. (By contrast we may note that the relativity fine structure, first revealed by the second member of the expansion (26) of (24), also cannot be shown in fig. 3, but for a different reason, as on the scale of fig. 3 the splitting would amount to only about a millionth of an inch.)

The states of negative energy are obviously supernumerary and superfluous if viewed in a conventional fashion, and to get a theory that has a meaning, they must somehow be stricken off the books. Dirac suggested that the negative states are to be regarded as filled, each having the one electron allowed by the Pauli exclusion principle. This idea, of course, would not work with conventional Boltzmann statistics without the exclusion principle, as then there would be an overwhelming probability that the electrons be in states of negatively infinite energy. As there is a nondenumerable infinity of negative energy levels, there would be an infinite number of electrons housed in such states, even with the limitations imposed by the Pauli rule. Since the electron has a negative charge, there would hence be an infinite negative charge density. Dirac proposed that the charge is not to be counted in computing the charge density to be used in the Poisson law, etc.

According to this apparently fantastic conception, if an electron were somehow taken from one of the normally filled states of negative energy and placed in one of the conventional ones of positive energy, not only would an electron be created, but also a particle of equal mass but positive charge, now called the positron. Namely, a deficit in the full complement of negative charge, carried, so to speak, at zero on the books, is equivalent to a corresponding surplus of positive charge. (Dirac suggested originally that the shortage might correspond to the proton, but this idea is now considered untenable as, for one thing, no explanation is given of the diversity of mass between electron and proton.) Fantasy turned to reality, however, when Anderson obtained cloud chamber photographs showing the existence of positrons, *i.e.* particles equal to the electron in mass but positively charged. They should not be confused with protons, which are almost two thousand times heavier. Unlike the protons, which are stable, positrons are extremely short lived, as there is always the possibility that an electron be captured out of a state of positive energy and fill the gap in the negative one. Raising of an electron from a negative to a positive level is equivalent to the creation of an electron and a positron, or in other words to "pair production." The minimum energy involved in such a transition is very approximately $2mc^2$. Hence, the absorption of gamma rays can give rise to pair production if, and only if, their frequency exceeds $2mc^2/h$. In the experimental confirmation of this phenomenon, an apparent difficulty of the Dirac theory is turned into a triumph. Still there is much about the filled but uncounted continuum of negative energy states which is exceedingly hard to understand. J. Robert Oppenheimer and Wendell H. Furry tried to give a precise mathematical formulation to the bookkeeping procedure in which these states are omitted from the charge density, but encountered difficulties in showing that their accounting scheme had the proper relativistic invariance.

WHAT QUANTUM MECHANICS HAS ACCOMPLISHED

By way of summary, it is perhaps well to list some of the outstanding contributions which quantum mechanics has made to the understanding of atomic physics:

1. All the success of the old Bohr theory. The great triumph of the original Bohr version of quantum theory was its ability to explain the spectral frequencies of hydrogenic atoms, *i.e.* hydrogen, ionized helium, etc. This is done equally well by wave mechanics, in fact better in some respects.

2. A procedure for calculating the intensities rather than merely the frequencies of spectral lines.

3. Qualitative explanation of the spectra of nonhydrogenic atoms. The reason that quantitative precision is usually not possible is simply that when there is more than one electron the wave equation becomes too complicated mathematically to solve exactly. In the particular case of the neutral helium atom, which involves a three-body problem, it is possible to calculate the energy levels very accurately after considerable labour. The computed energy of the ground state of the neutral helium atom agrees with the observed to within one part in 10,000. This atom, on the other hand, was a stumbling block of the old Bohr theory.

4. An understanding of the phenomena of magnetism. Here electron spin plays an important role.

5. A quantum theory of the chemical bond. Although chemical processes are so complicated that one cannot hope to calculate accurately from theory the heats of the reactions, still quantum mechanics does enable one to understand the salient features—why valence rules are as they are—why there should be saturated bonds, etc. The Pauli exclusion principle is the key to the interpretation. The spin quantum number of an atom is intimately connected with its valence. Atoms with spins other than zero can be regarded as having unsaturated valences. The bonding is not due to any large magnetic coupling between the spins, and usually arises from the so-called exchange energy, which is electrostatic in character but which is correlated with spin alignment because of the constraints imposed by the Pauli exclusion principle. As a rule, the exchange energy is favourable to bonding when the spins are antiparallel. Besides codifying valence numbers, quantum mechanics has furnished a qualitative understanding of the directional valence characteristic of stereochemistry. It has also introduced the concept of resonance energy in chemical bonds. Previously one thought of the molecule as having a fixed structure, but quantum mechanics shows that it can coexist in several states at once, and a deeper energy is often obtained if a molecule resonates among a variety of configurations.

6. A quantum theory of the solid state. Thanks to quantum mechanics, one can explain in a general way how atoms are held together in solid bodies, and various properties of solids such as compressibility, thermal and electrical conductivity, specific heat, etc. Because solids involve more complicated aggregates of atoms than do individual molecules, the difficulties in the way of a strictly rigorous numerical computation are even greater than for the calculation of chemical binding. Nevertheless, semiquantitative as well as qualitative predictions are sometimes possible.

7. Collisions of electrons with atoms. Space prevents our discussing how quantum mechanics provides the basis for the interpretation of ionization potentials, capture phenomena and especially questions connected with the scattering of electrons or other particles (neutrons, protons, etc.) when they come near atoms or molecules.

8. Dispersion, and the absorption and emission of radiation. Numerous phenomena associated with the interaction of radiation with matter have been first adequately explained by quantum mechanics, such as the Compton effect or the photoelectric effect, and various questions connected with absorption and emission. By means of the so-called Kramers formula, a far more profound and realistic description of dispersion is provided than in classical theory. The standard quantum theory of radiation is that of Dirac, who regards the degrees of freedom of the ether as essentially an ensemble of quantum-mechanical harmonic oscillators. It should, however, be mentioned that attempts at a completely rational quantum electrodynamics have always run into difficulties connected with an infinite so-called "zero point energy," which must rather arbitrarily be subtracted off.

9. Explanation of the existence of the positron.

10. A new philosophy. Finally, we must not forget the philosophical implications of quantum mechanics, especially as embodied in the Heisenberg uncertainty principle, which shows that there is a limit to the precision with which we can observe nature.

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See also ATOM; NUCLEUS; TRANSMUTATION OF THE ELEMENTS; RADIOACTIVITY; SPECTROSCOPY; UNCERTAINTY PRINCIPLE, THE.

QUARANTINE, a term originally applied to the old sanitary preventive system of detention of ships and men, unlading of cargo in lazarets, fumigation of susceptible articles, etc., which was practised at seaports on account of the plague, in connection with the Levantine trade. It is now a thing of the past in Great Britain and in the majority of other states. But, in common usage, the same word is applied to the sanitary regulations which are the modern substitutes for quarantine. *See* PLAGUE.

QUARE IMPEDIT, in English law, a form of action by which the right of presentation to a benefice is tried. It is so called from the words of the writ formerly in use, which directed the sheriff to command the person disturbing the possession to permit the plaintiff to present a fit person, or to show cause "why he hinders" the plaintiff in his right. The action was one of the few real actions preserved by the Real Property Limitation Act, 1833, and survived up to 1860. The effect of the Common Law Procedure Act, 1860, s. 26, was to assimilate proceedings in *quare impedit* as far as possible to those in an ordinary action. It is now brought against a bishop to try the legality of his refusal to institute a particular clerk. Except when a person presented is refused on the ground of doctrine or ritual, *quare impedit* became obsolete on the passage of the Benefices Act, 1898. (*See* BENEFICES.) In the United States, owing to the difference of ecclesiastical organization, the action is unknown.

QUARITCH, BERNARD (1819–1899), English bookseller and collector, was born at Worbis, Germany, on April 23, 1819. He went to London in 1842, and was employed by Bohn the publisher. In 1847 he started a bookseller's business off Leicester square, becoming naturalized as a British subject. In 1848 he started to issue a monthly *Catalogue of Foreign and English Books.* About 1858 he began to purchase rare books, one of the earliest of such purchases being a copy of the Mazarin Bible, and within a period of forty years he possessed six separate copies of this rare and valuable edition. In 1860 he removed to Piccadilly. In 1873 he published the *Bibliotheca Xylographica, Typographica et Palaeographica,* a remarkable catalogue of early productions of the printing press of all countries. He became a regular buyer at all the principal book-sales of Europe and America, and from time to time published a variety of other catalogues of old books. Amongst these may be mentioned the *Supplemental Catalogue* (1877), and *General Catalogue of Old Books and Manuscripts* (12 vols., with supplements, 1887–8). By this time Quaritch had developed the largest trade in old books in the world. He died at Hampstead on Dec. 17, 1899, leaving his business to his son.

QUARLES, FRANCIS (1592–1644), English poet, was born at Romford, Essex, and baptized there on May 8, 1592. He was entered at Christ's college, Cambridge, in 1608, and subsequently at Lincoln's Inn. He was made cupbearer to the Princess Elizabeth, Electress Palatine, in 1613, remaining abroad for some years; and before 1629 he was appointed secretary to Ussher, the primate of Ireland. About 1633 he returned to England, and spent the next two years in the preparation of his *Emblems.* In 1639 he was made city chronologer, a post in which Ben Jonson and Thomas Middleton had preceded him. At the outbreak of the Civil War he took the Royalist side, drawing up three pamphlets in 1644 in support of the king's cause. He died on Sept. 8, in that year. Quarles married in 1618 Ursula Woodgate, by whom he had eighteen children.

Of the numerous works of Quarles the only one which has importance is the *Emblems,* originally published in 1635, with grotesque illustrations engraved by William Marshall and others. The forty-five prints in the last three books are borrowed from the *Pia Desideria* (Antwerp, 1624) of Herman Hugo. Each "emblem" consists of a paraphrase from a passage of Scripture, expressed in ornate and metaphorical language, followed by passages from the Christian Fathers, and concluding with an epigram of four lines. The *Emblems* was immensely popular but little esteemed by critics.

An edition of the *Emblems* (Edinburgh, 1857) was embellished with new illustrations by C. H. Bennett and W. A. Rogers. These are reproduced in the complete edition (1874) of Quarles included in the "Chertsey Worthies Library" by Dr. A. B. Grosart.

QUARRYING, the art of winning or obtaining from the earth's crust the various kinds of stone used in construction, road building and the various manufacturing processes for which rock minerals are employed, the operation being, in most cases, conducted in open workings. There are two distinct types of quarrying, one being that employed in the quarrying of what is constantly referred to as "building stone," for which purpose the stone must be obtained in large unshattered blocks or masses, and the other, the quarrying of stone in rough irregular shapes for road building, concrete aggregate, fluxing and various manufacturing processes, for which purposes it must be broken up, crushed or pulverized in preparing it for utilization. The quarrying of stone in blocks for use in construction may be further divided, as will be described later, into the several types of quarrying processes that are employed by reason of the character and physical properties of the different types of rock used for "building stone."

Building Stone.—According to their general character and composition, building stones are broadly classed as granites, sandstones, limestones, marbles and slates. Under the first of these heads is included a number of crystalline rock species, of igneous origin such as granite, syenite, gneiss, schist, etc., which to the geologist are quite distinct, but which in commerce are all spoken of as granite. They are chiefly composed of one or more minerals of the felspar group mingled with one or more of the micas or with hornblende and usually contain quartz. Sandstones are sedimentary rocks chiefly composed of fragments of quartz consolidated by pressure or cemented into solid rock by silica and oxide of iron. Of these there are many varieties, including bluestone and flagstone used for foot-pavements. Thoroughly cemented sandstones are termed quartzites. Limestones are rocks also of sedimentary origin and consist principally of carbonate of lime or of a combination of the carbonates of lime and magnesia. Their chief variations are the crystalline form known as marble and the deposit from mineral springs known as Mexican onyx.

The type of limestone used principally for building stone is the oolitic variety, a calcareous-sand rock made up of shells and shell fragments on the sea floor consolidated into a solid mass or in layers and later uplifted to become a part of the land. Slates are mudstones or shales hardened by heat and pressure and rendered fissile by the latter agent. Chemically they consist chiefly of hydrous silicate of alumina. Theoretically, the sedimentary rock, sandstone, limestone and slate are of a layered

formation, although certain limestones and sandstones are massive in character, while all granites are massive, and have no bedding or stratification like sandstones and limestones; but all rock masses are usually found to be more or less affected by movements of the earth's crust which occur as a result of its constant readjustment to the cooling and shrinking interior, so that the rocks are divided by cracks or fissures, which are commonly known as joints. In the massive granites these joints, which usually occur in two or more planes at right angles to one another, are of the greatest importance to the quarryman, as they enable him to separate masses of stone with approximately parallel faces. In gneisses the parallel arrangement of the minerals usually coincides with a direction of easy cleavage known to quarrymen as the "rift"; at right angles to this direction is usually one less easy parting, known as the "grain." Sandstones and limestones being stratified rocks which have been formed as sediments in bodies of water, whether their beds are found in the normal position of horizontality, or whether they have been tilted and folded by earth movements, the direction of easiest separation is coincident with the original planes of sedimentation and parallel to them. Strictly speaking, the term rift applies only to massive crystalline rocks, the term bedding-plane being a better one to apply to sedimentary rocks.

In gneisses, sandstones and limestones, joints also occur; and while frequently convenient for the division of the beds into masses of useful size, they may be a detriment, as when they occur so close together as to fall within the limits of a block suitable or economically usable for commercial purposes. In commerce the various kinds of building stone are usually designated by the name of the locality or region in which the quarry is situated. In the case of the more important varieties this geographic name usually conveys to the architect or builder sufficient information concerning colour, texture and other properties of the material.

Methods of Quarrying.—The methods of quarrying vary with the composition and hardness of the rocks, their structure, cleavage and other physical properties; also with the position and character of the deposits or rock-masses. In the quarrying of building stone, the general purpose of the work is to separate the material from its bed in masses of form and the size best adapted to the intended use. Cutting the stone to accurate dimensions, dressing, moulding and finishing by tooling, rubbing or polishing are subsequent operations not involved in quarrying. Crushing all kinds of hard, durable stone to angular fragments for macadam type roads and for concrete aggregate is also an operation subsequent to quarrying.

The practice of quarrying consists in uncovering a sufficient surface of the rock by removing superficial soil, sand, clay, or overborder of overlaying waste rock by some suitable process or by sinking a shaft or slope, and then with proper tools or explosive, detaching blocks of form and size adapted to the purpose in view. Frequently the exposed outer portion of the rock has been either cut up and eroded away in fissures or has been affected by the action of various atmospheric agencies, until it has become discoloured or softened by decay. This weathered material must be removed before stone can be obtained for economic use in the production of dimension stone.

The separation of blocks of building or dimension stone is ordinarily carried on by some specific variation of one of the two general present-day methods of quarrying known respectively as the "blasting" and "channeling" process. Blasting is used for the harder rocks that do not tend to shatter and channeling for most other kinds of rock. The blasting process consists of drilling holes along the outlines of the block to be removed, and then, by exploding blasting-powder in the holes, exerting sufficient force to overcome the cohesion of the rock and rend it asunder. In many quarries it is found most convenient to separate a large mass and afterwards divide it into blocks of the required size, by drilling holes for further charges of blasting powder, or by driving wedges into these to split the rock. When the rock is stratified, or has an easily determined rift, the holes are drilled at right angles to the plane of separation.

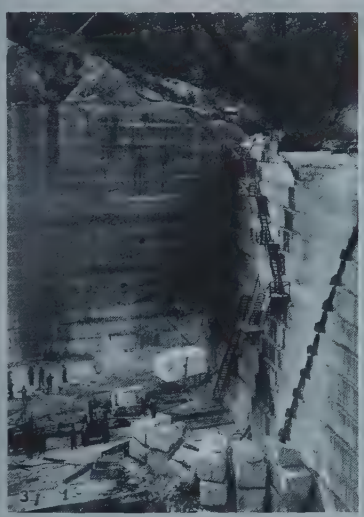
When there is no stratification or rift, or these natural planes of separation are too far apart, or when the position of the joints is not advantageous, a row of horizontal holes must be drilled into the face or breast of the quarry, along which separation is effected either by blasting or the use of wedges. At certain American quarries, in a granite which has no rift or direction of ready cleavage, compressed air has been brought into service to effect the separation of extensive layers. A hole is drilled as deep as the desired thickness of the layer to be separated, and a small charge of dynamite is exploded at the bottom of it. This develops a cavity in which a small charge of powder is next exploded, producing a crack or crevice parallel to the surface of the rock. A pipe for conveying compressed air is now sealed into the opening, and gradually increasing pressure is introduced. This results in the gradual extension of the crevice developed by the explosion of the powder. In the absence of compressed air, water under pressure may be used and also small powder charges exploded at intervals of a few days.

Crushed-stone Quarrying.—A very large and important branch of the quarry industry has recently come into existence, since the era of improved highways and the extensive use of Portland and other hydraulic cements; this is distinguished from "building or dimension stone" quarrying and is generally referred to as crushed-stone quarrying. The object of crushed-stone quarrying is to drill, blast with high explosives and remove or excavate the stone in the cheapest possible manner from either hillside or pit quarries, so that it may be loaded with power shovels and then be fragmented by crushing and grinding machinery of various types to commercial sizes for aggregate, or pulverized to be manufactured into cements. The quarrying of stone for flux in manufacture of steel and glass, for burning into lime and for various other mineral industries also falls in this category. Commercial sizes for crushed stone will vary from 5 to 6 in. in greatest dimension (limestone fragments for lime kilns or blast furnaces) to dust, which has many commercial uses. The commonest and largest uses of crushed stone are for surfacing highways and for use as aggregate with bituminous binders or Portland cement to make concrete. Most commercial crushed-stone quarry operations differ in no essentials from open-pit mining. There are also numerous underground quarry-mining operations for the purpose of winning crushed stone for similar purposes.

In thinly bedded sandstone, where vertical joints are frequent, it is often possible to separate the desired slabs and flagstones with crowbars and wedges, without drilling or the use of explosives. When blasting is necessary, some form of gunpowder is generally used, rather than a violent explosive like dynamite, in order to avoid shattering the rock. This, however, applies only to dimension stone. When the production of broken stone for road-making, concrete or similar purposes is the sole end in view, violent explosives are preferred.

Channeling Machines.—In limestones and marbles and in the softer sandstones, the channeling process is almost invariably employed. Channeling machines, driven by steam, compressed air, electricity, or a combination of these are used, by which vertical or oblique grooves or channels can be cut with great rapidity to a depth of from 8 to 12 feet. A level bed of rock is cleared, and on this are laid rails, along which the machine moves opposite to the bottom of the channel cut. After the channels are cut and a row of holes drilled perpendicular to the channel—opposite the bottom of the channel cut—wedges are driven and the required blocks or cuts of stone are separated from the ledge. These cuts, frequently of great size, running 60 to 80 ft. in length, by 10 to 12 ft. in depth and 4 to 5 ft. in width in some limestone quarries, are then with the aid of the derrick power turned over on the side, after which they are drilled and split up into blocks of convenient sizes for transportation and handling. These are called mill blocks, and are usually from 3 to 4 ft. by 3 to 5 ft. in cross-section and 6 to 12 ft. in length.

When the beds of stone to be quarried are comparatively thin, with heavy overburden, or when to remove the whole of the overlying mass of earth or rock would be too expensive, it has been found convenient to treat the quarry as if it were a mine, and to rely upon methods similar to those practised in mining.



BY COURTESY OF (1, 4) THE ROCK OF AGES CORPORATION, (2, 7) THE INDIANA LIMESTONE COMPANY, (3, 5) THE GEORGIA MARBLE COMPANY, (6) THE ALABAMA POWER COMPANY

OPEN-CUT QUARRYING

1. Open-cut method of excavating Vermont granite by hand. 2. Turning over a large cut of limestone in an Indiana quarry. 3. Georgia marble quarry. Depth at time photograph was made, 80 feet. Weight of block being hoisted, 14 tons. 4. Hoisting blocks of granite from a Vermont quarry. 5. Gang-saw used for sawing marble. The cutting tool, a steel saw-blade aided by the abrasive action of a mixture of sand and water, cuts the blocks into the required thickness. 6. Marble quarry in Alabama, showing large cranes used for hoisting. 7. General scene at a Bedford, Ind., quarry. The large cut is shown "turned over" at the left, and being split up into smaller blocks before hoisting to railroad cars

Since great advances have been made in both the quarrying and working of building stone during recent years, few articles will be found that are really up to date. As a supplement to the following references the reader is referred to the more recent articles on the subject of quarrying that have appeared in trade press and technical publications of this industry as the most reliable source of additional information.

See Institution of Quarry Managers, *Quarrying* (Conway, 1924); G. C. Mance, *Power Economy and the Utilization of Waste in the Quarry Industry of Southern Indiana* (Indiana Univ. Studies, 1917), also the *Quarry Managers' Journal* (Conway). (F. J. H. M.)

QUARTER DAYS, the days that begin each quarter of the year; in England, March 25 (Lady day), June 24 (Midsummer day), Sept. 29 (Michaelmas day) and Dec. 25 (Christmas day). They are the days on which it is usually contracted that rents should be paid and houses or lands entered upon or quitted. In Scotland there are two legal terms, May 15 (Whitsunday) and Nov. 11 (Martinmas); these, together with the two conventional terms, Feb. 2 (Candlemas) and Aug. 1 (Lammas), make up the Scottish quarter days. In the Scottish burghs, however, the removal terms are May 28 and Nov. 28. In the United States the quarter days are, in law, the 1st of January, April, July and October.

QUARTERMASTER, a commissioned officer of a unit whose chief duty is the care of the stores, rations, equipment, etc. Quartermasters were mentioned as early as 1447, and were found on the regimental lists of the Army in Ireland in 1660. The former title was "harbinger's clerk," the quartermaster-general being styled the Harbinger. Early quartermasters were usually warrant officers (unless holding a separate combatant commission), except in the Household Cavalry, where they were always commissioned officers. Cavalry regiments usually had a quartermaster to each troop but infantry never had more than one to a battalion. In the British service the rank is reserved for warrant officers and N.C.O.'s of exceptional ability and continuous exemplary conduct. In the U.S.A. there is a quartermaster corps which performs the duties comparable to the quartermaster-general's branch of the British service. In the French service similar duties are carried out by the *intendance,* the executive branch of which is officered by *officiers d'administration* recruited from *sous-officiers* (warrant officers and sergeants).

(T. J. E.)

Naval quartermasters are petty officers in rank or, in smaller vessels, are selected leading seamen or able seamen, who in harbour perform, under the officer of the watch or officer of the day, duties comparable to those of a night-watchman during the dark hours, while during working hours they assist the duty officers by attending to the details of the routine, the good order of the quarter deck, the employment of the duty boats and the general curriculum of the ship's company. At sea the quartermaster is stationed at the wheel and either steers himself, under the orders of the officer of the watch or navigating officer, or closely supervises the seaman who is steering, to ensure that he keeps a good course and promptly and quickly obeys any orders given for the movements of the helm.

In a big ship the quartermasters are usually assigned for service in four watches. In smaller ships they may also combine the duties of boatswain's mate. The term is also used in the mercantile marine, where a quartermaster's duties are similar to those on a man of war. In old navy days the quartermaster's duties are described as being to supervise "stowing the ballast and provisions in the hold, coiling the cables in the platforms, overlooking the steerage of the ship, keeping the time by the watch glasses, and in turn overlooking the purser's steward in his delivery of provisions, etc." (E. A.)

QUARTER SESSIONS, COURT OF, in English law, the name for the justices of the peace of any county, riding, parts, division or liberty of a county, or of any county of a city or county of a town, in general or quarter sessions assembled; it includes the court of the recorder of a municipal borough having a separate court of quarter sessions. The word "general" in this context is contrasted with "special" or "petty" The court is a local court of record having a limited criminal jurisdiction, and also to some extent civil jurisdiction. As a court of record it has, in addition to its other jurisdiction, power to punish summarily without the assistance of a jury contempts committed in its presence, such as insults to the justices or disturbance of its proceedings. At the present time the whole of England and Wales is within the local jurisdiction of some court of quarter sessions.

The court derived its name from the direction in a statute of 1388 that the "justices shall keep their sessions in every quarter of the year at the least." By s. 22 of the Criminal Justice Act 1925, general quarter sessions for any county must be held at such times within the period of 21 days immediately preceding or immediately following March 25, June 24, Sept. 29 and Dec. 25 in every year as may be fixed. The justices are free to sit oftener by adjournment of the quarterly sessions to another time, and even to another place, in their county, or to hold additional sessions. All the sessions thus held are "general," though not all may be "quarter" sessions. The Assizes and Quarter Sessions Act 1908 gave the useful power of dispensing with the holding of quarter sessions if there is no business to transact, and under the Criminal Justice Act 1925 there is power to dispense with the grand jury where all persons committed have pleaded guilty.

In all the counties, except that of London, the justices in the commission elect a chairman and vice-chairman, neither of them necessarily a lawyer, to preside at the sittings of the court. In the county of London there are a paid chairman and deputy chairman, who must be barristers of at least ten years' standing, and are appointed by the Crown. Under the Quarter Sessions Act 1858 the court may sit in two divisions of at least two justices at the same time and place, but not simultaneously in separate parts of the same county.

The jurisdiction of the court of quarter sessions of a borough does not depend upon the commission of the peace, but upon the Municipal Corporations Act 1882. Before the Municipal Corporations Act 1835, many boroughs had criminal jurisdiction under their charters. Under that Act and the Act of 1882 a grant of quarter sessions to a city or borough is made by the Crown in council on petition of the town council. The recorder (*q.v.*), a barrister of not less than five years' standing appointed by the Crown, is sole judge of the court.

The city of London is not subject to the Municipal Corporations Act 1882, and its court of quarter sessions is created by the city charters, and is held before the mayor and aldermen with the recorder. It does not now sit to try indictments, which all go to the Central Criminal Court.

Criminal Jurisdiction.—Courts of quarter sessions in counties and boroughs have both original and appellate jurisdiction depending on the commission of the peace and on legislation beginning in 1344. This jurisdiction is derived in counties from the commission of the peace. The jurisdiction of quarter sessions is governed chiefly by the Quarter Sessions Act 1842, and they are forbidden to try the following offences: treason or misprision of treason; murder, capital felony or any felony (except burglary) which is punishable on a first conviction by penal servitude for life; offences against the king's title, prerogative, person or government, or against either House of parliament; offences against the Official Secrets Acts 1911 and 1920; offences subject to the penalties of praemunire; blasphemy and offences against religion, and composing or publishing blasphemous, seditious or defamatory libels; and various other offences prohibited by statutes. But their jurisdiction has been extended by the Criminal Justice Act 1925 and certain offences under the Perjury and Forgery Acts and other statutes and the so-called "long firm" frauds are cognisable by quarter sessions. Trials before the court with a jury are governed by the same procedure as trials on indictment in a court of assize. Under the Vagrancy Act 1823 and amending Acts, they have special powers of sentencing incorrigible rogues sent to them by courts of summary jurisdiction.

An appeal lies to quarter sessions from convictions by a court of summary jurisdiction only where such an appeal is expressly given by statute. (*See* SUMMARY JURISDICTION.)

Civil Jurisdiction.—By legislation in and since 1888 most

of the administrative powers and duties of justices in general and quarter sessions have been transferred to the incorporated and elective councils of counties, boroughs and urban and rural districts. But the justices still possess certain original, civil or quasi-civil jurisdiction with respect to licensing and as to closing highways. Most of the civil jurisdiction of quarter sessions is now appellate, *i.e.*, with reference to orders made by justices.

Rating appeals, although they are still made to quarter sessions, are heard by a committee of the justices of the county appointed by such sessions (Rating and Valuation Act 1925). The procedure as to each form of appeal depends partly on the statute by which it is given and partly on the general provisions of the Summary Jurisdiction Acts. Decisions on law may be reviewed by the High Court (king's bench division) by means of *certiorari, mandamus* or prohibition. Convictions on indictment before courts of quarter sessions are within the provisions of the Criminal Appeal Act of 1907, except convictions on indictments for obstruction or non-repair of a public bridge, highway or river, from which an appeal lies to the court of appeal in the same way as in the case of civil actions tried at assizes. Persons dealt with as incorrigible rogues are also within the Act of 1907. Quarter sessions can state a case on a point of law on an appeal to them against a conviction by a court of summary jurisdiction, and if they decline to do so may be ordered to state a case by the High Court (Criminal Justice Act 1925). (W. F. C.; W. DE B. H.)

United States.—There are one or two courts of quarter sessions in the United States, but in general, courts of other names, differing in the various jurisdictions, perform its functions.

QUARTER SQUARES. Among the labour-saving devices for multiplying is one which seems to be of Hindu origin and which may be stated as follows: to find the product of two numbers, take the difference between a quarter of the square of their sum and a quarter of the square of their difference. For example, $9\times8=\frac{1}{4}(9+8)^2-\frac{1}{4}(9-8)^2=\frac{1}{4}(289-1)=72$. It depends upon the algebraic identity, $ab=\frac{1}{4}(a+b)^2-\frac{1}{4}(a-b)^2$. If the computer has a table of squares sufficiently large, the method has considerable value, and this is more evident if he has a table of quarter squares. The plan is given in various Arabic works, as in al-Karkhî's *al-Kâfî fî'l-Hisâb* (*c.* 1020).

See J. Blater, *Table des Quarts de carrés de tous les nombres entiers de 1 à 200000* (1888). For a discussion of the subject, with a bibliography and a description of related methods *see* H. Mehmke, *Numerisches Rechnen,* in W. F. Meyer, *Encyklopädie der mathematischen Wissenschaften,* Band I., pp. 944–952.

QUARTER-STAFF. A staff of wood from six to nine feet in length, used as a means of attack and defence; originally no doubt it was the cudgel or sapling with which many heroes are described by early writers as being armed. The quarter-staff attained great popularity in England in the middle ages. It was usually made of oak, the ends often shod with iron, and it was held with both hands, the right hand grasping it one quarter of the distance from the lower end (whence the name) and the left at about the middle.

Egerton Castle (*Schools and Masters of Fence*) says that the staff was the "foil," or practice-substitute for the *long sword* or *two-hander.* In earlier times it may also have been used as a practice weapon for the spear and bill. In the prints illustrative of the life of Richard Beauchamp, earl of Warwick (1382–1439), reproduced in Joseph Strutt's *Manners, Customs, Arms, Habits, etc. of the Inhabitants of England,* may be seen a combat between two knights after they have splintered their lances and dismounted, in which both are fighting with pointed staves about as long as a quarter-staff and held in the same manner. In the 17th century the staff was still popular in England.

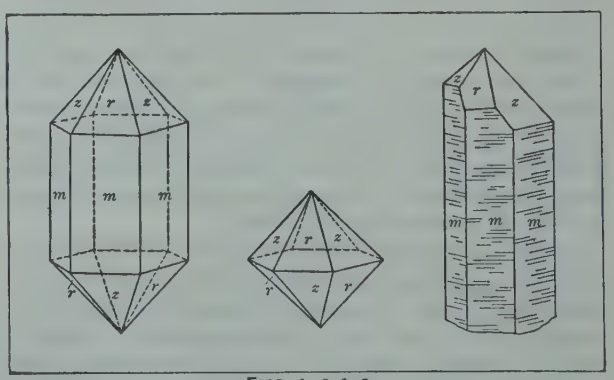
At the present time the quarter-staff is used to a limited extent in military circles as a school for bayonet play. (*See* FENCING.) (A. R. H.)

QUARTER TONES, in music. Although the semitone, or half tone, was formerly defined as "the smallest interval recognized in music" much smaller intervals have always been employed in oriental music (*see* INDIAN MUSIC), and later attempts have been made by various musicians to introduce similar intervals, such as quarter tones, in Western music. Foremost among these has been the Czech composer and theorist, Alois Haba, who has written a number of works based on the quarter-tone system, though so far, it must be said, without securing for them much appreciation even at the hands of the best disposed listeners. To the contrary, the opinion expressed has usually been that the effect was too closely akin to that of instruments playing out of tune to be agreeable, although it may be that with further experience of the music it might produce a more favourable impression. Another who theorized on the subject, and considered incidentally the possibility of employing even smaller intervals than quarter tones, was the eminent pianist and composer Busoni, while John Herbert Foulds, an English composer, has done the like. (*See* HARMONY.)

QUARTZ, a widely distributed mineral species, consisting of silicon dioxide, or silica, SiO_2. It is the commonest of minerals, and is met with in a great variety of forms and with very diverse modes of occurrence. The various forms of silica have attracted attention from the earliest times, and the water-clear crystallized variety was known to the Greeks as κρύσταλλος (clear ice), being supposed by them to have been formed from water by the intense cold of the Alps; hence the name "crystal," or more commonly rock-crystal, applied to this variety. The name quartz is an old German word of uncertain origin used by G. Agricola in 1529.

Quartz is a mineral which is put to many uses. Several of the varieties are cut into gems and ornaments, balance weights, pivot supports for delicate instruments, agate mortars, etc.; or used for engraving, for instance, cameos and the elaborately carved crystal vases of ancient and mediaeval times. Clear transparent rock-crystal is used for optical purposes; fused quartz is also used for the construction of lenses and laboratory vessels, and is drawn out into the finest elastic fibres and used for suspending mirrors, etc., in physical apparatus; for striking fire, flint is used even to the present day; and buhrstone, a cellular variety of chalcedonic quartz from the Tertiary strata of the Paris basin, is largely used for millstones. Quartz is a valuable grinding and polishing material, and is used for making sandpaper and scouring-soap, also in the manufacture of glass and porcelain, "silver sand" being a pure quartz sand.

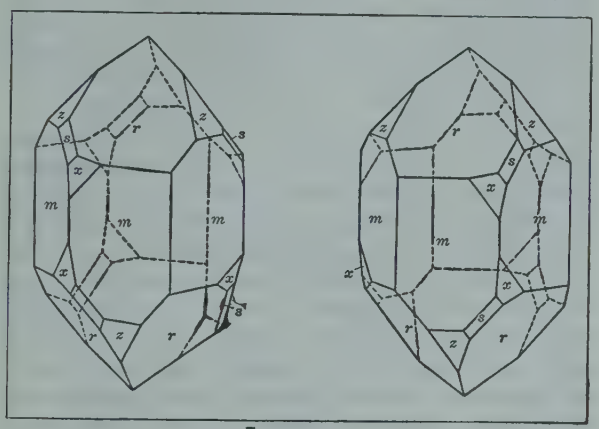
Crystallography.—Quartz crystallizes in the trapezohedral class of the rhombohedral division of the hexagonal system. Crystals of this class possess neither planes nor centre of symmetry, but only axes of symmetry; perpendicular to the principal triad axis there are three uniterminal dyad axes of symmetry. Usually, however, this lower degree of symmetry is not indicated by the faces developed on the crystals. The majority of crystals of



FIGS. 1, 2 & 3

quartz are bounded only by the faces of a hexagonal prism $m\{2\bar{1}\bar{1}\}$ and a hexagonal bipyramid (fig. 1), though sometimes the prism is absent (fig. 2). Frequently the faces are of different sizes (fig. 3): mis-shapen crystals are common and sometimes very puzzling, but they can always be orientated by the aid of the very characteristic striations on the prism faces, which serve also to distinguish quartz from other minerals of similar appearance. These striations (fig. 3) are horizontal in direction, being parallel to the edges of intersection between the prism and pyramid faces, and are due to the frequent oscillatory combination of these faces. The apparent

hexagonal bipyramid is really a combination of two rhombohedra, the direct rhombohedron $r\{100\}$ and the inverse rhombohedron $z\{22\bar{1}\}$. The faces of these two rhombohedra exhibit differences in surface characters, those of r being usually brighter in lustre than those of z; further, the former often predominate in size (figs. 4 and 5), and the latter may sometimes be completely absent. When both the prism and the rhombohedron z are absent, the crystals



FIGS. 4 AND 5

resemble cubes in appearance, since the angles between the faces of the rhombohedron are 85° 46′. The additional faces s and x (figs. 4 and 5), which indicate the true degree of symmetry of quartz, are of comparatively rare occurrence except on crystals from certain localities. The six small faces $s\{41\bar{2}\}$ situated on alternate corners at each end of the crystal, are called the "rhomb" faces, because of their shape; if extended they would give a trigonal bipyramid. The "trapezohedral," or "plagihedral," faces $x\{4\bar{1}\bar{2}\}$ belong to a trigonal trapezohedron. The two crystals shown in figs. 4 and 5 are enantiomorphous, *i.e.*, they are non-superposable, one being the mirror reflection of the other: they are left-handed and right-handed crystals respectively. The faces s are striated parallel to their edge of intersection with r; this serves to distinguish r and z, and thus, in the absence of x faces, to distinguish left- or right-handed crystals. Numerous other faces have been observed on crystals of quartz, but they are of rare occurrence. The basal plane, so common on calcite and many other rhombohedral minerals, is of the greatest rarity in quartz, and when present only appears as a small rough face formed by the corrosion of the crystal. Faces of prisms other than m are also small and of exceptional occurrence. Etched figures, both natural and artificial (in the latter case produced by the action of hydrofluoric acid), on the faces of the crystals are in accordance with the symmetry, and may serve to distinguish left- and right-handed crystals.

Twinned crystals of quartz are extremely common, but are complex in character and can only be deciphered when the faces s and x are present which is not often the case. Usually they are interpenetration twins with the principal axis as twin-axis; the prism planes of the two individuals coincide, and the faces r and z also fall into the same plane. Such twins may therefore be mistaken for simple crystals unless they are attentively studied; but the twinning is often made evident by the presence of irregularly bounded areas of the duller z faces coinciding with the brighter r faces. In a rarer type of twinning, in which the twin-plane is $\{52\bar{1}\}$ (a plane truncating the edge between r and z), the two individuals are united in juxtaposition with their principal axis nearly at right angles (84° 33′). A few magnificent specimens of rock-crystal twinned according to this law have been found at La Gardette in Isère, and in Japan they are somewhat abundant.

Electrical and Optical Characters.—The pyro-electric characters of quartz are closely connected with its peculiar type of symmetry and especially with the three uniterminal dyad axes. A crystal becomes positively and negatively electrified on alternate prism edges when its temperature changes. A similar distribution of electric charges is produced when a crystal is subjected to pressure; quartz being thus also piezo-electric. Use is made of this property in detecting extremely minute changes of pressure in the depth-sounding apparatus of submarines and in the resonators of radio-detectors.

In its optical characters, quartz is also of interest, since it is one of the two minerals (cinnabar being the other) which are circularly polarizing. This phenomenon is connected with the symmetry of the crystals, and is also shown by the crystals of certain other substances in which there are neither planes nor centre of symmetry. A ray of plane-polarized light traversing a right-handed crystal of quartz in the direction of the triad axis has its plane of polarization rotated to the right, while a left-handed crystal rotates it to the left. A section 1 mm. thick, cut perpendicular to the principal axis of a quartz crystal, rotates the plane of yellow (D) light through 22°, and of blue (G) light through 43°. Such a section when examined in the polariscope shows an interference figure with a coloured centre, there being no black cross inside the innermost ring (this is not shown in very thin sections). Superimposed sections of right- and left-handed quartz, as may sometimes be present in sections of twinned crystals, exhibit Airy's spirals in the polariscope. The indices of refraction of quartz for yellow (D) light are $\omega = 1{\cdot}5442$ and $\epsilon = 1{\cdot}5533$; the optic sign is therefore positive.

Other Characters.—Quartz has a hardness of 7 (being chosen as No. 7 on Mohs' scale), and it cannot be scratched with a knife; its specific gravity is 2·65. There is no distinct cleavage; though an imperfect cleavage may sometimes be developed parallel to the faces of the rhombohedron r by plunging a heated crystal into cold water. The glassy conchoidal fracture is a characteristic feature of the crystallized mineral. A peculiar rippled or "thumb-marked" fracture is sometimes to be seen, especially in amethyst (*q.v.*), and is due to repeated intergrowths of right- and left-handed material. The mineral is a non-conductor of electricity; it is unattacked by acids with the exception of hydrofluoric acid, and is only slightly dissolved by solutions of caustic alkalis. It is infusible before the gas blowpipe, but in the oxyhydrogen flame fuses to a clear colourless glass, which has a hardness of 5 and specific gravity 2·2.

When heated, quartz undergoes a series of remarkable changes. At 575° C it passes over into β-quartz, with a change in the degree of crystal-symmetry from rhombohedral-trapezohedral to hexagonal-trapezohedral and an alteration of the various physical properties. At 870° this β-quartz changes over into β-tridymite, and this again at 1,470° to β-cristobalite, the material finally melting at about 1,710°.

Many peculiarities of the growth of crystals are well illustrated by the mineral quartz. Thus in "ghost quartz," in which one crystal is seen inside another, the stages of growth are marked out by thin layers of enclosed material. In "capped quartz" these layers are thicker, and the successive shells of the crystal may be easily separated. "Sceptre quartz," in which a short thick crystal is mounted on the end of a long slender prism, indicates a change in the conditions of growth. Crystals with a helical twist are not uncommon. Enclosures of other minerals (rutile, chlorite, haematite, goethite, actinolite, asbestos and many others) are extremely frequent in crystals of quartz. Cavities, either rounded or with the same shape ("negative crystals") as the surrounding crystal, are also common; they are often of minute size and present in vast numbers. Usually these cavities contain a liquid (water, a saline solution, carbon dioxide, or petroleum) and a movable bubble of gas. The presence of these enclosed impurities impairs the transparency of crystals. Crystals of quartz are usually attached at one end to their rocky matrix, but sometimes, especially when embedded in a soft matrix of clay, gypsum, or salt, they may be bounded on all sides by crystal faces (figs. 1 and 2). In size they vary between wide limits, from minute sparkling points encrusting rock surfaces and often so thickly clustered together as to produce a drusy effect, to large single crystals measuring a yard in length and diameter and weighing half a ton.

The characters as given above apply more particularly to crystals of quartz, but in the various massive and compact varieties

the material may be quite different in general appearance. Thus in the microcrystalline chalcedony the lustre is waxy, the fracture fibrous to even, and the external form botryoidal or stalactitic: flint and chert are compact and have a splintery fracture: jasper is a compact variety intermixed with much iron oxide and clay and has a dull and even fracture. Further, these varieties may be of almost any colour, whereas transparent crystals have only a limited range of colour, being either colourless (rock-crystal), violet (amethyst), brown (smoky quartz) or yellow (citrine).

Occurrence.—Quartz occurs as a primary and essential constituent of igneous rocks of acidic composition such as granite, quartz-porphyry and rhyolite, being embedded in these either as irregularly shaped masses or as porphyritic crystals. In pegmatite (graphic granite) and granophyre it often forms a regular intergrowth with felspar. It is also a common constituent, as irregular grains, in many gneisses and crystalline schists, a quartz-schist being composed largely of quartz. By the weathering of silicates, silica passes into solution and quartz is deposited as a secondary product in the cavities of basic igneous rocks, and in fact in the crevices and along the joints of rocks of almost all kinds. Extensive veins of quartz are especially frequent in schistose rocks. Vein-quartz, often of economic importance as a matrix of gold, may, however, in some cases have been of igneous origin. In mineral veins and lodes crystallized quartz is usually the most abundant gangue mineral; the crystals are often arranged perpendicular to the walls of the lode, giving rise to a "comby" structure. In limestones of various kinds it occurs as nodules and bands of chert and flint, being in this case of organic origin. Quartz being a mineral very resistant to weathering agencies, it forms the bulk of sands and sandstones; and when the sand grains are cemented together by a later deposit of secondary quartz a rock known as quartzite results. Pseudomorphous quartz, *i.e.*, quartz replacing other minerals, is of frequent occurrence, and as a petrifying material replacing organic remains it is often met with. As a deposit from hot springs, quartz is much less common than opal. Crystals of quartz may be readily prepared artificially by a number of methods; for example, by heating glass or gelatinous silica with water under pressure.

For particulars respecting the special characters, modes of occurrence and localities of the more important varieties of quartz, reference may be made to the following articles: Agate, Amethyst, Aventurine, Bloodstone, Cairngorm, Carnelian, Cat's-Eye, Chalcedony, Chrysoprase, Flint, Jasper, Mocha-Stone, Onyx, Sard and Sardonyx. For other forms of silica see Opal and Tridymite[1]. (L. J. S.)

Recent research on the physical chemistry of silica has shown that at 870° C under atmospheric pressure quartz inverts to tridymite, which again at 1,470° C changes to cristobalite. These changes are, however, exceedingly slow in coming about, and in actual practice, as in the manufacture of silica bricks for furnace linings, the temperature actually employed has to be considerably above 870° C if the change is to be reasonably complete, a point of much practical importance, owing to the large volume-change during the inversion (about 15%). Cristobalite, on the other hand, has nearly the same volume as tridymite, so that it does not matter much which is present in the finished brick.

For details *see* C. N. Fenner, *Amer. Journ. Sci.*, vol. xxvi., 1913, pp. 331–348, or for a short summary, R. H. Rastall, *Physico-Chemical Geology*, 1927, pp. 216–220. (R. H. Ra.)

QUARTZITE, in petrology, a sandstone which by the deposit of crystalline quartz between its grains has been compacted into a solid quartz rock. As distinguished from sandstones, quartzites are free from pores and have a smooth fracture, since when struck with the hammer they break through the sand grains, while in sandstones the fracture passes through the cementing material and the rounded faces of the grains are exposed, giving the broken surface a rough or granular appearance. The conversion of sandstone into quartzite is sometimes the work of percolating water under ordinary conditions. In the Reading beds of England, which are for the most part loose sands, there are often many large blocks of quartzite which weather out and are exposed at the surface, being known as grey-wethers. The silicification of these rocks must have taken place at no great depth and under ordinary pressures. Most quartzites, however, are found among ancient rocks, such as the Cambrian or Pre-Cambrian and are products of metamorphism.

A normal quartzite has in microscopic section its clastic structure well preserved; the rounded sand grains are seen with patches of new quartz in the interspaces, and the latter is often deposited in crystalline continuity, so that the optical properties of the grains are similar to those of the material which surrounds them: a line of iron oxides or other impurities often indicates the boundary of the original sand grain. As might be expected, however, many of the oldest quartzites have been crushed by folding movements and the quartz consists in large part of a mosaic of small crystalline fragments of irregular shape with interlocking margins; these are called "sheared quartzites," and when they contain white mica in parallel crystalline flakes they become more fissile and pass into quartz-schists. Where sandstones are altered by intrusive rocks they are often converted into pure quartzite, the heat evidently occasioning the deposit of interstitial quartz.

The commonest minerals in quartzite, in addition to quartz, are felspar (microcline, orthoclase, oligoclase), white mica, chlorite, iron oxides, rutile, zircon and tourmaline. Except felspar they are usually present only in small quantity; the less frequent accessories include hornblende, sillimanite, garnet, biotite, graphite, magnetite and epidote. In colour quartzites are often snowy white; they frequently have a fine angular jointing and break up into rubble under the action of frost. Quartzites are too hard and splintery to be used as building stones to any large extent: they furnish a thin and very barren soil, and because they weather slowly tend to project as hills or mountain masses. (J. S. F.)

QUARTZ-PORPHYRY, in petrology, the name given to a group of hemi-crystalline acid rocks containing porphyritic crystals of quartz in a more fine-grained matrix which is usually of micro-crystalline or felsitic structure. In the hand specimens the quartz appears as small rounded, clear, greyish, vitreous blebs, which are crystals (double hexagonal pyramids) with their edges and corners rounded by resorption or corrosion. Under the microscope rounded enclosures of the ground-mass or fluid cavities are often seen; these are frequently negative crystals with regular outlines resembling those of perfect quartz crystals, and many of the latter contain liquid carbonic acid and a bubble of gas which may exhibit vibratile motion under high magnifying powers. In addition to quartz there are usually phenocrysts of felspar, mostly orthoclase, though a varying amount of plagioclase is often present. The felspars are usually cloudy from the formation of secondary kaolin and muscovite throughout their substance; their crystals are larger than those of quartz and sometimes attain a length of two inches. Not uncommonly scales of mica are visible as hexagonal plates. Other porphyritic minerals are few, but hornblende, augite and bronzite are sometimes found; the augite and hornblende are in most cases green, and are frequently decomposed into chlorite, but even then can usually be identified by their shape. A colourless rhombic pyroxene (enstatite or bronzite) occurs in a limited number of the rocks of this group and readily weathers to bastite. Apatite, magnetite, and zircon, all in small but frequently perfect crystals, are almost universal minerals of the quartz-porphyries.

Structure.—The ground-mass is finely crystalline and to the unaided eye has usually a dull aspect resembling common earthenware; it is grey, green, reddish or white. Often it is streaked or banded by fluxion during cooling, but as a rule these rocks are not vesicular. Two main types may be recognized by means of the microscope—the felsitic and the microcrystalline. In the former the ingredients are so fine-grained that in the thinnest slices they cannot be determined in this way. Some of the rocks show perlitic or spherulitic structure; such were probably originally glassy (obsidians or pitchstones), but by lapse of time have slowly passed into a very finely crystalline state. This change is called devitrification; it is common in glasses, as these are

[1]Still another form of silica is known as cristobalite (named after San Cristobal, its locality in Mexico), which, like tridymite, is of rare occurrence in nature as minute crystals in the cavities of certain lavas.

essentially unstable.

A large number of the finer quartz-porphyries are also in some degree silicified or impregnated by quartz, chalcedony and opal, derived from the silica set free by decomposition (kaolinization) of the original feldspar. This redeposited silica forms veins and patches of indefinite shape or may bodily replace a considerable area of the rock by metasomatic substitution. The opal is amorphous, the chalcedony finely crystalline and often arranged in spherulitic growths which yield an excellent black cross in polarized light. The microcrystalline groundmasses are those which can be resolved into their component minerals in thin slices by use of the microscope. They prove to consist essentially of quartz and feldspars, which are often in grains of quite irregular shape (microgranitic). In other cases these two minerals are in graphic intergrowth, often forming radiate growths of spherulites consisting of fibres of extreme tenuity; this type is known as granophyric. There is another group in which the matrix contains small rounded or shapeless patches of quartz in which many rectangular feldspars are embedded; this structure is called micropoikilitic, and though often primary is sometimes developed by secondary changes which involve the deposit of new quartz in the groundmass. As a whole those quartz-porphyries which have microcrystalline groundmasses are rocks of intrusive origin. Elvan is a name given locally to the quartz-porphyries which occur as dikes in Cornwall; in many of them the matrix contains scales of colourless muscovite or minute needles of blue tourmaline. Fluorite and kaolin appear also, and these minerals as a whole are due to pneumatolytic action by vapours permeating the porphyry after it had consolidated but probably before it had entirely cooled.

Older Forms.—Many of the older quartz-porphyries which occur in Palaeozoic and Pre-Cambrian rocks have been affected by earth movements and have experienced crushing and shearing. In this way they become schistose, and from their feldspar minute plates of sericitic white mica are developed, giving the rock in some cases very much of the appearance of mica-schists. If there have been no phenocrysts in the original rock, very perfect mica-schists may be produced, which can hardly be distinguished from sedimentary schists, though chemically somewhat different on account of the larger amounts of alkalis which igneous rocks contain. When phenocrysts were present they often remain, though rounded and dragged apart while the matrix flows around them. The glassy or felsitic enclosures in the quartz are then very suggestive of an igneous origin for the rock. Such porphyry-schists have been called porphyroids or porphyroid-schists, and in America the name aporhyolite has been used for them. They are well known in some parts of the Alps, Westphalia, Charnwood (England), and Pennsylvania. The *hälleflintas* of Sweden are also in part acid igneous rocks with a well-banded schistose or granulitic texture.

The quartz-porphyries are distinguished from the rhyolites by being intrusive rocks. All Tertiary acid lavas are included under rhyolites. (J. S. F.)

QUASIGROUPS. An important part of algebra is concerned with the study of sets of mathematical objects having the closure property that every pair of elements a and b of a set G can be combined to yield a unique element ab, called their product. In most studies of this sort the associative law $a(bc) = (ab)c$ is assumed. (*See* GROUPS; LINEAR ALGEBRAS.) There is a considerable interest, however, in nonassociative systems such as nonassociative algebras and quasigroups. The table of products of a finite quasigroup is called a Latin square; such tables are of interest to statisticians.

A quasigroup is a set G closed with respect to a product operation ab such that the equations $ax = b$ and $ya = b$ have unique solutions x and y in G for every a and b of G. An associative quasigroup is then a group. While every group G has an identity element e such that $ea = ac = a$, this is not a property of quasigroups. A quasigroup with an identity element is called a loop.

The concept of mathematical equivalence may be broadened to a concept called isotopy. Let S be a one-to-one mapping $a \rightarrow aS$ of G onto a second quasigroup G'. Then G and G' are said to be isomorphic (*i.e.*, equivalent) quasigroups if $(aS)(bS) = (ab)S$. If it is assumed instead that there exist three one-to-one mappings S, T and U of G onto G' such that $(aS)(bT) = (ab)U$, it is said that G and G' are isotopic. Every quasigroup is isotopic to a loop. A loop G is isotopic to a group G' if and only if G is a group and is isomorphic to G'.

If G is a loop the mapping of each element a of G on the product ax is a one-to-one correspondence of G onto itself; that is, a transformation R_x of G. Similarly, the mapping of a on xa is a transformation L_x. The transformations R_x and L_x lie in the group H of all transformations on G and generate a subgroup $T(G)$ of H. It has been shown that the properties of $T(G)$ with respect to normal (*i.e.*, invariant) subgroups and composition series (*see* GROUPS) imply corresponding properties of loops, and that a major part of the known theory of groups is valid also for loops. (A. A. AT.)

QUASSIA, the generic name given by Linnaeus to a small tree of Surinam (*Quassia amara*), superseded for medical purposes in 1809 by the bitter wood or bitter ash of Jamaica, *Picrasma excelsa*, which has similar properties and can be obtained in larger pieces. Since that date this wood has continued in use in Great Britain under the name of quassia to the exclusion of the Surinam quassia, which, however, is still employed in France and Germany. *Picrasma excelsa* is a tree 50 to 60 ft. in height, and resembles the common ash in appearance. It is found also in other West Indian islands, as Antigua and St. Vincent. *Quassia amara* is a shrub or small tree belonging to the same natural order as *Picrasma*, viz. Simarubaceae, but is readily distinguished by its large handsome red flowers arranged in terminal clusters. It is a native of Panamá, Venezuela, Guiana and northern Brazil. Jamaica quassia is imported into England in logs several feet long and often nearly one foot thick. The wood is nearly white, has a pure bitter taste, and is without odour or aroma. It is usually met with as turnings or raspings, the former being obtained in the manufacture of the "bitter cups" which are made of this wood. The chief constituent is a bitter neutral principle known as quassin. It exists in the wood to the extent of about 0.1%. It forms crystalline needles soluble in alkalis, chloroform and 200 parts of water. There is also present a volatile oil. The wood contains no tannin, and for this reason quassia, like chiretta and calumba, may be prescribed with iron. The infusion is useful as a bitter tonic—a group of substances of which calumba is the type—and is also a very efficient anthelmintic for the threadworm (*Oxyuris vermicularis*). It is a substitute for hops.

QUATERNARY, in geology, the time division which comprises all the time which has elapsed from the end of the Pliocene to the present day. The Quaternary is the fourth of the great time divisions in the geological scale, but it represents relatively such a small space of time that some geologists hesitate to give it equal rank, and regard it merely as a subdivision of the Tertiary. Two divisions of the Quaternary period are usually recognized: (1) Pleistocene, (2) Holocene or Recent.

The Quaternary is characterized by intense climatic fluctuations. Compared with the preceding division, the Tertiary, the climate of those latitudes which now constitute the northern temperate zone was on the whole colder, and large ice sheets developed repeatedly in Scandinavia, in the great mountain ranges of Europe and Asia, and in North America. For this reason the term "Ice Age" is often used as a synonym for the Pleistocene division of the Quaternary.

The several glaciations of parts of the northern hemisphere have supplied the major divisions of the Quaternary. Elsewhere, palaeontological divisions had to be adopted. The Pleistocene, comprising by far the largest part of the Quaternary, is the division comprising all the glaciations. The Holocene is the short period after the end of the Last Glaciation, and there is no agreement about the boundary line which separates it from the Pleistocene. The subdivisions of the Holocene are based on the development of the flora (see *Flora* below).

Divisions.—*Plio-Pleistocene Boundary.*—The beginning of the Quaternary is difficult to define, the transition from the last phase of the Tertiary, the Pliocene, being very gradual. The beginning

of the first large glaciation of the Alps (Günz) is perhaps the event most widely accepted as marking the beginning of the Pleistocene, and it coincides approximately with the beginning of the latest cycle of erosion over the entire earth. But the fauna of the late Pliocene, the Villafranchian, grades so imperceptibly into that of the lower Pleistocene that some workers prefer to include the Villafranchian in the Pleistocene.

Divisions Recognized in Certain Areas.—The major divisions of the Quaternary are not uniform over the whole earth. Lower, Middle and Upper Pleistocene are distinguished, but it remains to be shown to what extent the divisions are contemporaneous, for instance, in Africa, Europe and southeast Asia. The Holocene is not everywhere separated from the Upper Pleistocene.

Alps.—The Alpine divisions established by A. Penck and E. Brückner comprise four main glaciations, Günz (the earliest), Mindel, Riss and Würm, separated by the interglacial periods with a mild climate. Of these, the Mindel-Riss or Great Interglacial was by far the longest. The Alpine glaciations were subdivided, the first three into two, and Würm into three phases, the phases being separated by minor mild phases, called interstadials.

Scandinavia and North Germany.—The large ice sheet which descended from the Scandinavian mountains covered the north German lowlands from the Netherlands to the Hartz and Sudeten mountains. Three major glaciations have been recognized, called Elster, Saale and Weichsel. The Warthe phase is intercalated between Saale and Weichsel, and it is uncertain to which of these it should be assigned as a subdivision. Weichsel is regarded as the chronological equivalent of Alpine Würm; Saale has been equated with Riss, and Elster with Mindel. No certain equivalent of Alpine Günz is known from the Scandinavian ice sheet, though Leopold van Wervecke claims to have found one in deposits which he assigns to an Elbe glaciation.

British Isles.—Britain was glaciated at one time or other as far south as the Thames valley and probably north Devon. Ireland appears to have been glaciated completely, though in both Britain and Ireland the extension of the Last Glaciation (the Newer Drift) was considerably smaller. The southern quarter of Ireland, parts of Wales, the midlands, Derbyshire and Lincolnshire and all the southern counties were ice-free, except for a glacier which extended south along the coast of Lincolnshire and touched Norfolk at Cromer. The divisions of the Older Drift have received local names, mostly on the evidence of ground moraines (boulder clay, till). The East Anglian succession, for instance, distinguishes, below the Hunstanton (Hessle) Boulder Clay (= Newer Drift), a Great Chalky Boulder Clay, a Chalky-Jurassic Boulder Clay, and the Norwich brick earth, the latter resting on marine deposits, the Crags (see *Marine Fauna*).

North America.—Unlike the glaciations of Europe which emanated from mountainous areas, two out of the three North American centres of glaciation were situated at a low altitude, especially the Keewatin centre, west of Hudson bay in 62° N. lat. To the east, there was an independent centre in Labrador, while the third, the Cordilleran centre, was situated in the mountains of the western part of the continent. Four glaciations are usually distinguished, Nebraskan (the earliest), Kansan, Illinoian and Wisconsin. The Iowan phase is intercalated between Illinoian and Wisconsin, and it is uncertain to which of these it should be assigned as a subdivision. The interglacials are called Aftonian (Nebraskan-Kansan), Yarmouth (Kansan-Illinoian), Sangamon (Illinoian-Iowan), Peorian (Iowan-Wisconsin).

General Divisions.—It is generally believed that the Newer Drift of Britain, Weichsel of northern Europe, Würm of the Alps, and Wisconsin in America are contemporaneous. This Last Glaciation of the northern hemisphere was preceded by the last Interglacial, and this by a Penultimate Glaciation which was larger than the Last. The Penultimate Glaciation in turn was preceded by an interglacial of long duration, the Penultimate or Great Interglacial, during which erosion and weathering destroyed much of the evidence for even earlier glaciations. In many areas an Antepenultimate Glaciation appears to have had about the same extension as the Penultimate. Before this, there is evidence in some areas of a glaciation of moderate size at the beginning of the Quaternary, which may be called the Early Glaciation. (See also *Terrestrial Fauna*).

Climate.—At the beginning of the Quaternary, the climate of temperate Europe appears to have resembled that of the present day. Considerable cooling took place during the Early Glaciation, sufficient to exterminate many Pliocene types of mammals and to enable arctic species to spread south. But, on the whole, the effect of the first Quaternary glaciation was slight, and in the Antepenultimate Interglacial (that of the Cromer forest bed of East Anglia) decidedly temperate conditions prevailed again. The Antepenultimate Glaciation, however, was more intense, and it caused a sharp faunal break. In a broad zone surrounding the ice sheets (periglacial zone) the climate became cold and pronouncedly continental. Tundra and steppe prevailed, and from northern France to southern Russia a broadening belt of loess (windblown dust) was deposited. Those Pliocene elements in the fauna which had survived into the Antepenultimate Interglacial now died out. The following Penultimate or Great Interglacial was a prolonged period of temperate climate, at times apparently milder than the present (*e.g., Rhododendron ponticum* in the Alps). The Penultimate Glaciation, being of much the same size as the Antepenultimate, had similar effects on the environment. By this time, however, many animals had adapted themselves to the recurrent phases of rigid climate, and the fauna assumed a Pleistocene aspect, with ancestral mammoth, woolly rhinoceros, etc. Man also had by now adapted his economy to the cold and stayed in the periglacial zone. The Last Interglacial witnessed a repetition of the mild conditions of the Great Interglacial. Fossil soils, fauna and flora suggest higher summer temperature and absence of frost. The Last Glaciation, though smaller than the preceding two, appears to have had pronounced climatic effects. Its periglacial zone was slightly smaller than those of the two preceding glaciations, but many interglacial mammals which had survived into the Last Interglacial (*e.g.,* straight-tusked elephant, Merck's rhinoceros) became extinct, and a most characteristic arctic fauna reigned north of the Alps. A second faunal break is thus observed in the Quaternary at the beginning of the Last Glaciation. Since the Last Glaciation the climate has returned to the temperate conditions of the present day, with fluctuations for which the flora provides evidence.

Pluvials.—In the countries around the Mediterranean basin, pluvial phases correspond to the glacial phases. The anticyclonic conditions reigning over glaciated northern Europe forced many more depressions on to the Mediterranean path than is now the case. The Mediterranean countries were then covered with deciduous forest of the temperate type. It is noteworthy that three Mediterranean pluvial phases appear to correspond to the three phases of the Last Glaciation.

In the tropics, mainly in Africa, evidence from moraines shows that high mountains were repeatedly heavily glaciated in Quaternary times. Lakes were larger and more widespread than now. From this tropical pluvials have been inferred (in east Africa the Kageran, Kamasian and Gamblian pluvials, followed by the Makalian and Nakuran wet phases). But the contemporaneity of these pluvials with those of the Mediterranean and with European glaciations has not yet been proved.

Eustasy.—The formation of large ice sheets, especially in Europe and North America, resulted in the withdrawal of a large amount of water from the oceans. The sea level therefore was low during the glacial, and high during the interglacial phases. These fluctuations of the sea level are called eustatic. Evidence for low sea levels is provided by submerged terrestrial deposits (peats, etc.) and drowned river valleys; for high sea levels by traces of ancient shore lines (raised beaches) and terraces in the mouths of rivers. Raised beaches observed on coasts not affected by tectonic movements or isostasy suggest two Pliocene phases: Calabrian and Sicilian, the latter about 80–100 m. above present sea level, and three interglacial ones: Milazzian (60 m.), Tyrrhenian (32 m.), Monastirian (18–7.5 m.). The fact that the order in time is one of successively lower levels shows that the eustatic fluctuations are superimposed on a general and persistent drop of sea level which continued from the Tertiary into the Quaternary.

Isostasy.—The volume of the Scandinavian icecap of the Last Glaciation has been estimated at 5,000,000 cu.km., and that of the Labrador-Keewatin cap of North America at 21,000,000 cu.km. These masses depressed the ground covered by them and a narrow belt around them. When the ice disappeared and its weight was removed, the crust of the earth responded elastically, and the area recovered from the depression. This phenomenon is called isostasy. The isostatic rise of Scandinavia, for instance, has amounted locally to over 250 m. since the Last Glaciation.

Chronology.—The relative chronology of the Quaternary is based usually on the succession of climatic phases which provide convenient divisions wherever they have been studied. In the Pleistocene, glaciations, pluvials and phases of high sea level are used as outlined in the preceding paragraphs. In many parts of the world, however, palaeoclimatic evidence is very incomplete, and palaeontological divisions based on mammals and marine Mollusca are used instead. Where prehistoric implements are found in abundance chronologies of a more or less local nature have been based on them. (For Holocene, see *Flora.*)

Many attempts have been made to develop an absolute chronology of the Quaternary. Several methods are based on the time rates of erosion, sedimentation and soil formation. In the Alps, A. Penck arrived at 600,000 years for the whole Quaternary, with the Great Interglacial occupying about a quarter of this time. Other estimates range between 500,000 and 1,000,000 years. A more elaborate tentative time scale has been based on the correlation of the geologically established climatic phases with fluctuations of solar radiation caused by the perturbations of the earth's orbit. This method again yields 600,000 years for the whole Quaternary, 190,000 for the Great Interglacial and 20,000 years for the time elapsed since the Last Glaciation. This astronomical method, which allows detailed dating of minor climatic phases, was conceived by J. Adhemar in 1842 and developed by the British astronomers, J. Croll and Sir Robert Ball, in the second half of the 19th century. But it suffered many reverses owing to misinterpretation of the astronomical material. It was taken up again after M. Milankovitch, from 1913 onward, undertook a recalculation of the astronomical tables, but is not yet generally accepted except in parts of Europe where the geological evidence is well preserved. It is in any case not regarded as an explanation of the Ice Age as such.

Fauna.—*Terrestrial Fauna.*—The land fauna assumed its modern character in the course of the Quaternary. This was due to three causes: (a) dying out of Tertiary elements; (b) appearance of new, Pleistocene, types; and (c) change of Pliocene forms into modern species by gradual evolution. It is noteworthy that in mammals the lineages of which have been traced from the Villafranchian to the Holocene the change in specific characters is slight, differences between Pliocene ancestors and Holocene descendants being not greater than differences between existing related species. In the Mollusca, which have been studied equally closely, these phylogenetic changes are even slighter, and changes in the composition of the fauna are chiefly the result of migration (*e.g.*, the freshwater shell *Corbicula* in the Pleistocene of Britain, now from Egypt southward).

Characteristic mammals of the European Villafranchian are: monkeys (*Macacus*), a cheetah, sabre-tooth tiger, zebra-like horses (*Equus stenonis*), Etruscan rhinoceros, tapir, *Leptobos* (primitive ox), mastodon, southern elephant; of the Lower Pleistocene: the same, except cheetah, tapir and *Leptobos*, but with red deer, elk (*Alces*), roe deer and a giant beaver (*Trogontherium*). The Middle Pleistocene fauna is devoid of the earlier exotic elements, and new types appear which survive into the Upper Pleistocene. In the latter the warm, interglacial faunas and the cold, glacial faunas have become more sharply separated. Interglacial species are the brown bear, beaver, Merck's rhinoceros, hippopotamus (west Europe), red deer, etc., straight-tusked elephant; glacial species, the arctic fox, varying hare, susliks (*Citellus*), lemmings, jerboa (loess steppe), true horses, woolly rhinoceros, reindeer, musk ox, mammoth, etc. Some of these became extinct before the Holocene began.

Marine Fauna.—The marine faunas of the Quaternary show slight evolution in the species, but there is evidence of much migration caused by climatic changes. The Crags of East Anglia, Lower Pleistocene beach deposits rich in shells, illustrate this point. In the Sicilian, temperate shells like *Cyprina islandica* and the common whelk extended to the Mediterranean. The Tyrrhenian and Monastirian faunas (collectively called Tyrrhenian by palaeontologists) are generally warmer than the modern ones, with the west African *Strombus bubonius* in the Mediterranean, and *Astralium rugosum* in the Channel Islands.

Flora.—The specific composition of the flora has changed much less than that of the fauna in so far as it is the result of phylogenetic evolution, though the shifting of vegetational zones in connection with climatic changes is a most characteristic phenomenon. With the growth of the ice sheets, the forest belts moved south, and tundra and cold steppe covered much of the periglacial zone. Each time the ice retreated, the vegetation belts moved north again, producing a succession of plant associations which have been studied in peat deposits by means of pollen analysis, chiefly for the time since the Last Glaciation. The subdivisions of the Holocene make use of these changes in the vegetation. Complicated divisions are now used in technical papers, but the classical scheme of Axel Blytt and R. Sernander may, with modifications, still serve in summarizing the major features: (a) Subarctic phase (to *c.* 8,000 B.C.), treeless, with *Dryas octopetala*, dwarf willows and birches, interrupted by the mild Alleröd Oscillation, when Scotch pine and tree birches appeared temporarily; (b) Preboreal (8,000–7,000 B.C.), birch and pine immigrating; (c) Boreal (7,000–5,500 B.C.), with pine and birch dominating, and alder, oak, lime and elm as subordinate, but increasing associates—later, hazel woods become prominent, climate continental; (d) Atlantic (5,500–2,000 B.C.), mixed oak forests culminate, hazel reduced to undergrowth. Climate oceanic and in part warmer than at the present; (e) Subboreal (2,000–500 B.C.), climate begins to deteriorate, mixed oak forest retreats from the extreme limits reached, pine increases, but beech and hornbeam continue to spread north; (f) Subatlantic, mixed oak forest continues to retreat, beech culminates, present-day conditions.

Man.—The Quaternary is the age of man. Though it is now probable that man originated in the Tertiary, his skeletal and industrial remains are known from the Quaternary only. Pithecanthropus of Java and Sinanthropus of China are of Lower Pleistocene age. In the Middle Pleistocene types like Swanscombe man (from the lower Thames) are regarded by some authorities as closer to modern *Homo sapiens* than is Neanderthal man, who is characteristic of the lower division of the Upper Pleistocene. In Europe, *Homo sapiens* appears around the second phase of the Last Glaciation as an immigrant from the south and east.

The cultural evolution of man in Quaternary times is evidenced by his implements, mostly of stone. At the beginning of the Pleistocene, very primitive tools (the human origin of which is debated) have been found in East Anglia. In the Antepenultimate Interglacial, the Chellian or Abbevillian hand-ax culture flourished, and flake industries of the Clactonian variety appear. By Great Interglacial times, the Chellian had developed into the Acheulian which used the refined "wood technique" in manufacturing implements. The Clactonian persisted, but later the Levalloisian technique of making flakes from specially prepared cores marks another step forward in mental evolution. In the Last Interglacial, the Acheulian develops its final phase, the Micoquian; Levalloisian persists, and from the fusion of these the Mousterian results, the culture of Neanderthal man par excellence. All these cultures are grouped together as Lower Palaeolithic. *Homo sapiens* brought with him the Upper Palaeolithic culture of blade industries (Aurignacian, Gravettian, Solutrian, Magdalenian) which flourished during the Last Glaciation. When the Holocene began, man had reached the Mesolithic stage; many of his stone tools were now composite, being made up of numerous hafted, small microliths. In temperate Europe, the Mesolithic was replaced by the Neolithic which introduced agriculture, about 5,000 B.C. (*see* also GLACIAL EPOCH).

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QUATERNIONS, a linear algebra consisting of four-dimensional vectors whose co-ordinates are any real numbers. The theory of this algebra was discovered by Sir William Rowan Hamilton in 1843 while he was trying, by analogy with the complex number representation of real two-dimensional vectors, to represent space vectors by the elements of a number system. For the definition of the algebra of quaternions and its place in the theory of algebras, *see* LINEAR ALGEBRAS. Quaternions were intensely studied during the early part of the 20th century before the general theory of linear algebras came into being. Later, they were usually thought of as a special case of such algebras. Their early importance lay in applications to geometry and mathematical physics. These applications later became a part of vector theory. *See* VECTOR ANALYSIS. (A. A. AT.)

QUATORZAIN, the term used in English literature, as opposed to "sonnet," for a poem in 14 rhymed iambic lines closing (as a sonnet strictly never does) with a couplet. The distinction was long neglected, because the English poets of the 16th century had failed to apprehend the true form of the sonnet, and called Petrarch's and other Italian poets' sonnets quatorzains, and their own incorrect quatorzains sonnets. Almost all the so-called sonnets of the Elizabethan cycles, including those of William Shakespeare, Sir Philip Sidney, Edmund Spenser and Samuel Daniel, are really quatorzains. They consist of three quatrains of alternate rhyme, not repeated in the successive quatrains, and the whole closes with a couplet.

QUATRAIN, sometimes spelt *Quartain*, a piece of verse complete in four rhymed lines. The length or measure of the line is immaterial. This form has always been popular for use in the composition of epigrams, and may be considered as a modification of the Greek or Latin epigram.

QUATREFOIL or QUARTERFOIL, in architecture, a decorative form of four lobes or cusps, usually of approximately the shape of a four-leafed clover, and frequently with the whole surrounded by an enclosing circle.

QUATREMÈRE, ÉTIENNE MARC (1782–1857), French orientalist, the son of a Parisian merchant, was born in Paris on July 12, 1782. Employed in 1807 in the manuscript department of the imperial library, he passed to the chair of Greek in Rouen in 1809, entered the Academy of Inscriptions in 1815, taught Hebrew and Aramaic in the Collège de France from 1819, and finally in 1827 became professor of Persian in the School of Living Oriental Languages.

Quatremère's first work was *Recherches . . . sur la langue et la littérature de l'Égypte* (1808), showing that the language of ancient Egypt must be sought in Coptic. His translation of Tagi-al-Din Ahmad Maqrīzi's Arabic history of the Mameluke sultans (2 vol., 1837–41) shows his erudition at the best. He published among other works *Mémoires sur les Nabatéens* (1835); a translation of Rashīd al-Dīn's *Hist. des Mongols de la Perse* (1836); *Mém. géog. et hist. sur l'Égypte* (1810); the text of Ibn Khaldūn's *Prolegomena;* and a vast number of useful memoirs in the *Journal asiatique*. His numerous reviews in the *Journal des savants* should also be mentioned. Quatremère made great lexicographic collections on oriental languages, fragments of which appear in the notes to his various works. His manuscript material on Syriac was utilized in Payne Smith's *Thesaurus*. A biographical note by Barthélemy Sainte-Hilaire was prefixed to Quatremère's *Mélanges d'histoire et de philologie orientale* (1861).

QUAVER, in music, a note representing an eighth part of a semibreve, wherefore it is known as an eighth note in America and an *Achtelnote* in Germany.

QUAY, MATTHEW STANLEY (1833–1904), U.S. politician, was born in Dillsburg, Pa., on Sept. 30, 1833. His father was Anderson Beaton Quay, a Presbyterian minister. In 1850 Quay was graduated from Jefferson college, at Canonsburg, Pa., which later became Washington and Jefferson college. He was admitted to the bar in 1854. During the Civil War he served as colonel of the 134th Pennsylvania infantry, Aug.–Dec. 1862; and was Gov. Andrew G. Curtin's military secretary, 1863–65. Quay was awarded the congressional medal of honor for his war services.

Quay was a member of the state house of representatives, 1865–67, and was owner and editor of the *Beaver Radical*, 1867–72. He then became secretary of the commonwealth, holding that office until 1878, when he took the newly created position of recorder of Philadelphia. He was also chairman of the Republican state committee. Resigning as recorder, he was again secretary of the commonwealth, 1879–82. After retiring from public office for a brief period, he served as state treasurer, 1886–87. In 1888, as chairman of the Republican national executive campaign committee, Quay managed the successful presidential campaign for Benjamin Harrison. Quay later broke with Harrison and did not actively participate in the campaign of 1892, in which Harrison was defeated by the Democratic candidate, Grover Cleveland. Quay was a U.S. senator from Pennsylvania, 1887–89 and 1901–04.

For nearly 20 years he dominated the government of Pennsylvania and also played a very prominent part in national affairs. He was married on Oct. 10, 1855, to Agnes Barclay of Beaver, by whom he had two sons and three daughters. Quay died May 28, 1904.

See S. W. Pennypacker, *The Autobiography of a Pennsylvanian* (1918); "Matthew Stanley Quay: Memorial Addresses," *Sen. Doc. 202*, 59th congress, 3rd session.

QUAY, a wharf or landing place for the loading and unloading of water-borne cargo. The word, pronounced "key," takes the form of the French *quai*, older *cay* or *caye;* cf. Spanish *cayo*, a bar, barrier or reef. The earlier form in English is "kay," and it was so pronounced. "Key" was also earlier pronounced "kay," and the change in pronunciation in the one was followed also in the other. In spelling also the word was assimilated to "key," in the sense of a reef or, especially, of the low range of reefs or islets on the coasts of Spanish America; *e.g.*, on the coast of Florida, the chain of islets known as Florida Keys. (*See* also DOCKS.)

QUAYLE, WILLIAM ALFRED (1860–1925), U.S. educator and clergyman, was born in Parkville, Mo., on June 25, 1860, the son of immigrants from the Isle of Man in the Irish sea. After the death of Quayle's mother shortly after his birth, he lived in Kansas with Edward Gill, a Methodist minister and brother-in-law of his father, until he was 13 years of age, when he went to live with James Boicourt, also a Methodist clergyman.

He studied at a country school near Auburn, Kan., and at the state agricultural school, Manhattan, Kan. Graduated in 1885 from Baker university, Baldwin, Kan., he became a teacher of ancient languages at the university and in 1888 was elected president. Four years later he left the university and served as a Methodist pastor in Kansas City, Mo., Indianapolis, Ind., again in Kansas City, and finally in Chicago, Ill. Elected to the episcopacy of the church in 1908, he served in Oklahoma City, Okla. (1908–12), St. Paul, Minn. (1912–16), and St. Louis, Mo. (1916–24).

Quayle wrote a number of books, including *The Poet's Poet and Other Essays* (1897), *In God's Out-of-doors* (1902) and *With Earth and Sky* (1922). He was married on Jan. 28, 1886, to the

daughter of the first president of Baker university, Allie (Davis) Perry Robbins. Quayle died in Baldwin on March 9, 1925.

QUEBEC. The northeastern mainland province of Canada, bounded on the southwest and west by part of Ontario, James bay and Hudson bay, on the north by Hudson strait and Ungava bay, on the east by the coast of Labrador and the Gulf of St. Lawrence, on the south by the Bay of Chaleur, New Brunswick, Maine, New Hampshire, Vermont, New York and part of Ontario. Its greatest extent is from the U.S. border, about 45° N., to Cape Wolstenholme, about 62° 30′ N., and from Hudson bay, at a point about 79° 30′ W., to Anse Sablon, about 57° W. The total area is 594,860 sq.mi., or about one-sixth the total area of Canada. The area includes 71,000 sq.mi. of fresh water.

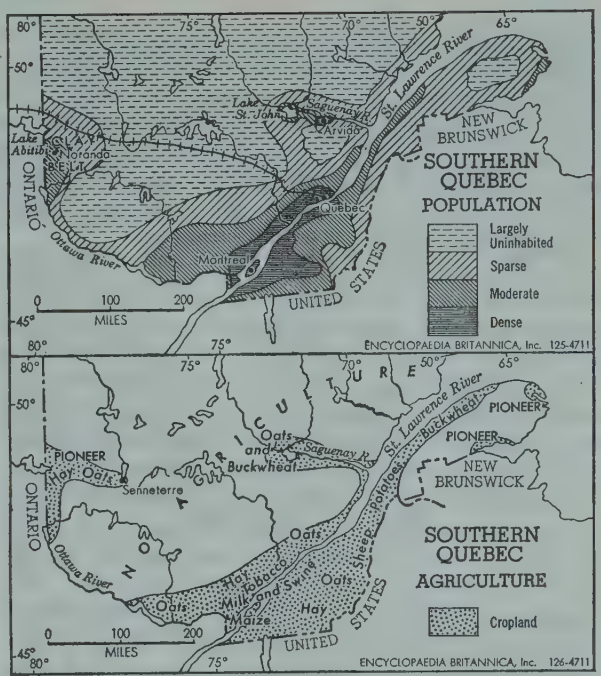
Climate.—The wide spread of latitude and the considerable distance from the Atlantic to the western parts of Quebec produce marked continental characteristics in the climate. In the centre of northern Quebec the range of temperature probably is as much as 70° F.; but along the St. Lawrence river near Montreal the range (between January and July) is about 57° F. (*i.e.*, from 13° to 70° F.). In July the isotherm of 57° F.—which determines the northern limit of the growth of crops—runs west-east through James bay. Hence it is the poor quality of the soils in southern Quebec rather than the temperatures which limits the northern extension of agriculture.

The outstanding feature of the climate is of course the constant passage of low-pressure eddies (cyclones) along the St. Lawrence. This results in an almost uniform type of rainfall in the southern part of the province, since these cyclones are the rain bringers in this part of the world. The weather, however, is quite variable, since the front of such a cyclone gives warm moist winds from the south, while the rear is accompanied by cold dry winds from the north. The annual rainfall increases fairly regularly from 15 in. in the north to more than 40 in. on the southern boundary of the province.

The snowfall in the high plateau behind Quebec (in the vicinity of the Laurentides provincial park) is perhaps the highest in the continent, and usually exceeds 120 in. in winter. This in part accounts for the popularity of skiing in this part of Canada.

Physiography and Geology.—Physiographical studies divide the province into three main regions: Canadian shield, St. Lawrence and Appalachian. More than 90% of Quebec is built up of the Pre-Cambrian rocks of the shield. In general these consist of various forms of granite and gneiss, of which most perhaps belong to the Algoman formation. There are, however, large areas of altered sediments and of ancient lavas and ash beds; so that there is plenty of variety among the rocks of the shield. The shield exhibits an undulating surface or peneplain, possibly dating back to a period of 500,000,000 years ago. This peneplain surface is by no means near sea level; for large areas of it in Quebec province at the head of Moisie river are more than 2,000 ft. above the sea. It is clear that quite late elevation *en masse* affected a considerable area of the shield. One of the highest points reaches 3,900 ft. and is only about 50 mi. N.E. of the city of Quebec. Covering this extremely ancient peneplain surface is a layer of glacial till, spread in a haphazard fashion all over the shield. This deposit was only laid down in the last phases of the Ice Age, about 30,000 years ago. Hence we find in this part of Canada a curious association of an extremely old surface of rock covered by a thin veneer of the youngest deposit of all. So comparatively recent has been the deposition of the till that the rivers have not developed a regular drainage pattern. An infinite number of small lakes fills the hollows in the till, river divides are very low, and as a result the topography lends itself well to widespread canoe travel.

The most remarkable of the river valleys is that of the Saguenay which, after a swift descent from the Lake St. John reservoir, falls into a vast chasm running from west to east, in places almost 2,000 ft. above and 300 fathoms below sea level. Hundreds of rivers, large and small, flow southward and northwestward ensuring to Quebec a huge potential water power which, with the forests covering the hills and valleys, preserving and preserved by this water supply, constitute an enormous reservoir of resources.



ABOVE: POPULATION. WITH TWO SMALL EXCEPTIONS, THE AREAS OF DENSE AND MODERATE SETTLEMENT ARE ALONG THE ST. LAWRENCE RIVER ON THE FLOOR OF THE FORMER CHAMPLAIN SEA. BELOW: AGRICULTURE. AREAS OF PRODUCTION ARE CONCENTRATED IN THE ST. LAWRENCE LOWLAND AWAY FROM THE INFERTILE CANADIAN SHIELD

One subregion, Abitibi, on both sides of the Canadian National main line and reaching the Ontario border, is heavily mineralized; both Abitibi and the level region surrounding Lake St. John have soils suitable for cultivation, the former largely clay covered by other soils of varying nature, the latter also clay with a lighter topsoil. The rest of the area has a light moraine soil supporting both softwood and hardwood forests but not otherwise fertile.

The St. Lawrence region seems to be separated from the shield by a major fault and includes: (1) an area divided by the river, narrowing from about 60 mi. breadth at Montreal to about 20 mi. breadth at Quebec; (2) an area on the south side of the river only, stretching about 300 mi. N.E. from Quebec and 6 to 10 mi. in depth. This region has been divided into three subregions, the Montreal plain, the St. Lawrence valley between Montreal and Quebec and the south shore (Cote Sud) below Quebec. The Montreal plain is low, 250 ft. or less above sea level. The surface slopes evenly and very slowly down to the river on both sides and also downward from northeast to southwest; *i.e.*, against the direction of the river. The basement is of Ordovician rock broken near Montreal by the Monteregian hills, remnants of considerable volcanic mountains now almost completely eroded.

After the ice cap vanished, the sea temporarily invaded the lowlands forming the Champlain sea. The soil consists of clay and sand from the Champlain sea with more recent deposits, and is in most places good, although large parts have become sour. Considerable areas are covered by newly formed peat. The St. Lawrence valley basement is likewise Ordovician rock; a mixed soil lies on a clay bed, much deeper on the south than on the north shore. The south shore is comparatively level, based on Ordovician rock with many outcrops. The soil is mainly sandy, although there are considerable areas of black vegetable deposit, in one section already turned to peat, and is strewn with glacial boulders.

The rest of the province constitutes the Appalachian region, mainly Ordovician with lesser amounts of Cambrian and Devonian dotted with granite, and serpentine hills, well weathered and largely tree-clad, rising in the south of the region to about 3,000 ft. Logan's fault separates the folded rocks of the Appalachian

region from the less disturbed area near the St. Lawrence. The Gaspé peninsula in the east has a central axis of Devonian rocks, and rises steeply from the north coast, ending in a high, narrow and precipitous promontory (Cape Gaspé). On the north side are the Shickshock mountains, much folded and faulted. On the south side is another range, with red sandstone and conglomerate along the western end of the Bay of Chaleur. At the east end of the south shore of the peninsula is a much eroded shore line of rocks filled with fossil shells from which a one-time peninsula, Percé rock, has comparatively recently been cut.

History.—Prior to its cession to Britain most of the present province of Quebec and also a vast ill-defined area stretching from the far west to the Alleghenies and from the Great Lakes to the Gulf of Mexico, as well as the French territories on the North Atlantic, were subject to the crown of France under the name of New France; the district in the St. Lawrence and watershed area was called Canada. Government was held closely in the hands of the crown at Paris; the governor, advised by a "sovereign council," had some powers of initiative but he was called to task if he overstepped and was rivalled by the bishop. His chief financial adviser, the intendant, was responsible to Paris for economic control. Except for elections of churchwardens, very few official traces of democratic government existed. "Canada" was by 1750 the home of about 65,000 French Canadians, descendants of settlers who had been arriving during a century and a half. They had a quasi-manorial system of land tenure: seigneurs received grants of about six miles' frontage and generally greater depth on the St. Lawrence and like areas in the interior. These were parcelled out to habitants who paid annual dues, mostly in kind, to the seigneur as well as making special payments on transfers of property. Some traces of the system were still visible at mid-20th century. There were about 15,000 bourgeois in Quebec, Montreal and Trois-Rivières where the seigneurial system also existed. There was a complete system of land registration and a notarial system for land transfers, marriage contracts, gifts, etc., which were unchanged at the cession and which, modernized, remained at mid-20th century. Births, marriages and deaths were recorded in the church of one or both of the persons concerned. These French Canadians who had become completely differentiated from the French (now mainly officials and soldiers), calling themselves "Canadiens" and not French, attributed vast importance to all these customs, to the civil law and to their religion.

After the victory of James Wolfe at Quebec, a British military government carried on satisfactorily, making no important changes. By the treaty of Paris, Feb. 10, 1763, New France passed formally to Britain. This treaty followed in one respect the terms of the capitulation of Quebec in 1759, which had provided *inter alia* that the French Canadians were to retain their houses, goods, effects and privileges and that the Catholic Church was to be preserved. The treaty also provided for the maintenance of the Catholic Church but subject to the laws of Britain (under which Catholics were debarred from almost all offices). The "privileges" of the capitulation, taken as meaning French civil law and customs, were maintained, but English law was to be followed so far as compatible with them. This to most judges meant that the common law of Britain prevailed and as no French Canadians knew what that law was there was great confusion.

The province of Quebec as a governmental and geographical entity first appeared under the name of the Government of Quebec in a proclamation made by the crown of Great Britain (in virtue of the somewhat dubious royal prerogative right to legislate for newly conquered territory) on Oct. 7, 1763. This proclamation reached Quebec Aug. 10, 1764. The "Government" included the St. Lawrence valley, except for what is now the Ontario section, and the Ottawa valley, bounded on the north by a line from Lake Nipissing to Lake St. John. The governor and captain general was authorized to, and did, set up a council to make laws and ordinances replacing the sovereign council. The governor in council was also authorized to, but did not, set up a popular assembly. The confusion as to law and religion resulting from the proclamation, as well as the wish of the British government to curb the American settlers to the south, brought about the Quebec act of 1774 which set up the "Province of Quebec" including most of the area now in the United States west of the Alleghenies. This act guaranteed the maintenance of French civil law and customs and freedom of worship. An executive and a legislative council, both nominated by the crown, were created and both continued in existence, although the executive council, under the same name, became a provincial cabinet.

The French Canadians were used to bureaucracy and were well enough pleased with the Quebec act to fight the invading Americans in 1775, and not at all concerned when the treaty of Paris in 1783 set the southern boundary west of the Quebec-Maine mountains back to the 45th parallel. In 1791, by the Constitutional act (enacted June 10, 1790), a government was set up for "Upper Canada" west of the Ottawa (except for a small triangle at the junction of the Ottawa and St. Lawrence) and "Lower Canada" extended by the act over the Magdalen Islands, Anticosti and Quebec Labrador. The act provided for Lower Canada an appointive legislative council (15) and an elective assembly (50).

The appointive council was at first all-powerful and there were many abuses of power, but there was little complaint until after the War of 1812, in which the French Canadians again fought and, in Lower Canada, defeated the Americans. The revolutionary ideas inspired liberals (French- and English-speaking) in the assembly; the struggle for responsible government and judges independent of the government which ensued culminated in the "rebellion" of the *patriotes* in 1837.

The Union act (July 23, 1840) became law on July 23, 1841, uniting Lower and Upper Canada as Canada East and Canada West, with one council and one assembly in which the two sections had equal numbers, the French language being for the first time recognized although only for debate.

After a conflict with the governor responsible government, in the modern sense, came into effect in 1841. The union was never much more than nominal, since the practice was to require a majority of the representatives from each section to pass any act while many acts referred to one section alone. The powers of self-government vested in the colonial parliament gradually increased, judicial reform was obtained, the French language was accepted for all purposes in 1849. In 1867, at confederation, the province of Quebec reappeared with its own lieutenant governor, legislative council and assembly. French-Canadian control of Quebec was assured but the rights of the powerful and rich English-speaking minority were carefully safeguarded, particularly their control over their own education. At mid-20th century they constituted only about 15% of the population, but the growing French-Canadian majority had scrupulously regarded its obligations.

The boundary of Quebec on the north at confederation was the height of land north of the St. Lawrence valley. This was extended to the Eastmain and Hamilton rivers in 1898 and to Hudson strait in 1912. The boundary between Quebec and Labrador (as an adjunct of Newfoundland) was decided by the Labrador act (1825). The boundary was placed as a line due north from Anse Sablon, and for more than a century Newfoundland was presumed to have jurisdiction only over the coastal strip of Labrador, not over the interior (practically unknown). Exploration and the prospect of development raised dispute as to the boundary and in 1927 a decision of the privy council awarded to Newfoundland all of interior Labrador draining to the Atlantic (112,000 sq.mi.). The period after confederation left the government of Quebec practically unchanged; parliamentary procedure and democratic practice follow British precedent even more than that of most other provinces, but the French-Canadian majority is quite firmly in the saddle. Quebec is a French-speaking island in North America owing allegiance to a queen who for it (and perhaps correctly) is queen of Canada, interpreting the Atlantic charter as confirming its right to its own religion, laws and language.

Population.—The 1951 census was 4,055,681, mostly French-Canadians. English-speaking people were mainly centred in the larger cities, in Pontiac and Abitibi counties, where there were many new Canadians, the Saguenay and St. Maurice industrial areas, Gaspé and the eastern townships north of the New Hamp-

shire and Vermont border.

Government.—The queen is represented by the lieutenant governor, appointed for a renewable term of years by the governor general in council. The legislative council at mid-20th century had 24 members, each sitting for a geographical district, appointed for life by the lieutenant governor in council (Quebec is the only province with such a body). The legislative assembly had 92 members, each elected for a constituency. Rural constituencies are larger but far less populous than urban. The distribution of powers between the three sections is identical with that between queen, lords and commons in Britain, the assembly having complete control of taxation and finance. Treasury bills issued under orders-in-council must be covered by appropriate votes. All private and some public bills are discussed in and reported by appropriate committee sessions at which persons affected may appear personally or by legal representative before passage. Otherwise the formalities duplicate those of the parliament at Westminster. The premier leads in the assembly, and a leader named by the government, generally also a minister without portfolio, in the council. The executive council is the provincial cabinet; its members must, as a rule, hold seats in the assembly, thus ensuring maintenance of the representative principle. Members are premier, provincial treasurer, provincial secretary, attorney general, ministers of roads, public works, colonization, agriculture, game and fisheries, lands and forests, trade and commerce, municipal affairs, health, labour, mines, social welfare and youth, each of whom has one or more deputies while the premier has a *chef du cabinet* ranking as a deputy minister. There are generally a number of ministers without portfolio, of whom the leader of the council is generally one. Elections are governed by the Provincial Elections act, substantially in accord with British practice. There are two parties, Liberal and National Union; a local organization of each usually selects a candidate prior to an election. Independents may run if nominated. Municipal government is carried on by 76 county municipalities and rural and urban municipalities generally under the Cities and Towns act and municipal code, although there are many special charters and acts which demand much parliamentary time for their enactment and revision.

Agriculture.—In 1948 Quebec's farm capital totalled $1,064,868 (being outranked by Ontario, Saskatchewan and Alberta, in that order). Main products and values (1943–47 averages); wheat, 424,000 bu., $509,000; oats, 36,365,000 bu., $25,335,000; barley, 2,978,000 bu., $2,733,000; rye, 146,000 bu., $148,000; peas, 315,000 bu., $1,067,000; beans, 198,000 bu., $711,000; buckwheat, 1,642,000 bu., $1,615,000; potatoes, 11,460,000 cwt., $22,605,000; turnips, 5,217,000 cwt., $4,817,000; hay and clover, 6,110,000 tons, $83,304,000; alfalfa, 164,000 tons, $2,469,000; fodder corn, 758,000 tons, $4,652,000; sugar beets, 14,000 tons, $167,000. Quebec's place among the provinces (1949) was as follows: acreage of field crops fifth, with 6,424,000; value of field crops fourth, with $183,376,000; value per acre third, $59; net income from farming operations fourth, $244,666,000.

The main features of Quebec agriculture are: (1) Family farming: on most farms most of the work is done by the farmer and his family, eliminating most of farm labour costs. (2) Farm arts and crafts, mainly in the eastern section where most of the wool produced is woven locally. (3) Co-operation increasing rapidly. In 1950 there were 962 co-operatives (1936: 167, 1940: 364) with 89,365 members (1940: 26,790); of these, 776 were marketing and purchasing agencies and 113 were service; fisheries and electric power distribution co-operatives were late developments. Total 1950 volume of business was $122,074,000, of which $71,539,000 was sales of products and the rest for merchandise purchases. In addition there were 1,133 credit unions in 1950; 630,224 members; $234,388,000 total savings; $525,336,000 total loans since inception. (4) Farm credits (under revised statutes of Quebec 194, chap. 113): a farmer whose debts exceed 65% of the value of his farm may borrow 75% thereof, provided his creditors accept this in full payment. A farmer establishing a new farm may borrow 75%. Interest is 3% per annum, plus 2.714% amortizing loan in 25 years.

The department of agriculture comprises ten services: education, rural economics, extension, animal husbandry, horticulture, field husbandry, information and research, handicrafts and home economics, health of animals, rural engineering. There are also special provincial organizations of farm credit bureau, research council, rural electrification bureau, dairy industry commission. The province is divided into 20 districts, in each of which there is a district agronomist with a staff of one agronomist for each county and a number of assistant and special agronomists with demonstration farms, etc. The province assists agricultural colleges, holds county farm improvement contests (covering more than 5,000 farms in 1930–50), conducts drainage projects, maintains plant-breeding stations.

Environment and Settlement.—The people of Quebec, except for two districts, settled in the lands south of the shield. However, the accompanying population map shows that there is a notable number of settlers near Lake St. John at the head of the Saguenay river. As usual this can be explained in terms of the structure. A block of the earth's crust has sunk, forming a graben. In this depression clays and silts have accumulated, giving rise to much better soils than those which generally characterize the peneplain surface of the shield. Here also the waters of the lake rushing through gorges to the Saguenay have been harnessed by many power stations. Hence, there is a close industrial settlement around the towns of Arvida, Chicoutimi, etc., where large supplies of aluminum and other manufactured goods are produced. At the western margin of the shield there is a large area covered with the clays of the "clay belt." These are due to lake silts deposited in a bygone glacial lake and, as at Lake St. John, the soils are relatively fertile. From Senneterre to Abitibi lake there are many families of habitants who have developed a pioneer hay-oats-dairy economy, which is able to supply many of the needs of the flourishing mines around Noranda.

In the St. Lawrence valley there is extensive farming based in part on the good soils laid down in the temporary Champlain sea. In the warmest part of the province there is a large area devoted to tobacco, and also to maize. The latter is, however, fed green to animals, and the cobs do not generally ripen. In the same rich agricultural region is the densest dairy distribution and on the skim milk many swine are fed, as indicated in the map. Throughout the southern part of the province oats and hay are grown, while in the colder districts potatoes and buckwheat become relatively more important. In the rough foothills of the Appalachians, along the southeast border, is one of the main areas for sheep in eastern Canada.

Education.—Education in Quebec has three main branches: (1) formal school system; (2) college and university system; (3) technical and special schools. There is a growing system of adult education.

1. The formal system is under the control partly of government, partly of committees. Superintendent of education (appointed by the government) is chairman of a council of education which does not sit as such but is divided into a Catholic and a Protestant committee, each with its secretary (a deputy minister). The Catholic committee includes all Roman Catholic bishops, an equal number of laymen and some additional members. The Protestant committee has half the number of members and a number of associate members. In virtue of sec. 93 of the British North America act the Protestant committee has sole control of the curriculum in, and recommends all government grants to, Protestant schools. The Catholic committee deals likewise with Catholic schools. Under jurisdiction of the committees are: (*a*) Catholic elementary, complementary, intermediate and high schools, colonization area schools and Catholic high schools; (*b*) Protestant elementary, intermediate and high schools. With the universities each committee controls normal schools. There are a few private schools (English-speaking). In school municipalities (erected and divided by the government), commissioners are elected by majority (Protestant or Catholic) and trustees by minority. In large cities there are two sets of commissioners. These finance schools and pay teachers.

2. The college and university system is independent of govern-

ment control except where agreements exist. There are 32 classical colleges (Roman Catholic) which give an eight-year arts and science course leading to a university baccalaureate. Convent schools train a large number of girls. Sir George Williams college (Y.M.C.A.), Montreal, gives a degree course. McGill university (non-sectarian), Montreal, Ste. Anne de Bellevue and St. Johns, have arts and science, professional and graduate faculties. Three Protestant theological colleges are affiliated. Bishop's university (Anglican) at Lennoxville, mainly residential, gives several degree courses. Laval university, Quebec, and the University of Montreal, with several affiliated schools, provide many branches of professional training.

3. The technical schools of Quebec are not concentrated under a department of education but are spread through the fabric of the government. For example, the department of agriculture is responsible for schools of veterinary medicine, dairy science, pottery making, fisheries, forestry and domestic science; the department of youth and social welfare is responsible for schools of furniture making, papermaking and graphic arts, and in addition for 38 schools teaching common trades and 13 schools recognized as youth protection schools. Under the department of the provincial secretary there are several special schools affiliated to universities for standards and degrees, including the Montreal school of higher commercial studies, and the Montreal polytechnical school; and an institute of music and dramatic art, and a school of fine arts, which give instruction in Montreal and Quebec city.

4. Adult education is carried on in housekeeping schools, night schools and dressmaking schools, by McGill university in Montreal and rural areas, by the department of education and Canadian Legion educational services.

Forests.—Quebec forests are the most important asset of the province. By a 1948 calculation the net value of Quebec sawmill products was $69,957,892 out of a Canadian total of $409,267,472.

The total forest area covered 356,059 sq.mi., of which 329,154 sq.mi. were still in the hands of the crown and 26,737 sq.mi. were privately owned. Of the crown lands, 78,524 sq.mi. were leased in 1949 to pulp and paper and to lumber companies; of the private forestlands, 9,317 sq.mi. were farm woodlots and the rest owned by corporations or individuals. Varieties are spruce, balsam fir, white pine, red pine, jack pine, hemlock, cedar (white and red), tamarack, birch, maple, basswood, elm, ash, white birch, aspen, poplar, oak (white, red, burr), butternut, cherry, beech, walnut, hickory. Control is by the department of lands and forests.

Mineral Production.—Mineral production at mid-century was characterized by rapid recent growth resulting from the rediscovery of copper (known to the Indians and described by them to Jacques Cartier in 1535) in Abitibi and the finding of gold in the same district. The region as known stretches about 120 mi. E. from the Ontario border about the northern line of the Canadian National railways and varies from 10 to 40 mi. in width. A considerable group of modern cities and towns (Rouyn, Noranda, Amos, Val d'Or, Duparquet, La Sarre, etc.) developed in consequence. As a world producer Quebec takes first place in one article only, asbestos of the serpentine type which exists throughout the Appalachian region. The main production is concentrated southeast of Montreal (Thetford Mines, Black Lake, Asbestos). In 1948 the production was 716,769 tons valued at $42,231,475, mainly shipped to the United States as raw material. In value gold continued in first importance accounting for $21,819,473 out of a total metallic mineral production of $66,115,266 in 1948.

Power and Manufactures.—The development of manufactures marched with that of hydroelectric power, probably the most extensive per capita of population, having increased from 2,165,445 h.p. on Jan. 1, 1928, to 6,130,097 h.p. on Jan. 1, 1950. The Shipshaw plant near Arvida on the Saguenay was the world's largest hydroelectric plant at mid-century. Partly because of this power supply, and partly because of favourable labour conditions, manufacturing returns grew from $158,287,994 in 1901 to $3,017,649,422 in 1947, when the main products and receipts in order of value were pulp and paper $346,119,699, nonferrous metals $145,131,521, women's factory clothing $123,177,572, cotton yarn and cloth $111,477,647, men's factory clothing $108,220,280, electrical apparatus $92,803,880.

Transportation and Communication.—The St. Lawrence waterway forms a section of the shortest route between Europe and the central United States, furnishing deepwater communication to Quebec's main ports, Montreal, Sorel, Three Rivers, Quebec and (via the Saguenay) Port Alfred. Montreal is one of the most important rail-water-air connecting points in North America and Quebec manufactures are largely based on transportation facilities. Further development of aviation should not change the situation since Quebec is at the centre of a web of potential great-circle flying trade routes to areas of economic importance (*e.g.*, north and central Africa). Montreal airport, headquarters of R.A.F. transport command, became of vital war importance during World War II.

In 1949 the province had 4,791 mi. of railway lines, of which nearly 3,000 mi. were Canadian National, nearly 1,700 Canadian Pacific railways, and the rest pulp and paper company lines, together with about 50 mi. of New York Central feeder line into Montreal. In 1950 a 360-mi. railway was started at Sept-Îles to run to the iron-ore deposits adjacent to the Labrador boundary.

Montreal and Quebec City are major ocean ports used regularly by about a score of Canadian and foreign shipping lines; and in 1949 1,459 international service ships totalling 4,240,698 net tons and 3,286 coasting service ships totalling 3,820,906 net tons used the Montreal port alone. Totals for all ports were: foreign, 2,640 ships, 7,384,839 tons; coastwise, 11,086 ships, 9,900,656 tons.

Roads in 1949 were as follows: first class, 5,521 mi. built and maintained by the provincial government (department of roads), second class, 20,041 mi.; third class, 15,088 mi. built and maintained by the provincial and local authorities. After many years of experiment, difficulties caused by weather extremes had been largely overcome. The Quebec countryside retained a picturesque and old-world aspect and this with its remarkable scenery made the province a tourist centre.

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(W. BY.; G. TR.; C. CY.)

QUEBEC, the capital of the Canadian province of the same name, situated on the north bank of the St. Lawrence river, at its junction with the St. Charles, about 300 mi. from the Gulf of St. Lawrence and 180 mi. by river northeast of Montreal, in 71° 12′ 19.5″ W. and 46° 48′ 17.3″ N.

The origin of the name Quebec has been much disputed, but it is apparently the Algonkin word for a strait, or sudden narrowing, the river at its junction with the St. Charles being about 2,500 yd. wide, but narrowing opposite Cape Diamond to 1,314 yd. Pop. (1951) 161,439; metropolitan area, 271,236.

Quebec is built on the northern extremity of an elevated tableland which forms the left bank of the St. Lawrence for a distance of eight miles. The highest part of the headland is Cape Diamond, 333 ft. above the level of the water, and crowned by the citadel; toward the St. Lawrence it presents a bold and precipitous front, while on the landward side and toward the St. Charles the declivity is more gradual.

The harbour of Quebec is spacious and deep enough for the largest ships. Wharves near Wolfe's cove add to the accommodation afforded by the Louise basin; the harbour is closed by ice only three or four months in the year.

Quebec consists of an upper and a lower town, the two connected by steep, winding streets and by an inclined elevator. Much of the lower town still recalls the older portions of such French provincial towns as Rouen or St. Malo; the streets, with one or two exceptions, are narrow and irregular. In the upper town, where the streets are wider and well paved, are the better-

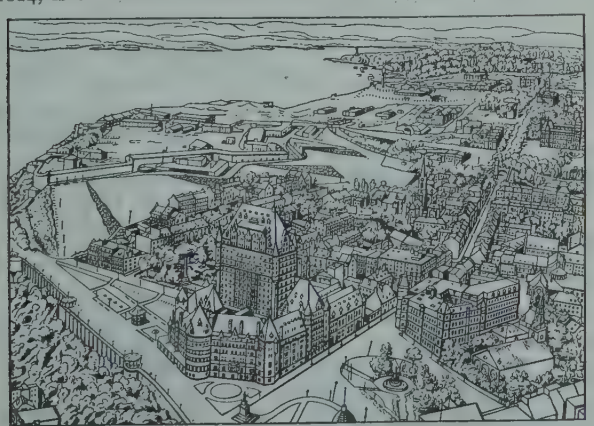
class dwelling houses and public buildings, most of the churches, public parks and many retail shops.

Beyond the citadel are the historic Plains of Abraham, now become a national battlefields park, where the British army in Canada in 1849 marked the spot where James Wolfe fell by a simple, high column. In the Governor's garden is the famous monument dedicated to the two generals who fell in the battle, Wolfe and the marquis de Montcalm. A point of much interest in the upper town is Dufferin terrace, a magnificent promenade overlooking the St. Lawrence, 1,400 ft. long and 200 ft. above the level of the river. Part of this terrace occupies the site of the old Château St. Louis, which was destroyed by fire in 1834. Near by, and in full view of the river, is the Château Frontenac, erected by the Canadian Pacific railway on the model of an old French château. Nothing remains of the fortifications erected under the French regime. The present walls and the citadel, which covers an area of about 40 ac., were built in 1823–32. Since then several of the gates have been destroyed, and others rebuilt, but in other respects the walls are practically intact and, though obsolete as fortifications, add greatly to the picturesqueness of the city. Between 1865 and 1871 three forts were built on the Lévis side of the river, but were neither manned nor armed.

Quebec's natural position still makes it one of great military strength, though depending on naval control of the sea and of the Gulf of St. Lawrence.

Churches and Institutions.—Although almost nine-tenths of the population are Roman Catholics, there are several Protestant churches, among them the Anglican cathedral, built in 1804. Of the numerous Roman Catholic churches the most noteworthy is the cathedral, the basilica, founded in 1647 and enlarged at various times, containing some valuable paintings and relics. Fire destroyed this in 1922, but it was later rebuilt on the original model. Perhaps the most interesting, historically, is a church in the lower town, the Notre Dame des Victoires, erected in 1688, and named for the defeat of Sir William Phips in 1690 and the shipwreck of Sir Hovenden Walker in 1711. Laval university, which receives its name from the first bishop of Quebec, who founded in 1663 a seminary for the training of priests, is under Roman Catholic control. It was instituted in 1852 by royal charter from Queen Victoria, and in 1876 received a charter from Pope Pius IX. It includes faculties of theology, law, medicine and arts, a library of more than 850,000 volumes, a museum and a picture gallery. The Ursuline convent, founded in 1641, possesses some good paintings and a number of relics, among them the skull of Montcalm.

High schools and numerous academies are supported by Protestants under the dual system of education in the province. The Literary and Historical society, founded by Lord Dalhousie in 1824, is the oldest chartered institution of the kind in Canada.



BY COURTESY OF THE CANADIAN PACIFIC RAILWAY

QUEBEC, SHOWING A VIEW OF THE UPPER TOWN

The old town, which resembles a French provincial town, lies below. The citadel, 333 ft. above the river, is seen to the left on the river front. In the foreground is the modern Dufferin terrace with the Château Frontenac hotel built in the style of a French château

The principal benevolent institutions are the Marine hospital, the Hôtel Dieu, founded in 1639 by the duchess of Aiguillon, and the asylum at Beauport controlled by the Grey Nuns. The provincial parliament buildings, erected in 1878–92, are set in extensive grounds and finely ornamented with statues. The seat of the lieutenant governor is at Bois de Coulonge (formerly called Spencerwood) outside the city.

Commerce, Industries, etc.—Quebec owes its electric light, electric streetcars and industrial plants to a plentiful supply of power from Montmorency falls (265 ft. in height) and Shawinigan falls. The climate is severe but bracing, the mean temperature in winter being 10° and in summer 68°. The city returns three members to the provincial house of assembly and four to the house of commons. Economically, Quebec was long the chief port of Canada; then followed years of reverses when Montreal became the shipping port. Later, increased railway facilities at Quebec, greater difficulty for larger ships reaching Montreal, the development of vast water power near Quebec, all contributed to an improved commercial and industrial position for that city. The Quebec bridge, connecting the north and south shores of the St. Lawrence river at Cap Rouge, 9 mi. above the city, was completed in 1917, after ten years of work and two serious accidents to the structure. The completion of the bridge made possible the running of six railways simultaneously into Quebec from the south shore. The Canadian National railway has a line running into Quebec from Prince Rupert, thus affording a much shorter route from west to east; the Canadian Pacific also gives ample connection with other parts of the country. The industries of the city are largely determined by the two great natural resources of the province, forests and water power. The Anglo-Canadian Pulp and Paper company operates one of the most modern pulp and paper mills in the world; the power is from the Shawinigan falls and the capacity is more than 3,000 tons a week. Manufactures include machinery, cutlery, gunpowder, musical instruments, ropes, steel, boots and shoes.

History.—The first known white man to visit Quebec was Jacques Cartier, the French navigator, in 1535, who found on the site a large Indian village, called Stadacona. In July 1608 the present city was founded, and named by Samuel de Champlain. Its growth was slow, and in 1629 it had but two permanently settled families, with a shifting population of monks, officials and fur traders. In that year it was captured by the English under Sir David Kirke (1597–1656; *see* H. Kirke, *The First English Conquest of Canada*, 1871, reprinted 1908), but in 1632 it was restored to the French by the treaty of St. Germain-en-Laye. In 1663 the colony of New France was created a royal province, and Quebec became the capital. In 1690 Sir William Phips, governor of Massachusetts, attempted to reconquer it with a fleet and army fitted out by New England, but was defeated by the French governor, the comte de Frontenac. In 1711 a great British expedition sent against it under Sir Hovenden Walker was shipwrecked in the Gulf of St. Lawrence, and the French held possession till 1759 (*see* below), when it was captured by the British troops on Sept. 18, five days after the battle of the Plains of Abraham; it was finally ceded to Great Britain by the treaty of Paris in 1763. In 1775 the American generals Richard Montgomery and Benedict Arnold attacked the city, but Montgomery was killed (Dec. 31, 1775) and Arnold was compelled to retreat in the following spring. From 1763 till 1791 Quebec was the capital of the province of Quebec, as then existing; from 1791 till 1841 the capital of Lower Canada; from 1851 to 1855 and from 1859 to 1865 the capital of the United Province of Canada, and from 1867 the capital of the province of Quebec. (A. P. Co.; W. S. Wa.; X.)

Wolfe's Quebec Expedition, 1759.—Both in itself and also as the central incident of the British conquest of Canada, the taking of Quebec is one of the epics of modern military history. The American campaigns of the Seven Years' War, hitherto somewhat spasmodic, were, after Lord Jeffrey Amherst's capture of Louisburg in 1758, co-ordinated and directed to a common end by that general, under whom James Wolfe, a young major general 33 years of age, was to command an expedition against Quebec from the lower St. Lawrence, while Amherst himself led a force from

New England by Lake Champlain on Montreal. Wolfe's column consisted of about 8,000 troops, and was convoyed by a powerful fleet under Admiral Saunders.

The voyage to Quebec was not the least hazardous phase of the expedition, for the currents and shoals of the St. Lawrence were notorious, and its achievement—due largely to the skill of Captain Cook, later famous as the discoverer—astonished the French. Vaudreuil, the governor, wrote: "The enemy have passed sixty ships of war where we dare not risk a vessel of a hundred tons by night and day." Wolfe disembarked on the Isle of Orleans, four miles below Quebec, on June 27. The defenders were commanded by Montcalm, a soldier whose character and abilities, like Wolfe's, need no comment here. The French were superior in numbers, but a considerable part of their force was irregular, and *morale* and discipline were indifferent. On the other hand their position was of great natural strength. Wolfe began the attack by seizing Point Lévis, and thence bombarding Quebec across the St. Lawrence. This, however, affected the main defences of the upper city but little, and they were protected from closer attack by the St. Lawrence and the St. Charles. The third side of the triangle was the "plains of Abraham," to which it was thought there was no approach from the river.

Trusting in this obstacle and in the guns of the city to control the narrow passage which led to the upper reaches of the river, Montcalm entrenched his army on the north shore just below Quebec, between the St. Charles and the Montmorency. Wolfe tried various baits to entice his opponent out of his fastness, but after wasting some weeks, he decided to cross the St. Lawrence 7 m. below Quebec and to fight his way to the city by the St. Charles side. But Montcalm's fortified posts spread out from Quebec through Beauport as far as the Montmorency, and this formidable obstacle checked the English advance at the outset. A mile to the west of Montmorency, there was a narrow strip of land between the river and the heights where the French had built redoubts. Wolfe now planned to land here with all the available grenadiers and part of a brigade hoping, by the capture of a detached redoubt, to tempt the French army down to regain it, and so bring on a battle in the open. Meanwhile two other brigades were to be ready to ford the lower reaches of the Montmorency and join him.

On July 31, the attempt was made, covered by the guns of several ships and by the batteries across the Montmorency gorge. But when the troops got ashore, the grenadiers rushed impetuously on the enemy's entrenchments without waiting for the main body to form up. As a storm of fire broke in their faces, a storm of rain broke on their heads, and the steep slopes, slippery with blood and rain, became unclimbable, as the muskets became unfireable. Realising that his plans had gone awry, Wolfe broke off the fight and re-embarked the troops. It was a severe set-back, and the French were proportionately elated. The Governor wrote, "I have no more anxiety about Quebec." Wolfe's fragile health gave way under the disappointment, and despondency set in in the English camp. But as soon as the young leader had recovered a little, he summoned his brigadiers and worked out a plan for attacking by the upper waters and the heights of Abraham. Access to the heights could be obtained, it was found, by a tiny cove (the Anse du Foulon, now called Wolfe's cove), from which a steep footpath led to the summit. It was no place for artillery, and even for infantry the climb was long and exhausting, but the attempt was made. If it seemed desperate, the annals of military history show that even the most hazardous indirect approaches have often succeeded where the easy direct approach has failed—because the former does not follow the line of natural expectation. Here, one favourable factor was that for some weeks British frigates and smaller vessels had been slipping past the guns of Quebec, as part of a scheme to cut off the French supplies from upstream. On September 3 Wolfe evacuated the Montmorency camp, and on the 5th, after concentrating his forces on the south shore, marched the bulk, some 3,600, overland up the river bank, and embarked them in the ships.

Each day the ships drifted up and down with the tide, perplexing the French command and wearing out their troops with ceaseless marching and counter-marching. At last, just before sunset on Sept. 12, Admiral Saunders with the main fleet drew out along the shore opposite Montcalm's camp below Quebec, and, lowering their boats to suggest a landing, opened a violent fire. This ruse admirably fulfilled its purpose of fixing the enemy, for Montcalm concentrated his troops and kept them under arms during the night—miles away from the real danger point. And while they were straining their eyes to detect the threatened landing, a lantern rose to the maintop of the *Sutherland,* miles up river, and 1,600 troops of the first division noiselessly embarked in their flat-boats. At 2 A.M. as the tide began to ebb, two lanterns rose and flickered, and the whole flotilla dropped silently down-stream, the troops in boats leading. Discovery was narrowly averted when a French-speaking officer twice replied to a sentry's challenge from the shore, his deception helped by the fact, of which deserters had told Wolfe, that the enemy were expecting a convoy.

The landing was safely made at the Foulon cove: a band of picked volunteers swarmed up the steep face of the cliff, and overpowering the French picket on the summit, covered the landing of the main body. Before dawn the army, reinforced by another 1,200 troops under Colonel Burton direct from the south bank, was moving towards Quebec. Wolfe had found, on the heights of Abraham, the open battlefield for which he had thirsted. Should he be beaten he was certainly in a desperate position, but he had sure ground for confidence in the quality of his own men to offset the French quantity in open battle.

Wolfe disposed his force in a single line—to gain the utmost fire effect, wherein lay his strength,—with his left thrown back to guard the inland flank, and one regiment—Webb's (the 48th)—in reserve. Montcalm, warned too late, hurried his troops westwards across the St. Charles and through the city. Wolfe's bait this time had succeeded, even beyond expectation, and Montcalm attacked before his whole force was ready, probably because part was pinned by fear of the threatened landing below Quebec.

The clash was preceded by an attempt of the Canadian irregulars and Indians to work round Wolfe's left, but if their fire was galling, their effort was too uncontrolled to be effective. About 10 A.M. the French main body advanced, but their ragged fire drew no reply from the British line, obedient to Wolfe's instructions that "a cool well-levelled fire is much more destructive and formidable than the quickest fire in confusion." He himself was shot through the wrist, but, wrapping a handkerchief round it, continued his calls to the men to hold their fire. At last, when the French were barely forty yards distant, the word was given, and the British line delivered a shattering volley, repeated it, and then, on Wolfe's signal, charged a foe already disintegrating. At the head of his picked grenadiers Wolfe was an inevitable target. A bullet penetrated his groin, a second his lungs, and he fell, unobserved by the charging ranks. A few minutes later he was dead. His dying words, when told that the enemy were on the run—"Now God be praised, I die happy,"—are historic. But the words preceding these are a finer tribute to him as a general—even on the point of death: "Go, one of you, with all speed to Colonel Burton and tell him to march Webb's regiment down to the St. Charles River, and cut off the retreat of the fugitives to the bridge."

In the city all was confusion, for Montcalm had been gravely wounded in the rout, and that night the wreckage of the French army streamed away up the river in flight. With the death of Montcalm and Townshend's energetic pressing of the siege, Quebec surrendered four days later. (B. H. L. H.; X.)

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QUEBEC ACT, the title usually given to a bill which received the royal assent on June 22, 1774. This act extended the boundaries of Quebec to include much of the country between the Ohio and the Mississippi. The French inhabitants of the province were granted the liberty to profess "the religion of the Church of Rome"; the French civil law was established, though in criminal law the English code was introduced. Government was vested in a governor and council, a representative assembly not being granted till the Constitutional Act of 1791

The granting of part of the western territory to Quebec, and the recognition of the Roman Catholic religion, greatly angered the American colonies. On the other hand, it did much to keep the French Canadians from joining the Americans in the coming struggle. The act is still regarded by the French in Canada as their great charter of liberty.

QUEDLINBURG, a town in the Prussian province of Saxony, Germany, on the Bode, near the northwest base of the Harz mountains, 12 mi. S.E. by rail from Halberstadt. Pop. (1939) 30,235. Quedlinburg was a fortress of Henry the Fowler about 922, its early name being Quitlingen. It joined the Hanseatic League. The abbey of Quedlinburg was founded by Otto the Great and it owned, at one time, a territory about 40 sq.m. in area. The abbesses ranked among the princes of the empire, and had no ecclesiastical superior except the pope. The town at first strove to maintain its independence of them, and to this end invoked the aid of the bishop of Halberstadt. In 1477, however, the abbess Hedwig compelled the bishop to withdraw, and for the next 200 years both town and abbey were under the protection of the elector of Saxony. In 1539 the townsmen accepted the reformed doctrines and the abbey was converted into a Protestant sisterhood. In 1697 the elector of Saxony sold his rights over Quedlinburg to the elector of Brandenburg. The abbesses, however, retained certain rights of jurisdiction, and disputes between them and the Prussian Government were frequent until the secularization of the abbey in 1803.

QUEEN, the title of the consort or wife of a king ("queen consort"), or of a woman who is herself the sovereign ruler of a State ("queen regnant"); the widow of a former reigning sovereign is a "queen dowager," and, when the mother of the reigning sovereign, a "queen mother." For the position of the queen in English constitutional law *see* CONSORT, and for her household *see* HOUSEHOLD, ROYAL.

QUEEN ANNE'S BOUNTY, the name applied to a perpetual fund of first-fruits and tenths granted by a charter of Queen Anne, and confirmed by statute in 1703, for the augmentation of the livings of the poorer Anglican clergy. First-fruits (*annates*) and tenths (*decimae*) formed originally part of the revenue paid by the clergy to the papal exchequer. The former consist of the first whole year's profit of all spiritual preferments, the latter of one-tenth of their annual profits after the first year, but the First Fruits and Tenths Measure 1926 has made provision for the extinction of *annates* and *decimae* in most cases and for their redemption in the remaining cases. In accordance with the provisions of two Acts (5 and 6 Anne, c. 24, and 6 Anne, c. 27) about 3,900 poor livings under the annual value of £50 were discharged from first-fruits and tenths. Since that date there has been a large mass of legislation dealing with Queen Anne's Bounty, the effect of which will be found set forth in a *Report of a Joint Select Committee on the Queen Anne's Bounty Board* (1900). (*See* TITHES.)

QUEEN ANNE'S LACE: *see* WILD CARROT.

QUEENBOROUGH, a municipal borough in the Faversham parliamentary division of Kent, England, in the Isle of Sheppey, close to the junction of the Swale and Medway, 2 mi. S. of Sheerness on the S.R. Pop. (1951) 3,137. Area, 2.2 sq.mi. A fortress, called Sheppey castle, existed from an early period guarding the passage of the Swale river. Queenborough castle was built about 1361 by Edward III, who named the town after Queen Philippa and made it a free borough, with a governing body of a mayor and two bailiffs. The town has regained its prosperity by the establishment by the railway company of a branch line from Sittingbourne in connection with a service of mail and passenger steamers to Flushing (Holland).

QUEEN CHARLOTTE ISLANDS, a compact group lying off the northern part of the coast of British Columbia, and forming part of that province of Canada. Pop. (1951) 2,379; area, 3,780 sq.mi. It was named by Capt. George Dixon, who visited the islands in the "Queen Charlotte" in 1787. Although the islands promise to become important because of their excellent harbours, the discovery of good seams of bituminous coal (beside the anthracite already known), their abundant timber of certain kinds and their prolific fisheries, comparatively little settlement has taken place. The fisheries (largely halibut and herring) of Hecate strait, which separates these islands from the mainland and its adjacent islands, are wonderfully productive. There are also whaling stations on the islands. Steamers run fortnightly from Prince Rupert to Queen Charlotte city. The natives (1951 pop. 767), the Haida people, constitute one of the finest and most artistic races of the west coast of North America.

QUEENSBERRY, EARLS, MARQUESSES AND DUKES OF. The Queensberry title, one of the many with which the Scottish house of Douglas (*q.v.*) is associated, originated in the creation of SIR WILLIAM DOUGLAS (d. 1640) as earl of Queensberry in 1633. He was the eldest son of Sir James Douglas of Drumlanrig (d. 1616). His grandson WILLIAM the 3rd earl (1637–1695), was created marquess of Queensberry in 1682 and duke of Queensberry in 1684; he held many high offices in Scotland under James II. His son JAMES DOUGLAS, the 2nd duke (1662–1711), was the royal commissioner to the famous Scottish parliament which met in 1700, and just after the accession of Anne in 1702 he was made one of the secretaries of state for Scotland. In the latter part of 1703 he came under a temporary cloud through his connection with the Jacobite intriguer, Simon Fraser, Lord Lovat. Queensberry was deprived of his offices, but in 1706 he was again commissioner to the Scottish parliament; in this capacity he showed great ability in carrying through the treaty for the union of the two crowns. In 1708 he was created duke of Dover and marquess of Beverley. In 1709 he was appointed third secretary of state.

CHARLES DOUGLAS, the 3rd duke (1698–1778), who had been created earl of Solway in 1706, was lord justice general from 1763 until his death in October 1778. In 1720 he married Catherine, daughter of Henry Hyde, 4th earl of Clarendon; this lady, a famous beauty, although very eccentric; was the friend of many of the wits and writers of her day, notably of Gay, Swift and Walpole. Their two sons predeceased the duke, and when he died his British titles, including the dukedom of Dover, became extinct, but the Scottish titles passed to his cousin, WILLIAM, 3rd earl of March (1724–1810).

This William Douglas, who now became the 4th duke of Queensberry, is best known by his sobriquet of "Old Q." On the turf he was one of the most prominent figures of his time, and his escapades and extravagances were notorious. From 1766 to 1776 he was vice-admiral of Scotland, and in 1760 he was made a lord of the bedchamber by George III.; but later he was an associate of the prince of Wales, being removed from his office in the royal household in 1789. He died unmarried, and the dukedom of Queensberry and some of his other titles, together with his fine seat Drumlanrig Castle, now passed to HENRY SCOTT, 3rd duke of Buccleuch, in whose family they still remain; but the marquessate of Queensberry descended to SIR CHARLES DOUGLAS (1777–1837), the representative of another branch of the Douglas family, who became the 5th marquess. In his family the marquessate remained.

QUEENSLAND, a state of the Commonwealth of Australia, occupying 670,500 sq. miles (22·54%) in the north-east of the continent. A coast-line of 3,000 miles—after that of Western Australia the longest of any individual State—bounds it on the north from the Gulf of Carpentaria and on the north-east and east from the Coral Sea and the Pacific Ocean, Cape York Peninsula being the only outstanding feature of the horizontal profile. In the west the boundary runs successively with that of North Australia and Central Australia along long. 138° E., with that of South Australia along lat. 26° S. and long. 141° E. to the north-west corner of New South Wales. On the south the boundary marches with that of New South Wales along lat. 29° S., by the Upper Darling (Barwon-Macintyre-Dumaresq) rivers and the Macpherson Range to Point Danger. The waters and islands to the north of Cape York nearly to the coast of New Guinea, as well as the Great Barrier Reef, are included within the political boundaries. The maximum length (north–south) is *c.* 1,300 miles; the maximum breadth (east–west) *c.* 900 miles.

Physiography.—Physiographically the area falls into two main

divisions, the eastern highlands and plateaux and the western plains and lowlands, each of these again containing two main elements. Lowlands occupy the north-west and south-west corner of the State, viz., a broad fringe round the Gulf of Carpentaria (*q.v.*) and irregular semicircles in the south-west and south, portions of the Lake Eyre and Upper Darling basins respectively. Mostly under 500 ft. above sea-level they are relieved here and there by low swellings (Grey, Beal, McGregor "ranges") and rise gradually eastwards as gently undulating country to levels of about 1,000 ft. They consist superficially mainly of younger (Cretaceous–Tertiary) rocks covered in the lower parts by spreads of (flood) alluvium; and the Great Artesian Basin (max. bore-depth 7,000 ft.) underlies practically the whole, and also extends beyond them (*v. inf.*). Between the Gulf and the interior plains a broad swell or saddle (500–1,000 ft.) of older (Palaeozoic) rocks —the Selwyn and Kynuna highlands—connects the eastern highlands with the Barkly Tableland (North Australia) and the great tableland of Western Australia and brings valuable mineral deposits near to the surface. Eastwards the lowlands merge gradually into highlands which occupy the eastern two-thirds of the State. They consist of: (a) A broad belt of uplands and plateaux (upwards of 1,000 ft.) due partly to up-warping of the crust or, where they are higher, usually to great basalt flows. Cape York Peninsula is flanked along the east by a low sandstone-capped ridge which mounts southwards. From its south-eastern corner the main belt begins and runs southwards to about Charleville, Roma, and the south-eastern corner of the State. (*Cf.* the basalt Darling Downs.) Of the few parts which rise above 2,000 ft. (*e.g.*, Clarke Range; Buckland Tableland) the most noteworthy is the Atherton Plateau in the north-east, where an area of *c.* 15,000 sq. miles all over 2,000 ft. rises eastwards to over 4,000 ft. (Mount Bartle Frere, 5,438 ft.) and falls abruptly upon the coast. This belt now forms the main watershed. (b) Along the coast runs a line of granite masses—and in the south-east a series of volcanic (Tertiary) cones (Peak Range and Glasshouse Mountains)—which are the relics of a former range and earlier watershed now largely broken down and submerged. For the remarkable eastern and north-eastern coast of Queensland, with its islands, rock promontories, north-south inlets, sunken plains, and the beauty, amounting sometimes to grandeur, of its mountain-buttressed sounds, is due to a series of vertical movements, in which subsidence has on the whole predominated, and which have cut transversely across the former relief. Thus the Great Barrier Reef has probably been built upon the submerged edges of the former land-mass, while the flat shorelines and low shelving plains of the Gulf of Carpentaria (*q.v.*) are apparently due to elevation. In this surface, not itself naturally rugged except along the east, the coastward-draining streams are excavating considerable basins, eroding out gorges, sharpening residual highland strips into "ranges" and introducing a scenery of wild and broken upper scarplands, roomier and richer lower valleys and, often, silt-choked deltaic plains. The natural drainage of Queensland, which includes many fine streams, is of four main types: the Gulf, the eastern coast, the Darling (Barwon), and the Lake Eyre (Eyre, Cooper's, etc., Creeks, Diamantina, and others). The subject has been referred to under AUSTRALIA: *Drainage,* and, broadly speaking, only the streams of the two first types are perennial and of much economic value. On the other hand, practically the whole of the interior south-west of a line from Normanton (Gulf of Carpentaria) to Warwick (except a semicircle westwards from Cloncurry)—in all 376,000 sq. miles or 56% of the State—is underlain by the water-bearing beds of the Great Artesian basin, of which some 50,000 sq. miles of "intake" beds are exposed along the eastern highlands and are thought to receive seepage and soakage from that source. Water is struck at depths varying from 10 ft.–7,000 ft. and the 1,462 flowing wells (1936) yielded nearly 254,000,000 gal. a day, besides which some 2,100 other wells yielded "sub-artesian" or pumped supplies. In the nine years 1914–23 the yield of the Queensland wells diminished by 4.6% per ann. or, averaging the yield with the number of bores, 6% per ann.

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QUEENSLAND ABORIGINES, THROWING BOOMERANGS

Climate.—With 359,000 sq. miles (·535) of her territory north of the tropic of Capricorn, Queensland has a warm to hot climate —a mean ann. temp. of over 70° F everywhere in the south-east. Temperatures naturally increase northwards and north-westwards, while the range of temperature increases inland. Thus, in the south, the coastal parts have av. ann. temps. of 85°–45° F, the interior 93°–41° F, northern coastal 88°–58°, northern interior 96°–51° F. Frosts, though not universally common, are liable to occur during 5–7 months or more in the south-east and during decreasing periods further west and north-west. The rainfall, which tends to show a summer max. increasingly towards the north and the interior, varies between wide limits both in average and in annual amounts. Most of it comes from the ocean lying to the east and north-east and the seaward parts of the Atherton Plateau are the wettest in Australia, having an average fall of 144–165 in. with not uncommon falls of 200 in. and over, and at various other parts along the east and north-east (Cape York Peninsula; Mackay, and in the extreme south-east) averages of 60–70 in. are found. The whole of Cape York Peninsula and most of the eastern highland fringes and river-basins average 30 in., but inland the amounts rapidly fall off to less than 10 in. in the south-west (Birdsville: 6·4 in.). The fall is also mostly unreliable, very heavy falls alternating with relative scarcity. Thus over the inland and Gulf portions of the State (534,680 sq. miles), while the mean ann. fall is 19·9 in., the actual yearly averages varied (1888–1913: 26 yr.) from 9 in. to 33·3 in., and even the coastal areas (135,820 sq. miles), with a mean ann. fall of 52·3 in. ranged during the same period from 26·85 to 73·4 in. (*Cf.* Harvey Creek: 254·8 in.–80·5 in.) The effect of these conditions upon river flow, vegetation, and economic conditions in general is such that special precautions and provisions are necessary to secure stability. Along the lowlands of the coast the heat is humid and, to those unaccustomed to it, uncomfortable. The interior, though often hot and trying—Boulia has had as many as 76 consecutive days with shade temperatures over 100° F— is not unhealthful. From Dec.–April (mainly) the northeast coast is liable to hurricanes—an average of one or two a year. They come mainly from the east, but sometimes from inland, and may work considerable destruction. (For further climatic details *see* BRISBANE, ROCKHAMPTON, TOWNSVILLE, CARPENTARIA, GULF OF. For vegetation and fauna *see* AUSTRALIA.)

Population, Settlement and Development.—The population of Queensland—947,534 in 1933 plus some 17,700 aboriginals and half-castes—represents a density of 1.41 per sq. mile, after Western Australia and the Northern Territory the lowest in the commonwealth, and males show an excess over females of 5.57%. In the year 1937 her birth rate (19.36 per 1,000) came after that of Tasmania but before New South Wales, her death rate (9.10 per 1,000) is relatively low, and her rate of increase has been consistently high in later years (1931–36: 1.14%, the highest in the commonwealth). Settlement varies in different areas, and about two-fifths of the population is concentrated in the southeast. A large part of the remainder is contained in individual areas spaced out along the east coast up to and including the Atherton plateau, with centres Maryborough, Rockhampton, Townsville, Cairns, etc.; settlement in the south and centre is spreading westwards along the main railway lines; nearly 23% of the state is unoccupied, and a much greater proportion has a negligible population density. Geographically the following areas may be distinguished: (i) the great plains and downs of the central west and northwest interior with their almost exclusively pastoral occupation; (ii) the eastern highlands, with some outliers—notably that of the Cloncurry area in the northwest—with hitherto mainly mining but also pastoral industries; (iii) the southeast districts

with an expanding and intensifying mixed agricultural and dairying regime, as well as mining and some manufactures; (iv) the eastern coastal lowlands with prevailing subtropical to tropical agriculture, some dairying and timber-cutting; (v) the coasts with their harbours, ports, trade and commerce, besides some manufacturing and fishing interests.

(i) The pastoral industry is by no means confined to the *interior plains*. Some of the largest cattle stations are in the coastal belt, and many sheep are kept as an element in the mixed-farming areas of the southeast. Queensland is pre-eminently the pastoral state, itself, in certain respects, a sign of youthful development. Droughts, though often fairly local, cause severe fluctuations: thus in 1926, 31.64% of the total number of sheep was lost, 4,500,000 head (84.4% of the total loss) through drought, the remaining losses being due to disease, dingoes and natural causes. The state of the cattle industry also gives cause for concern. (*See* AUSTRALIA). Yet Queensland had (1939) 379,036 sq.mi. (242,583,160 ac.), slightly more than half of its total area, occupied under pastoral lease, with considerably more territory set aside for grazing. The net value of her pastoral products (1939–40: £17,693,000) comes second among the six states. Artesian water worked a revolution; in 1939–40 6,514 bores served an area of thousands of square miles and supplied 260,000,000 gal. a day.

Sheep, nearly all merinos, have varied in recent years between 21,000,000–16,000,000 (1936: 20,011,749), *c.* 19% of the commonwealth's total, second only to New South Wales. Holdings ("runs" or "stations") are still often large: the largest was (1923) *c.* 5,000 sq.mi., and holdings of under 60,000 ac. are called "grazing farms" or "selections," but the tendency is towards smaller and more-intensively-managed units. In 1926 there were 4,860 owners of holdings having an average flock of 3,470 head apiece.

Cattle, which average 5,500,000–7,000,000 head (1939: 6,198,798, including 1,080,430 dairy cattle), usually represent *c.* 48% of the commonwealth's total, Queensland leading easily in this respect. Cattle (for slaughter) have a much wider range than sheep, thrive in the hot and humid north and east coastal districts, but are more dependent on ample food and water supplies—the drought of 1925–26 caused the loss of *c.* 1,000,000 head—and do not pay so well as sheep. Although average holdings and the size of average herds in Queensland are fairly small, much larger holdings and herds exist in the eastern coastlands and in the northwest (10,000–50,000 head).

Of the total pastoral production (1939–40 £17,693,000), wool always represents a large proportion, usually well over half. In 1939–40 wool production was 195,770,270 lbs., valued at £10,375,824. Livestock slaughtered during the same period included 1,256,953 cattle, 1,232,477 sheep and 1,952,552 pigs. (For chief towns and settlements see *Transport.*)

(ii) The ancient rocks of the *Eastern Highlands,* with the outlying area in the northwest (Cloncurry, etc.) contain the bulk of the state's mineral wealth. The production of silver in Queensland in 1938 reached about 3,500,000 oz.; that of copper 4,459 tons, valued at £203,967. Gold production in 1939 was 147,248 fine oz. The output of tin declined in 1938, when only 1,005 tons, valued at £141,547, were produced. Production in the state formerly went as high as 5,000 tons. Output of coal has remained fairly constant although value has steadily increased. Output in 1939 was 1,317,488 tons, valued at £1,167,844. Queensland produced 41,196 tons of lead in 1938, the second largest amount in Australia and a slight increase over the years immediately preceding. Coal and lead make the bulk of the total production of minerals and quarry products in the state. Tin is worked in the district behind Cooktown (north), at Stanthorpe (southeast), and at Kangaroo Hills near Townsville, but the mineral fields of the Atherton plateau behind Cairns (*q.v.*), notably those of Herberton (120 mi.), are the most productive. Coal is scattered over the eastern highland belt. The seams mainly worked in 1939 were those of the districts of Ipswich (627,965 tons); Bowen (246,713 tons); Clermont (111,945 tons); Maryborough (101,967 tons); Darling downs (88,819 tons); and Rockhampton (88,053 tons); with smaller amounts from the Chillagoe (Mount Mulligan), Mount Morgan, Mackay and other districts. Queensland coals have a great range of variety and utility—anthracite (Dawson-Baralaba field) to bituminous (Ipswich), and the reserves (actual and probable) are 2,305,000,000 tons. The state owns and works coal mines on the Bowen, Baralaba, Styx river and Mount Mulligan fields, besides mineral-testing batteries and drilling plants in various mining areas. An opal field of value exists at Anakie (Rockhampton–Longreach railway) east of Emerald and other gems (sapphires, etc.) occur.

(iii) The *Southeastern* portion of Queensland—*i.e.,* the area contained approximately south and east respectively of the airlines Gympie to Roma and Roma to Warwick—being relatively cool, in parts elevated, and easily accessible from the coast, is on the whole the most progressive and rapidly developing portion of the state. Here is the Brisbane basin, a fertile lowland, drained by a network of streams (rivers: Brisbane, navigable for light craft to Ipswich, Logan, etc.), open to the sea but enclosed elsewhere by highlands (2,000–3,000 ft.), with ample rainfall (30–70 in. and upwards), coal reserves, capital city and leading port, and excellent commercial position. Along the coast are further fertile and well-watered lowlands, possessing in addition attractive scenery (Glasshouse mountains) and seaside resorts (Southport; Coolangatta); while further inland (Dalby to Roma), are good wheat and fruit-growing soils and climate which merge into the more purely pastoral western interior. Here, therefore, is the most highly and rapidly growing population, with the bulk of the state's dairying, arable agriculture (including all the wheat-growing), and manufacturing industries, in addition to a fair proportion of the production of minerals and temperate and subtropical climate fruits. Purely pastoral industries, along with large holdings, are yielding to closer settlement and to mixed (including wheat and sheep) farming. The total area which is cultivated in Queensland is relatively small: (1939) 1,726,209—of which *c.* 550,000 ac. was cultivated grassland—or only 0.4% of the area of the state. Partly this is due to the fact that development is recent but partly to uncertain rainfall so that the figures of annual production show remarkable variations. Queensland ranked first in number of dairy cattle in 1939–40 with a mean for the year of 1,010,884, and second only to Victoria in milk production with 325,342,000 gallons. The Brisbane basin (Beaudesert, Ipswich, etc. areas), the Wide Bay (Gympie) district, and the Darling downs (Toowoomba, Warwick and other districts) lead in production and associated are the manufacture of butter (142,846,421 lbs. in 1939–40), cheese (13,848,936 lbs. in 1939–40) and preserved milk; bacon- and ham-curing (20,040,740 lbs. in 1939–40); and poultry and beekeeping. Of cultivated crops, maize is most generally suited to the climate and is widely grown. In 1939–40, Queensland was Australia's leading producer, with the 176,844 ac. under cultivation yielding 3,345,000 bu., 18.9 bu. per ac. Dairying and maize cultivation are extending all up the east coast, but wheat is confined to the 10–15 in. winter (April–Oct.) rainfall areas of the Darling downs and westwards as far as Roma. The amount and yield vary widely according to season. In 1935–36, for example, there were only 240,000 ac. under cultivation with a yield of 2,690,000 bu. In 1938–39 442,000 ac. yielded 8,584,000 bu., but by 1940–41 acreage was reduced to 322,000 yielding 5,687,000 bu. The ten-year average for the period ending 1939–40 was 293,000 ac. with a yield of 4,374,000 bu. Some wheat may in future be grown in the summer-rain areas further north (*e.g.,* Emerald district), but other cultures will probably always limit production. Fodder crops (hay, lucerne) and potatoes are of some importance, while fruits—bananas, pineapples, but mainly citrus, grapes, etc. (*e.g.,* Roma)—and "northern" varieties in cooler areas (*e.g.,* Stanthorpe) are widely grown. The value of Queensland's total agricultural production varied in the decade 1930–40 from a low of £8,944,145 in 1932–33 to a high of £13,696,000 in 1939–40. Dairy production (net value) was valued at £9,799,000 in 1939–40.

The eastern coastal highlands and scarps carry considerable areas of well-grown forests; in the north more of the tropical rain-forest (brush), further south more of the temperate rain-

forest. Soft and hard woods—the latter mainly eucalyptus—occur, and in the south are large areas of pure eucalypt forests (*e.g.*, Gympie-Darling downs; Macpherson range). Timber-felling and sawmilling are carried on right up the coast but of the 438 sawmills in the state in 1939–40 most were in the southern districts. Queensland produced (1939–40) 210,375,000 sup.ft. of sawn timber, more than one-fourth the total for Australia. Total value of Queensland's forest products in 1939–40 was £2,531,000. Over half was pine and one-third hardwoods, the remainder including "cedar," "oak," silkwood, silky oak, etc. The total Queensland output of dressed timber (1936–37) was valued at £2,342,000. The State Forest service held in working trust in 1940 6,347,373 ac. timber and fuel reserves and dedicated forests, besides additional acreage reserved as National parks.

(iv) *The Coastal Lowlands,* though they consist of a series of individual and more or less independently developed units—the main coast railway line now complete from Brisbane to Cairns will assist in drawing them together—have many common features in virtue of their physical composition (rough highland interiors, river basins, rich alluvial lowlands, coast-lines, estuarine or rock-sheltered deep-water harbours, hot, humid climate). Thus their present by no means fully developed economy is capable of summary survey, and for further details reference may be made to the towns mentioned below. In many respects the Brisbane area also can not be distinguished from its northern analogues. Cattle, and to an increasing extent dairying even as far north as Cooktown, are common to nearly all—the former naturally more and more restricted to wilder and rougher ground, the latter to richer workable ground within reach of factories and markets. Mining has already been dealt with, the most important area at present being that of the Atherton plateau, based upon Cairns (*q.v.*). Timber, in some cases a by-product of settlement, is sawn in 61 mills—23,500,000 cu.ft., noteworthy being the 12,500,000 cu.ft. of softwoods from the northern districts, in particular the Atherton plateau. Along the east coast very poor areas alternate with others having extremely rich soils. The agricultural products at present commonly associated with the latter areas are sugar, tropical fruits, and, more recently, cotton, though the cultivation of groundnuts or peanuts (1937: *c.* 8,000 tons) and tobacco is developing and others again (*e.g.*, coffee) are physically, if not at present economically, possible. Large possibilities, for dairying no less than for agriculture, lie by way of irrigation for which climate, soils, river regimes, and commercial situations are peculiarly favourable. In 1939, *c.* 55,000 ac. were under irrigation in Queensland, the Dawson river being by far the most important area under development (*see* Rockhampton); further the Burdekin river (Inkermann area 5,000 ac., being extended to 10,000 ac.), besides numerous smaller undertakings, which did not, however, prove prosperous.

Sugar is grown in rich bottom lands with a high rainfall (40–60 in.). In 1939–40, 353,996 ac. were under cultivation for sugar (*i.e.*, other than fodder cane), of which 262,181 ac. were cut and yielded 6,038,821 tons of cane, which in turn yielded 891,738 tons of sugar. In sugar production Queensland outdistances New South Wales (*q.v.*), the only other Australian producer, but her yields per acre are lower than those of New South Wales. Of tropical fruits, the chief are bananas (1939–40, 8,534 ac.; crop valued at £373,750) and pineapples (7,350 ac.; crop valued at £467,369), but mangoes and others have also some importance. "Mediterranean" fruits (4,370 ac.; crop valued at £145,517), peaches, apricots, etc., are extensively grown but perhaps mainly in the southeast of the state. The banana industry is not free from serious insect pests the nature of which is being investigated. The sugar industry is conducted under fiscal and labour conditions which lend it a somewhat artificial appearance. (*See* Australia.) Cotton-production, on the other hand, though physically possible over considerable areas, is less amenable to economic "hot-house" methods and the future of the industry, for which great hopes were entertained, is dubious. In 1936 there were 62,200 ac. bearing 19,198,000 lb. of unginned cotton valued at £330,000; in 1940, 41,262 ac. bearing 12,108,491 lbs.

(v) To distinguish the coast of Queensland as a separate geographical entity is not so artificial when it is remembered that much of the manufacturing industry, as well as of trade and commerce is concentrated in the ports; that the last-named is conducted by means of shipping or over railway systems based upon the ports, and that these play an altogether major part in the general development of the state. Fisheries (*see* Australia and Barrier Reef) are mainly for pearl, turtle, trochus shell, and the total ann. value of all products (1936–37) was £370,000. There are two state fish-supply establishments (turnover 1926–27: £45,000). Manufactures are mainly those concerned immediately with the working up of raw materials—the making of butter, cheese, preserved milk, jams, etc.; bacon-curing, meat-freezing and preserving; tanning; sugar-crushing; saw-milling; smelting, etc. They are naturally located where circumstances demand, *e.g.*, smelters at Cairns; sugar-crushing mills: various cane-centres, *e.g.*, Mackay; meat-works mainly near ports. Ipswich and Toowoomba, and other towns possessing coal, have developed important railway engineering or repair works, while most towns, according to their development, have a variety of minor industries. Brisbane (*q.v.*), however, is by far the greatest centre: of the total number of factories in the state (1936: 2,417) with an output (crude value added by process) of £51,857,000, Brisbane has 1,052 factories with output £18,400,000.

The total value of Queensland's production—primary and manufacturing—is estimated (1935–36) at £59,827,000 or £49.3 per head of population; the (corrected) index number during the decade 1916–26 having varied between 1.046 (1924–25) and 0.939 (1925–26) of the production in 1911. (*Cf.* commonwealth as whole: 1925–26: 0.950.)

Trade was valued (1936–37) at £66,907,000 (*cf.* 1925–26: £40,158,000—variations being due mainly to bad seasons), of which exports represented £37,719,000 (*c.* £37 per caput) and imports £29,188,000 (*c.* £29), these figures representing "overseas" trade only, though interstate trade amounts perhaps to about as much again. The chief items of export were wool (£10,170,000); sugar (£2,873,000); dairy products (£3,200,000); meat, excluding bacon (£2,900,000); hides, leather, tallow, rabbitskins (£860,000)—total pastoral: £13,720,000; total agricultural and dairy: £6,571,000; mineral: £2,115,200. The chief ports, in order of importance, are (1937): Brisbane (total overseas trade: £22,600,000); Townsville: £2,500,000; Cairns: £1,150,000; Rockhampton: £1,390,000; Gladstone: £1,380,000; Mackay: £879,000.

Of interest are the state (Queensland government) trading and other enterprises which besides mines, batteries, drilling plants included (1927) 5 sawmills (net capital value: £82,000); 14 cattle stations (total stock: 212,000); 112 retail trading establishments and agencies with a turnover of £1,100,000, in addition to the state services (including railways) usual in Australian states. The state public revenue was (1937) £16 6*s.* 0*d.* per caput and expenditure from revenue £17 1*s.* 9*d.*

Transport in Queensland ranges from the camel train and bullock-wagon of the pioneer to railway and motor traction and air transport. Motorcars are, as elsewhere on the great plains of Australia, working a revolution, but a still greater is being worked by the aeroplane. Queensland "squatters" have shown great enterprise in the use of aeroplanes, not only for personal use, but also for the conveyance of fodder to drought-stricken herds. Official air-services covered (1936–37) 8,238,000 mi. with the loss of 19 persons killed and 14 injured. The most important line is that linking the terminals of the three main railway systems—Charleville, Longreach, Cloncurry, with Mount Isa, Camooweal and, by recent arrangement, continued to north Australia (825 mi. in all). In the "bush," roads are mainly dirt tracks, liable to floods and "washaways" in wet seasons. There were (1937) 12,993 mi. of gazetted roads in the state and 111,765 motor vehicles. Of railways, besides 136 mi. (1936–37) of private (light) lines serving cane-fields, mines, etc., there were (1937), 6,567 mi. (3′ 6″ gauge) government lines. The main systems are based upon the ports, viz., Brisbane: with a fairly well-developed "branch-work" of lines serving the Brisbane basin, the Darling downs, and longer trunk lines serving the pastoral interior, southwest to centres such as Goondiwindi and Dirranbandi (416 mi.), west to

Roma, Charleville (483 mi.), Quilpie (608 mi.) and Cunnamulla (*c.* 600 mi.); Rockhampton (*q.v.*), in addition to a local "branchwork," has a main trunk system serving the pastoral centres Emerald (branch lines to Blair Athol 240 mi., Springsure 206 mi.), Barcaldine (361 mi.), Blackall and Yaraka (476 mi.) and Longreach (428 mi.), with extension under construction to Winton and Elderslie; Townsville, a similar trunkline to Charters Towers (83), Hughenden (236), Winton (368), Cloncurry (481), itself a centre for a branching system serving the mining area (Dajarra, 582 mi.); Cairns likewise serves as a base for the Atherton plateau and Forsayth lines into the interior. The main coast line links Brisbane with all the coast towns as far as Cairns, and Brisbane itself is linked with Sydney via Warwick—Stanthorpe—and Tenterfield (New South Wales). The new "direct" route (standard gauge: 4′ 8½″) was finished in 1930 from Warwick to Kyogle (New South Wales). In addition various ports (Bundaberg, Cooktown, Maryborough, Normanton, etc.) have smaller sections of local lines. It is proposed to join the western termini of the great inland lines by a transverse south-east–northwest line which will probably be continued via Camooweal and the Barkly tableland to Daly Waters (Northern Australia, *q.v.*) thus linking this territory as well as the northern and northwestern portions of Queensland with Brisbane and Sydney (the latter via Bourke, New South Wales). The capital cost of Queensland's railway lines (including lines not yet open) was (until 1940) £65,597,851 and the revenue from working for the year £1,722,000.

Queensland has a well-developed post and telegraph system and in addition submarine cables from Southport to Vancouver Island via Norfolk Island, Suva, Fanning Island, thence overland to Montreal, etc.; also Southport to Sydney; and, in addition to services of regular overseas steamship lines, coastal shipping services plying up the east coast to Thursday Island, the Gulf of Carpentaria and Darwin (north Australia). (O. H. T. R.; X.)

HISTORY

Explorers.—The Portuguese may have known the northern shore nearly a century before Torres, in 1606, sailed through the strait since called after him, or before the Dutch landed in the Gulf of Carpentaria. Captain Cook passed along the eastern coast in 1770, taking possession of the country as New South Wales. Flinders visited Moreton bay in 1802. Oxley was on the Brisbane in 1823, and Allan Cunningham on Darling downs in 1827. Sir T. L. Mitchell in 1846–47 explored the Maranoa, Warrego and Barcoo districts. Leichhardt in 1845–47 traversed the coast country, going round the gulf to Port Essington, but was lost in his third great journey. Kennedy followed down the Barcoo, but was killed by the blacks while exploring York peninsula. Gregory, between 1855 and 1858, examined the Gilbert river and made his way right to Brisbane. Burke and Wills crossed western Queensland in 1860. Landsborough, Walker, M'Kinlay, Hann, Jack, Hodgkinson and Favenc continued the researches, and squatters and miners opened new regions.

Early History.—Before its separation in 1859 the country was known as the Moreton bay district of New South Wales. A desire to form fresh penal depots led to the discovery of Brisbane river in Dec. 1823, and to the proclamation of a penal settlement there in Aug. 1826. The convict population was gradually withdrawn again to Sydney, and in 1842 the place was declared open to free persons only. The first land sale in Brisbane was held on Aug. 9, 1843. An attempt was made in 1846, under the colonial ministry of Gladstone, to establish at Gladstone on Port Curtis the colony of North Australia for ticket-of-leave men from Britain and Van Diemen's Land. Earl Grey, when secretary for the colonies, after strong colonial representations, arrested this policy, and broke up the convict settlement. In 1841 there were 176 males and 24 females; in 1844, 540 in all; in 1846, 1,867. The first stock belonged wholly to the colonial government, but flocks and herds owned by settlers came on the Darling downs in 1841. In 1844 there were 17 squatting stations round Moreton bay and 26 in Darling downs, having 13,295 cattle and 184,651 sheep. In 1849 there were 2,812 horses, 72,096 cattle, and 1,077,983 sheep.

Some settlers who sought a separation from New South Wales offered to accept British convicts if the ministry granted independence. In answer to their memorial a shipload of ticket-of-leave men was sent in 1850. In spite of the objection of Sydney, the Moreton bay district was separated from New South Wales by an Order in Council of May 13, 1859, and proclaimed the colony of Queensland. The population was then about 20,000, and the revenue £6,475. The constitution, which was based upon the New South Wales Act of 1853, provided for 16 electoral districts, with a representation of 26 members. A legislative council was also formed, to which the governor of New South Wales, Sir William Denison, appointed five members, holding office for four years, and Sir George Ferguson Bowen, the first governor of the new colony, eight life members. Robert (afterwards Sir Robert) George Wyndham Herbert was the first premier, and held office until 1866. The white population at the end of 1859 was 25,788, and exports were valued at £500,000. In the next six years the population was quadrupled and trade trebled. The first parliament opened on May 29, 1860.

Gold mining is the foundation upon which much of the progress of the colony has been built. The Gympie field was discovered in 1867, Charters Towers and the Palmer diggings in 1872, and the celebrated Mount Morgan mine in 1881. In 1900, dredging the northern rivers for gold became an established industry. In 1941 the value of gold produced in Queensland was £1,154,000, third in order of importance in Australia.

Political History.—A resolution in favour of payment of members was carried in 1871. In the following year, electoral representation was increased to 42 members, and the first agent-general in London, Richard Daintree, was appointed. Railway building began in 1864, and in 1872 the Railways Act Amendment act authorized the construction of railways by private enterprise, land being offered as compensation for outlay. This act was passed during the administration of A. H. Palmer, the only premier of importance during the period 1866–79.

On Jan. 21, 1879, Thomas (afterwards Sir Thomas) McIlwraith first became premier. The opposition was led by Samuel (afterwards Sir Samuel) Griffith, and the political history of Queensland from that date to 1893 is, in effect, the political biography of these two remarkable men. In 1881 R. L. Jack, the government geologist, introduced artesian well-boring, which contributed largely to the subsequent prosperity of Queensland. In 1883 in view of Germany's activities in the Papuan gulf the police magistrate at Thursday island was instructed by Queensland to proceed to Port Moresby and take possession of the unappropriated portion of the island in the name of the crown. The step needed no justification when it is remembered that Papua lies nearer to Queensland than Tasmania to Victoria. This act was afterwards—to the indignation of Australia—repudiated by Lord Derby; and, eventually, under the Berlin Treaty of 1886, England and Germany entered into joint possession of that part of New Guinea lying east of 141°E. In 1887 the number of seats in the assembly was increased to 72 and the department of agriculture was established.

The first sugar crop was grown by the Hon. Louis Hope at Cleveland about 1862. From that date, Kanaka labour on the sugar plantations was a burning question in Queensland politics. After the defeat of Sir Thomas McIlwraith in 1883, on the issues of coloured labour and land-grant railways, Griffith formed his first administration. The period which followed was marked by labour troubles and financial difficulties. In Dec. 1884, a royal commission reported that many islanders had been deported by "force and fraud." In view of this report, the Griffith government passed an act prohibiting the importation of Kanakas after 1890. The impending stoppage of Kanaka labour and the low price of sugar almost ruined the planters. In 1890 a financial crisis occurred. A coalition ministry with Griffith as premier and McIlwraith as treasurer was formed, and in 1892 Sir Samuel Griffith announced his conversion to the policy of continuing Kanaka labour on the sugar plantations and also of building land-grant railways. From this year there was no further state legislation on the subject of Kanaka labour; but, in 1904, the federal government prohibited the importation of Kanakas, and by 1906 had

deported most of those in Australia. Since then the industry has made progress under a system of bounties and excise tariffs. Sir Samuel Griffith, who had been chief justice in Queensland since 1893, afterwards became chief justice of the federal high court, and played an important part in bringing Queensland within the federation. (*See* AUSTRALIA.) The history of Queensland continued to be a story of industrial disputes and financial distresses. Ultimately Queensland became a stronghold of the Labour party. The legislative council and capital punishment were both abolished in 1922. Two important acts were passed in the same year, the Primary Producers Organization act, which aimed at a united national organization of agriculture, and the Primary Products Pools act, which created boards to control all markets.

Queensland governments have passed various land acts, now in favour of the pastoralist, now in favour of the farmer, but on the whole in favour of the latter. Experiments in such legislation were made easy by the fact that the state held unalienated (1949) more than 93% of the total area.

According to the census of 1947, 59.74% of Queenslanders were classified as rural. Only Tasmania and Northern Territory had a larger proportion of their population on the land. The Queensland policy, unique in Australia, of developing a railway system from several maritime centres instead of from one capital city, may have helped to bring about this satisfactory result. But it must not be forgotten that Queensland enjoys a uniform rainfall near the coast from Cooktown southward, and that it possesses 234,000 sq.mi. of territory having a rainfall of more than 20 in.

(H. D. N.; X.)

Cotton commenced its career in Queensland about 1922. Mining production was mostly concerned with coal until about 1929, but by 1933 the silver-lead from Mount Isa had added £2,000,000 sterling to the wealth of the state. With the better price for gold, mining for the latter metal revived materially. Tariffs, organization and state assistance increased the production of sugar, cotton and maize, for which Queensland has the best climate among the states. By an extension of the chilled beef process the trade to the British market was greatly increased.

Sir John Dudley Lavarack became governor in 1946. At the elections of 1950, the Labour party won 42 of 75 seats; the premier was Edward M. Hanlon.

QUEENSTOWN, Australia: *see* TASMANIA.

QUEENSTOWN, Eire: *see* COBH.

QUEENSTOWN, a town in the province of Cape of Good Hope, Union of South Africa, in the upper valley of the Great Kei river, 154 mi. N.W. of East London by rail, 31° 53′ S., 26° 52′ E.; altitude 3,544 ft. Pop. (1946) 23,600, including 8,194 Europeans, 13,157 natives, 2,159 "coloured" and 90 Asiatics. The town is the centre of a good wheat- and wool-producing area.

QUELIMANE, QUILIMANE or KILMANE (officially MARTINHO DE QUELIMANE), a town of Portuguese East Africa in 18° 1′ S., 36° 59′ E. is 12 mi. inland from the mouth of the Rio dos Bons Sinais or Quelimane river. In 1936 it had a pop. of 9,702 of which about 500 were Europeans. It was formerly the chief port of the Zambesi valley, but lost its importance when Chinde (*q.v.*) was established. The harbour is near one of the mouths of the Zambesi river and is kept clear by constant dredging. The entrance to the harbour is obstructed by a bar which is covered by 9 ft. of water at low tide, by 26 ft. at high water springs. At Tangalane, 8 mi. from the town, is the outer harbour which can accommodate vessels up to 5,000 tons. The Mutu canal, which connects Quelimane with the Zambesi, is now sanded up. The town is linked with Maquival, a European farming centre of the Zambesia company, by a trolley line (18 mi.) and with Mocuba by rail (80 mi.). This railway is projected to connect with the Nyasaland railway (*see* NYASALAND PROTECTORATE). Quelimane serves as a port to the surrounding area which produces groundnuts, sugar, sisal, cotton and copra.

Quelimane was first settled by Arabs, probably in the 11th century. Vasco da Gama on his way to India entered the Quelimane river in 1498, but the present town was not founded by the Portuguese until 1544. In 1577 the Dominican friars established themselves and made it the centre for their missionary activities in the Zambesi region, after Francisco Baretto had penetrated from here to the Monomotapa state in 1569. The town was the starting point for David Livingstone's second expedition in 1858 which led to the discovery of Lake Nyasa. In 1937, following the administrative reorganization of Portuguese East Africa, Quelimane, whose commerce had declined during the previous decades, was made the capital of the province of Zambesia. As an administrative centre the town's telephonic and telegraphic communications with the interior of the province were developed, and new modernistic public buildings, for administrative and educational purposes, were erected after 1938.

The climate is tropical, rather unhealthful (danger of malaria) during the summer, but attractive during the winter. The annual rainfall (Dec. to March) averages about 57 in. (H. A. WF.)

QUELPART (CHAI-JU, in Japanese *Saishu*), an island to the south of Korea, once used as a Korean penal settlement. It measures 40 mi. from east to west and 17 mi. from north to south. It rises gradually from the seaboard, is heavily wooded and is cleared for cultivation to a height of 2,000 ft. There are several crateriform hills, and Hali San (Mount Auckland) has an altitude of 6,558 ft. The island is entirely volcanic, and the soil is finely disintegrated lava. The estimated population is 115,000, Korean by race, language and costume. There are about 90 villages. The valleys and slopes are carefully cultivated in fields divided by stone walls. Apart from agriculture, the industries consist in the manufacture of fine bamboo hats and mats, and wooden combs for export and local use. For fishing the islanders use double-decked raft boats, similar to those of southern Formosa. A valuable product is a species of clam, the shell of which furnishes a specially iridescent mother-of-pearl, which the natives barter with the Japanese for inlaying lacquer. Long tailed ponies are bred for the horsehair used in weaving Korean hats. Chu-sung, the capital and seat of government, a few miles from Port Pelto, has a black lava wall 25 ft. high, with three gates and towers; an imposing audience hall in Chinese style; and a great bell tower, with a fine bronze bell, sounded to drive off "evil dragons." Its population is estimated at 17,000. There are no good harbours, and the only anchorage for large vessels is Tai-chung, or Yung-su, at the east end, with 9 to 13 fathoms of water. Pelto has ancient breakwaters for the protection of small boats, erected probably by the Mongol conqueror, Kublai Khan, who in 1273 built on Quelpart 100 ships for the invasion of Japan.

QUENTAL, ANTHERO DE (1842–1891), Portuguese poet, was born in the Azores, and studied at the University of Coimbra. After the publication of one volume of verse, he joined the revolt of the young men which dethroned Castilho, the chief living poet of the elder generation, from his place as dictator over modern Portuguese literature. He adopted socialist opinions, worked as a compositor in Paris, though he had independent means, visited the United States, and then returned to Lisbon, where he worked actively for socialism. He found his way through a series of disappointments to the mild pessimism, a kind of western Buddhism, which animates his later productions. His melancholy was increased by a spinal disease which, after several years of retirement, eventually drove him to suicide in his native island. Quental seldom attempted any other form of composition than the sonnet, but few poets who have chiefly devoted themselves to this form have produced so large a proportion of really exquisite work. The comparatively few pieces in which he either forgets his doubts and inward conflicts, or succeeds in giving them an objective form, are among the most beautiful in any literature.

His friend, Oliveira Martins, edited the sonnets (Oporto, 1886), supplying an introductory essay; and an interesting collection of studies on the poet by the leading Portuguese writers appeared in a volume entitled *Anthero de Quental. In Memoriam* (Oporto, 1896). The sonnets have been turned into most European languages; into English by Edgar Prestage (*Anthero de Quental, Sixty-four Sonnets*, 1894), together with a striking autobiographical letter addressed by Quental to his German translator, Dr. Storck.

QUERCITRON BARK is the inner bark of *Quercus velutina*, a native of the middle and southern states of America. The exterior bark is removed from the tree by shaving, and the inner portion, which contains the colouring matter, is detached and

ground. The colouring matter of quercitron bark is quercitrin, $C_{21}H_{22}O_{12},H_2O$, a glycoside which by hydrolysis with acid yields quercetin, $C_{15}H_{10}O_7$, and the sugar rhamnose, $C_6H_{12}O_5$. When quercitron bark is exhausted with hot water under pressure, the extract deposits a crude quercitrin, which is known commercially as "yellow flavine." A second variety known as "red flavine," prepared by digesting an extract of the bark at the boil with dilute acid, is in reality a crude quercetin. These products dye wool mordanted with aluminum and tin bright yellow and orange shades and were, at one time, used with cochineal for obtaining specially vivid scarlets. (A. G. P.)

QUERCY, a former county of France, which derived its name from the Gallic tribe of the Cadurci and corresponds to most of the present departments of Lot and Tarn-et-Garonne. In the middle ages it was divided into Upper, or Black, Quercy and Lower, or White, Quercy, the capital of the former being Cahors and that of the latter Montauban. Its two other chief towns were Figeac and Moissac. Early in the 6th century Quercy passed under the authority of the Franks and in the 9th century it was part of the Frankish kingdom of Aquitaine. At the end of the 10th century its rulers were the counts of Toulouse, and it fell to the French crown with the inheritance of Alphonse de Poitiers (1271). In the 13th and 14th centuries it was in dispute between the kings of England and France. In 1259 some rights over Lower Quercy were ceded to England; in 1360 the treaty of Brétigny assigned the whole county to Edward III, but in 1440 the English were finally expelled. In the 16th century Quercy was a stronghold of the Protestants and the scene of a savage warfare. The civil wars of the reign of Louis XIII centred around Montauban.

Bibliography.—E. Sol, *La Vie en Quercy,* 2 vol. (Paris, 1941–44) and *La Révolution en Quercy,* 4 vol. (Paris, 1926); R. Latouche, *La Vie en Bas-Quercy du XIV^e^ au XVIII^e^ siècle* (Toulouse, 1923).

QUERÉTARO, a central plateau state of Mexico. Pop. (1950) 282,608. Area, 4,431 sq.mi., with the capital at Querétaro (*q.v.*). On the semiarid mesa, and traversed at the north by a spur of the Sierra Madre known as the Sierra Gorda, Querétaro is about evenly divided between mountainous, mineralized areas and the rolling plains and fertile valleys of the south which form part of Mexico's granary or *Bajío*. The trunk highway from Nogales to Mexico City traverses the state in a southeasterly direction, as do lines of the National Railways of Mexico. The climate is generally dry and temperate, except in the northwest portion, which is hot. Rainfall is moderate and frosts are few and light.

With soil 10 to 15 ft. deep in the southern lowlands, the state produces a large variety of crops: fruits, grain, medicinal plants and a notable sweet potato or *camote*. Though deposits of gold, copper, lead, tin and other metals occur, the chief products are opals and mercury, especially in a compound known as onofrite, from San Onofre where it is found. Mineral resources are not so well developed as the agricultural ones. (Hd. C.)

QUERÉTARO, a city of Mexico, capital of the state of Querétaro, 167 miles by railway N.W. of the national capital. Pop. (1940) 33,629, including a large Indian element. Querétaro is served by the Mexican National railway. The city stands on a plain at the foot of the Cerro de las Campanas, 6,168 ft. above sea level. Among the important buildings are the cathedral (said to have been built originally about 1535, and subsequently restored at various times), the Iturbide theatre (in which occurred the trial of Maximilian), the government offices, the federal palace and the churches of Santa Rosa, Santa Clara and San Augustín. The federal palace and the church of Santa Rosa are examples of the work of the celebrated Mexican architect, Francisco Eduardo de Tresguerras (1765–1833), who restored the church of Santa Clara also. The water supply is brought over a fine aqueduct 5 mi. long, dating from the 18th century. Among manufactures are cottons, woollens, pottery and ironwares. The city has one of the oldest and largest cotton factories in Mexico.

Querétaro occupies the site of an Otomie Indian town dating from about 1400. It was captured by the Spaniards in 1531 and was raised to the rank of a city in 1655. It was the scene of a revolutionary outbreak against Spain in 1810. In 1848 a Mexican congress met here to ratify the treaty of peace with the United States, and in 1867 Querétaro was the scene of Maximilian's last stand against the Republicans (under Escobedo) which resulted in his capture and execution on the Cerro de las Campanas north of the city. Querétaro was the seat of the convention which adopted the constitution of 1917.

QUESNAY, FRANÇOIS (1694–1774), French economist, was born at Méré, near Paris, on June 4, 1694, the son of an advocate and small landed proprietor. He studied surgery at Paris, where he qualified as a surgeon, and in 1737 he was appointed perpetual secretary of the academy of surgery founded by François la Peyronie. In 1744 he graduated as a doctor of medicine, became physician in ordinary to the king, and afterwards his first consulting physician.

Quesnay is mainly remembered, however, for his work as an economist. About the year 1750 he became acquainted with Jean C. M. V. de Gournay (1712–1759), and round these two men was formed the philosophic sect of the *Économistes* or the *Physiocrates*. The most remarkable men in this group were the elder Mirabeau (author of *L'Ami des hommes,* 1756–60, and *Philosophie rurale,* 1763), Nicolas Baudeau (*Introduction à la philosophie économique,* 1771), G. F. Le Trosne (*De l'ordre social,* 1777), André Morellet (best known by his controversy with Galiani on the freedom of the corn trade), Mercier Larivière and Dupont de Nemours. Adam Smith, during his stay on the continent in 1764–66, made the acquaintance of Quesnay and some of his followers, to whom he refers in his *Wealth of Nations*. Quesnay died on Dec. 16, 1774, having lived long enough to see his great pupil, Turgot, in office as minister of finance.

The *Tableau économique,* Quesnay's principal work, may be considered the principal manifesto of the school. It was highly esteemed by the followers of Quesnay, and is named by the elder Mirabeau, in a passage quoted by Adam Smith, as one of the three great inventions which have contributed most to the stability of political societies, the other two being those of writing and of money. Its object was to exhibit by means of certain formulae the way in which the products of agriculture, the only source of wealth, would, in a state of perfect liberty, be distributed among the several classes of the community (namely, the productive classes of the proprietors and cultivators of land, and the unproductive class of manufacturers and merchants), and to represent by other formulae the modes of distribution which take place under systems of governmental restraint and regulation, with the evil results arising from such violations of the natural order. It follows from Quesnay's theoretic views that the one thing deserving the solicitude of the practical economist and the statesman is the increase of the net product; and he infers also what Smith afterwards affirmed, on not quite the same ground, that the interest of the landowner is "strictly and indissolubly connected with the general interest of the society." A small *édition de luxe* of this work, with other pieces, was printed in 1758 in the palace of Versailles under the king's immediate supervision.

Quesnay's system is expounded in two articles on "Fermiers," and "Grains" in the *Encyclopédie* of Diderot and D'Alembert (1756, 1757); a discourse in the *Physiocratie* of Dupont de Nemours (1768); *Maximes Generales de gouvernement économique d'un royaume agricole* (1758); *Tableau économique* (1758); and *Dialogue sur le Commerce et des travaux des artisans.* Collections of his works are published by Guillaumin (Paris), and Oncken (Frankfort, 1888). A facsimile reprint of the *Tableau économique,* from the original ms., was published by the British Economic Association (London, 1895). *See* also F. J. Marmontel, *Mémoires; Mémoires de Mme. du Hausset;* H. Higgs, *The Physiocrats* (London, 1897).

QUESNEL, PASQUIER (1634–1719), French Jansenist theologian, was born in Paris on July 14, 1634, and joined the French Oratory in 1657. His Jansenist sympathies led to his banishment from Paris in 1681. He took refuge with the friendly Cardinal Coislin, bishop of Orléans; four years later, however, foreseeing that a fresh storm of persecution was about to burst, he fled to Brussels, and took up his abode with Antoine Arnauld (*q.v.*). There he remained till 1703, when he was arrested by order of the archbishop of Malines. After three months' imprisonment he made a highly dramatic escape, and settled at Amsterdam, where he spent the remainder of his life. After Arnauld's death in 1694 Quesnel was generally regarded as the

leader of the Jansenist party; and his *Réflexions morales sur le Nouveau Testament* played almost as large a part in its literature as Jansens's *Augustinus* itself. The bull *Unigenitus* (1713) condemned 101 sentences from the *Réflexions morales*. Quesnel died at Amsterdam on Dec. 2, 1719.

See also Mme. Albert Le Roy, *Un Janseniste en exil* (Paris, 1900); Maulvault, *Répertoire de Port Royal* (Paris, 1902).

QUETELET, LAMBERT ADOLPHE JACQUES (1796–1874), Belgian astronomer, meteorologist and statistician, was born at Ghent on Feb. 22, 1796, and educated at the lyceum of that town. He lectured in Brussels from 1819 onward, and in 1828 he was appointed director of the new royal observatory which it had been decided to found, chiefly at his instigation. From 1834 he was perpetual secretary of the Brussels academy, and published a vast number of articles in its *Bulletin*, as also in his journal, *Correspondance mathématique et physique* (11 vols., 1825–39). He died at Brussels on Feb. 17, 1874.

Quetelet published in 1835 his principal work, *Sur l'homme et le développement de ses facultés, ou essai de physique sociale* (2nd ed., 1869), containing a résumé of his statistical researches on the development of the physical and intellectual qualities of man, and on the "average man" both physically and intellectually considered. His ideas are further developed in his *L'Anthropométrie, ou mesure des différentes facultés de l'homme* (1871).

A detailed *Essai sur la vie et les travaux de L. A. J. Quetelet*, by his pupil and assistant E. Mailly, was published at Brussels in 1875.

QUETTA, the capital of Baluchistan, Pakistan, which also gives its name to a district. It rose to prominence in 1876, when Sir Robert Sandeman founded a residency there. The name is a variation of the word *kwăt-kot*, signifying a fortress, and the place is still locally known as Shal Kot. Quetta is the southernmost point in the line of frontier posts and system of strategic railways on the northwest frontier of India, 536 mi. by rail N. of Karachi. It forms the headquarters of a division and of the Western Command. The railway was built in 1879, with a view to its continuance to Kandahar; but its present terminus is New Chaman on the Afghan border. A branch line to Nushki was completed in 1905 and carried on to Duaz-ab during the World War. The cantonment and civil station of Quetta stand in the open plain about 5,500 ft. above sea-level, within a ring of mountains (such as Takatu, Murdar and Chiltan), which overlook it from a height of over 11,000 ft. North of Quetta is the open plain leading to Pishin and the Harnai, also traversed by the Sibi-Pishin railway, which passes through the fortifications. These defensive works, stretching from the base of Takatu to the foot of the Mashelak hills on the west, bar the way to advance from the Khojak pass. During the last quarter of the 19th century Quetta grew from a dilapidated group of mud buildings, with an inferior bazaar and a few scattered remnants of neglected orchard cultivation, into a strong fortress, and one of the most popular stations of the Indian army. The Indian Staff college opened here in 1907. Trade mart for western Afghanistan, eastern Iran and much of central Asia, its population grew to 64,476 by 1941. However a disastrous earthquake practically destroyed the city in June 1935, claiming a toll of from 20,000 to 40,000 lives—the most fatal quake in twenty years.

The DISTRICT OF QUETTA-PISHIN has an area of 5,310 sq.mi. The actual line of valley which contains Quetta and the Bolan pass was originally rented from the khan of Kalat. This perpetual leasehold was afterwards extended so as to include Nushki and give the British government the command of the trade route to Seistan. The Quetta district is administered, together with the assigned districts of Pishin, Tal Chotiali and Sibi by a regular staff of civil officials, the head being known as the Agent to the Governor-General. Pop. (1941) 156,289.

See Thornton, *Life of Sir Robert Sandeman* (London, 1896); *Quetta-Pishin District Gazetteer* (Ajmer, 1907). (T. H. H.)

QUEVEDO Y VILLEGAS, FRANCISCO GOMEZ DE (1580–1645), Spanish satirist and poet, was born at Madrid, and was educated at the University of Alcalá. At 21 he was in correspondence with Justus Lipsius on questions of Greek and Latin literature.

He betook himself to the court where the cynical greed of ministers, the meanness of their flatterers, the corruption of the royal officers, the financial scandals, afforded ample scope to Quevedo's talent as a painter of manners. In 1611 he fought a duel in which his adversary was killed, fled to Italy, and later on became secretary to Pedro Téllez Girón, duke of Osuna, and viceroy of Naples. Thus he learned politics (the one science which he had perhaps till then neglected), initiated himself into the questions that divided Europe, and penetrated the ambitions of the neighbours of Spain, as well as the secret history of the intriguers protected by the favour of Philip III. The result was that he wrote several political works, particularly a lengthy treatise, *La Politica de Dios* (1626). The disgrace of Osuna (1620) compromised Quevedo, who was arrested and exiled to his estate at La Torre de Juan Abad in New Castile. On the death of Philip III. (March 31, 1621), Olivares recalled him from his exile and gave him an honorary post in the palace, and from this time Quevedo resided almost constantly at court, exercising a kind of political and literary jurisdiction due to his varied relations and knowledge, but especially to his biting wit, which had no respect for persons. In the midst of incessant controversy he found time to compose a picaresque romance, the *Historia de la Vida del Buscón . . .* (1626); to write his *Sueños* (1627), in which all classes are flagellated; to pen a dissertation on *The Constancy and Patience of Job* (1631), to translate St. Francis de Sales and Seneca, to compose thousands of verses, and to correspond with Spanish and foreign scholars. But Quevedo was not to maintain unscathed the high position won by his knowledge, talent, and biting wit. An anonymous petition in verse enumerating the grievances of his subjects was found, in Dec. 1639, under the very napkin of Philip IV. Suspicion fell on Quevedo, who had enemies glad to confirm them. He was arrested on Dec. 7, and kept in rigorous confinement in the monastery of St. Mark at Leon till the fall of Olivares (1643). Two years later he died at Villanueva de los Infantes. (J. F.-K.)

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QUEZAL, QUETZAL or QUESAL, one of the most beautiful of birds, an inhabitant of the mountains of Central America. This bird, *Pharomacrus mocinno*, is one of the trogons (*q.v.*), and in body is about the size of a turtle-dove. The plumes of the tail, which may measure $3\frac{1}{2}$ ft., are golden-green and, before the Spanish conquest, were only allowed to be worn by chiefs. The rest of the plumage is green above and scarlet below. In the female the tail is short. The eggs are a pale bluish-green.

QUEZALTENANGO, the capital of the department of Quezaltenango, Guatemala, 120 mi. by Pan-American highway west of Guatemala City and 70 mi. inland from the Pacific port of Champerico. Pop. (1950) 36,209. It is on the river Siguila and at the foot of the volcano Santa María. In size the second city in the republic, it has a large agricultural trade and manufactures of linen, woollen and cotton goods. Its inhabitants are mainly Indians or mestizos of Quiché descent. Quezaltenango was the capital of a Quiché kingdom, and was known as Xelajú. In 1524 it was conquered by the Spaniards under Pedro de Alvarado. In 1902 it was almost completely destroyed by an earthquake and an eruption of Santa María.

QUEZON, MANUEL LUIS (1878–1944), Philippine statesman, was born at Baler, on the island of Luzon, and studied law at Santo Tomas university in Manila. He joined the insurrectionist movement of Aguinaldo, but later swore allegiance to the territorial administrators and became a provincial prosecutor. He was a member of the Philippine assembly 1907–09, resident commissioner to the U.S. Congress 1909–16, and president of the Philippine senate 1916–35. He was elected first president of the Commonwealth of the Philippines Sept. 17, 1935. He died Aug. 1, 1944, at Saranac, N.Y., U.S.A.

QUIBERON, CAMPAIGN AND BATTLE OF. Several plans were made for the invasion of the British Isles by the French during the Seven Years' War, and in 1759 an army was assembled

at Vannes in Brittany, with its transports lying in the Morbihan, the landlocked waters inside Quiberon bay. To protect this force while undertaking the invasion, the French planned to unite their fleets at Toulon and Brest; but these ports were blockaded by Admiral Edward Boscawen and Admiral Sir Edward Hawke respectively. During July 1759 Boscawen was compelled to take his squadron to Gibraltar for provisions and refitting, and Admiral de la Clue led the Toulon fleet through the straits of Gibraltar with the idea of reaching Brest. But he was pursued from Gibraltar by Boscawen, and in the running fight which finished in Lagos bay his force was completely disorganized and defeated.

Meanwhile Hawke continued the blockade of Brest with the utmost pertinacity, but on Nov. 9, 1759, he was forced to run into Torbay by lack of stores and exceptionally bad weather. On Nov. 14 he was again at sea; but by this time the French had learnt of his withdrawal, thanks to some ships from the West Indies which reached Brest without being held up. Admiral Conflans took the Brest fleet to sea on the same day that Hawke left Torbay (Nov. 14), and headed south. Hawke, on learning from one of his scouting ships the course taken by the French, also headed south. Continual changes of wind and weather made consistent navigation extremely difficult, but on the morning of Nov. 20 both fleets were about 30m. off Belle-Ile. Conflans, seeing a few English ships under Commodore Duff watching Quiberon bay, stood in close to capture them, but on sighting Hawke's fleet to the north-west, he changed his mind and determined to run into the bay itself, keeping his fleet as closed up as possible.

On sighting the French, Hawke signalled "line abreast" in order to concentrate his force, and followed this up by "general chase" and "line of battle ahead." Hawke's leading ships crowding sail with a fresh north-west gale astern of them, soon began to overhaul the French, who were sailing in close order at the speed of the slowest. At 2:30 p.m., just as Conflans was rounding Belle-Ile, his rearmost ships began to be attacked, and soon afterwards both fleets swept into the bay, between the Cardinal islands and the Four sandbank. Inside the bay, owing to its peculiar shape, the sea was terrific; there were innumerable reefs and sandbanks; the short winter's day was rapidly closing in; and both fleets were driving towards a lee shore. There were 21 of the line in each fleet, but the French had a great advantage in carrying pilots who knew the coast, and with scarcely three hours' daylight left there seemed little chance of a decisive action, especially as it was almost impossible to open the lower deck gun-ports. Nevertheless, two French ships were sunk and another was captured before Hawke made the signal to anchor. Next morning, Nov. 21, the French fleet scattered; seven ships after throwing their guns overboard ran up the River Vilaine, and nine ran out to sea for Rochefort, one sinking on the way. A ship which had struck the night before but had not been captured ran on the Four in trying to escape and was burnt, together with two English ships which had also run aground. Conflans' flagship, the "Soleil Royal," which had anchored nearly in the middle of the English fleet, ran herself ashore on Nov. 21 and was burnt by her own crew. An attempt to burn the ships in the Vilaine by a boat attack was abandoned, owing to bad weather and the strong defences of the river mouth. Nevertheless, the French Brest fleet was now quite useless as a tactical combination, and "had we had but two hours more daylight," wrote Hawke, "the whole had been totally destroyed or taken; for we were almost up with their van when night overtook us." With both their fleets defeated, the French were now compelled to abandon their invasion project, and cease all major naval operations for the rest of the war.

See Sir W. L. Clowes, *The Royal Navy*, vol. iii. (1898). Sir Julian Corbett, *England in the Seven Years' War* (1918).

(G. A. R. C.; W. C. B. T.)

QUICHÉ, the most important Indian nation in Guatemala at the time of the Spanish conquest. To-day the Quiché tongue, a Maya dialect, is spoken by about 275,000 pure-blooded natives throughout the Departments of Quiché, Quezaltenango, Totonicapán, Retalhuleu and Sacatepéquez.

Quiché history and tradition are preserved in a book known as the *Popol Vuh*, written by a native shortly after the Conquest. It relates four attempts to create a satisfactory world and people it. On the last attempt the gods made four men: Balam-Quitze, Balam-Agab, Mahucutah and Igi-Balam. Of these the first three became the ancestors of the Quiché. As first constructed these men had too many divine attributes to suit the gods, so their wits were dulled, but in compensation they were given wives. At this time the other Indian tribes were created and they all went to Tulan Zuiva to receive their household gods. The Quiché god, Tohil, then made the first fire by striking it from his sandal, while the other Indians learned the art from the Quiché. To gain this end, with one exception, they were tricked into giving human hearts in sacrifice. All then started to migrate to Guatemala, and when they arrived the first sunrise took place. Then the four leaders withdrew to the woods, and, after the Quiché had successfully fought a war, these holy men died. They were succeeded by their sons who immediately departed on a mystic journey to the East where they received the insignia of temporal power at the hands of the great king, Nacxit, who also taught them the secret of writing.

Upon the return of their leaders the Quiché settled in stone wrought cities, and from this point the *Popol Vuh* assumes a definitely historical character. It describes the reigns of many kings and pictures in detail their wars with neighbouring nations. The apogee of Quiché power was reached under Kicab, who made tributary all his neighbours, but these conquests were never consolidated into a kingdom. Fighting continued with varying fortunes until the arrival of the Spaniards.

In 1524 Pedro de Alvarado, the lieutenant of Cortés, entered Guatemala. The Quiché had received warning of his coming and of the strength of the Spanish arms from the Aztec emperor Montezuma. They had hastily made peace with warring neighbours but were unable to unite them in a common defence. Their preparations to repel Alvarado were impeded by the death of their king, Tanub. His successor, Tecum Umam, met the Spaniards with a huge army upon the plains of Zelahuh near the modern Quezaltenango. There followed a series of desperate actions in which the Indians failed to withstand the Spanish cavalry and artillery, backed by a force of native allies. Finally Tecum Umam personally attacked Alvarado and after unhorsing him was slain. Then the Quiché retreated to their capital, Gumacaah, leaving innumerable dead along the banks of a stream to this day known as Xiquiguel, the river of blood. However, the Quiché were not yet conquered, and the new king, Chignauivcelut, endeavoured to entice Alvarado into his capital, so that he might burn the houses over the Spaniards' heads while his men cut off their retreat over the narrow causeway by which the city was entered. Alvarado discovered this plan, captured the Quiché by stratagem and hanged the king. Thus the opposition was broken.

At the time of the conquest a king ruled the Quiché in regal style. He was surrounded by 24 councillors who gave the ruler their advice and acted as judges and revenue collectors. The principal towns were governed by appointed lieutenants who, however, had no jurisdiction over the nobility. Each governor had his council organized in the same fashion as the king's. All these officials and others down to the rank of door-keeper of the council were drawn from the nobility who took great care to preserve the purity of their blood.

To-day the Quiché live in small villages in the highlands of Guatemala, for the most part on various coffee plantations where the Indians are held in a state of peonage. Some of the towns, however, particularly Chiquinula, Nahualá and Chichicastenango, have maintained a semi-independence and run their affairs with little interference from the Central Government. Chichicastenango is of peculiar interest because its inhabitants claim descent from the Quiché nobility, and recognize one of their number, Manuel Ajanel, as king.

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(S. K. L.)

QUICHERAT, JULES ÉTIENNE JOSEPH (1814–1882), French historian and archaeologist, was of Burgundian origin. His father, a working cabinet-maker, came from Paray le Monial to Paris where Quicherat was born on Oct. 13, 1814. He was educated at the college of Ste. Barbe and at the École des Chartes. Inspired by the example of Michelet, who had just written an admirable work on Joan of Arc (*q.v.*), he published the text of the two trials of Joan, adding much contemporary evidence on her heroism in his *Procès de condamnation et de rehabilitation de Jeanne d'Arc* (5 vols. 1841–1849), as well as half a volume of *Aperçus nouveaux sur l'histoire de Jeanne d'Arc.* He wrote full biographies of two chroniclers of Louis XI., one very obscure, Jean Castel (in the *Bibliothèque d'École des Chartes,* 1840), the other, Thomas Basin, bishop of Lisieux, a remarkable politician, prelate and chronicler. Quicherat also published the works of the latter (4 vols., 1855–1859). In 1849 he was appointed professor of diplomacy at the École des Chartes. He died at Paris on April 8, 1882.

BIBLIOGRAPHY.—After his death his unpublished papers were printed in *Mélanges d'archéologie et d'histoire,* vol. i., Celtic, Roman and Gallo-Roman antiquities, ed. A. Giry and Aug. Castan (1885), and vol. ii., *Archéologie du moyen âge,* ed. R. de Lasteyrie. His *Histoire de la laine,* on which he was occupied for many years, was missing from his papers, and only the introductory chapters (up to the 11th century) of his lectures on archaeology were found. Among his lectures published in contemporary reviews are *La formation française des anciens noms de lieu* (1867); *De l'ogive et de l'architecture dite ogivale* (1850); *L'Âge de la cathédrale de Laon* (1874); and *Histoire du costume en France* (1875; 2nd ed., 1877), a popular work.

QUICHUA, a South American Indian tribe and stock, the ruling people of Peru when the Spaniards arrived. The Quichuan stock then included the Quichuas proper and the many vassal tribes of the ancient empire of Peru. To-day it numbers some three millions. They are skilful farmers and herdsmen. (*See* PERU; SOUTH AMERICA: *Ethnology.*)

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QUICHUA INDIAN OF PERU

QUICKENING. A popular term for the first movements of the developing child perceived by the mother. This generally occurs about the fourth month of pregnancy.

QUICK-MATCH. A quickfiring wick or fuse, made by saturating cotton-wick with a paste of starch and gunpowder and carefully drying it. Used to connect the various parts of a firework, it carries the flame from one part to another. It was formerly also used for firing industrial and military explosives.

QUICKSILVER, a common name for mercury (*q.v.*).

QUIETISM, a complicated religious movement that swept through France, Italy and Spain during the 17th century. Its chief apostles were Miguel de Molinos, a Spaniard resident in Rome; Fénelon, the famous French divine, and his countrywoman, Madame Jeanne Marie Guyon. Quietism was essentially a reaction against the bureaucratic ecclesiasticism always latent within the church of Rome, though it had come more especially to the front during the struggles of the counter-Reformation carried through by the Jesuits. Like their contemporaries, the French Jansenists, and the Quakers and Anabaptists of northern Europe, the Quietists fell back on a doctrine of immediate inspiration of the individual conscience. To the many God spoke only in general terms through the Church; but to the few He made His will directly known. But how did He do so? How distinguish the voice of God from the vagaries of our own imagination? Quietism offered an easy test. The less "sense of proprietorship" a man had in his own good actions—the more they came from a source outside himself—the surer might he be that they were divine. If, on the other hand, they were the fruit of his deliberate thought and will, that was enough to show that they did not come from God, but from his sinful self. Hence the first duty of the Quietist was to be "passive."

The Spanish monk, Juan Falconi, who is generally reckoned as the father of Quietism, died in the odour of sanctity in 1632; some thirty years later his fellow countryman, Molinos, transported his doctrines to Rome, where they gained unbounded popularity with bishops and cardinals, and even with pope Innocent XI. In 1675 Molinos published the *Guida Spirituale,* the great text-book of his school. But his success soon aroused the suspicion of the Jesuits, the great champions of militant ecclesiasticism. "Passivity" accorded ill with a zealous frequentation of the confessional, their chief centre of influence. Failing to turn public opinion against Molinos in Rome, they brought pressure to bear on Louis XIV. through his confessor, Père La Chaise. At the instance of the French ambassador Molinos was arrested (1685); his papers were seized, and his chief disciples examined by the Inquisition. Two years later he was convicted of heresy, and sentenced to imprisonment for life.

The later stages of the Quietist drama were played out in France. Here Quietist ideas had long been spreading under the leadership of enthusiasts like François Malaval (1627–1719), a blind layman of Marseilles. A more romantic figure was Jeanne Marie Guyon (1648–1717), a widow of good family and remarkable personal charm, who devoted her life to missionary journeys on behalf of "passivity." In 1688 fate brought her to the French court, where she made a great impression on Mme. de Maintenon and other persons of quality. But her most illustrious convert was Fénelon, then tutor to the duke of Burgundy, eldest son of the Dauphin. Mme. Guyon and Fénelon made Quietism famous. In 1697 Bossuet was at work on an *Instruction sur les états d'oraison,* which was intended to distinguish once for all what was true in Quietism from what was false. Fénelon, feeling sure that Bossuet would do the Quietists less than justice, determined to be beforehand with him. While Bossuet's book was still in the press, he suddenly brought out an *Explication des maximes des saints.* The little volume raised a violent storm. For two years Fénelon was at feud with Bossuet; he was banished from Versailles; finally, he was censured by the pope (1699), although in very measured terms. This condemnation, and Fénelon's bitter controversies with Bossuet, proved the death-blow to official Quietism.

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QUILL, a term applied to the bare, hard, hollow tube of the feather of a bird, also to the large flight feathers or *remiges,* and especially to the strong feathers of the goose, swan, or crow used in the making of quill pens (*see* FEATHER and PEN). Certain ancient stringed instruments were played with a *plectrum* or plucker made of the quill of a bird's feather, and the word has thus been used of a *plectrum* made of other material.

QUILLER-COUCH (kwil'lur kōōch), **SIR ARTHUR THOMAS** (1863–1944), English writer (pseudonym "Q"), born in Cornwall on Nov. 21, 1863. He was educated at Clifton college and Trinity college, Oxford, where he was afterwards appointed lecturer in classics (1886–87). While he was at Oxford he published (1887) his *Dead Man's Rock* (a romance in the vein of Stevenson's *Treasure Island*), following it up with *Troy Town* (1888) and *The Splendid Spur* (1889). Gaining some journalistic experience in London, mainly as a contributor to the *Speaker,* in 1891 he settled at Fowey in Cornwall, and wrote several Cornish tales, including *The Blue Pavilions* (1891), *The Ship of Stars* (1899), *Hetty Wesley* (1903), *The Shining Ferry* (1905). He published several volumes of critical articles, *Adventures in Criticism* (1896); *On the Art of Writing* (1916); *Studies in Literature* (1918; 2nd series, 1927; 3d series, 1929), and *Shakespeare's Workmanship* (Bristol, 1918). In 1898 he completed R. L. Stevenson's *St. Ives.* From his Oxford days he was known as a writer of excellent verse; most of his poetical work is contained in *Poems and Ballads* (1896). In 1895 he published a delightful anthology from the 16th and 17th century lyrists, *The Golden Pomp;* the in-

valuable *Oxford Book of English Verse 1250–1900* (1900); the *Oxford Book of Ballads* (1910); the *Oxford Book of Victorian Verse* (1912); the *Oxford Book of English Prose* (1925); *Poems* (1929); *The Poet as Citizen and Other Papers* (1934); *Q's Mystery Stories* (1937); *Victors of Peace: Florence Nightingale, Pasteur, Father Damien* (1937). In 1910 Quiller-Couch was knighted. In 1912 he was appointed King Edward VII professor of English literature at Cambridge, and was elected fellow of Jesus college, Cambridge. He died in Fowey, Cornwall, May 12, 1944.

QUILLOTA, a town of Chile in the province of Valparaíso, on the left bank of the Aconcagua river, 20 mi. above its mouth and 26 mi. E.N.E. of the city of Valparaíso. Pop. (1940) 17,220. The valley is noted for its beauty, fertility and healthfulness, and is the centre of thriving fruit and wine industries. Among its fruits is the "chirimoya" (*Anona Cherimolia*). Quillota is situated on a railway between Valparaíso and Santiago.

QUILON, a seaport of India, on the Malabar coast, in the state of Travancore. Pop. (1941) 49,500. The palace of the maharaja of Travancore stands on the bank of Quilon lake.

QUIMBY, PHINEAS PARKHURST (1802–1866), American mental healer, was born at Lebanon, N.H., on Feb. 16, 1802. In 1838, while in business as a clock-maker in Belfast, Me., his interest in hypnotism was aroused by a series of lectures. He studied the subject and delivered lectures. His experiments extended through mental suggestion to mental healing, sometimes accompanied by physical manipulation, which he practised at Portland, Me., having among his patients Mrs. Patterson, later Mary Baker Eddy.

He died at Belfast, Me., on Jan. 16, 1866.

See A. G. Dresser, *The Philosophy of P. P. Quimby.*

QUIMPER, formerly Quimper-Corentin, a town of France, capital of the department of Finistère, 158 mi. N.W. of Nantes and 68 mi. S.E. of Brest on the railway between those towns. Pop. (1946) 20,149. Quimper, or at least its suburb Locmaria on the Odet, was occupied in Roman times, and traces of the ancient foundations exist. Later Quimper became the capital of Cornouailles and the residence of its kings. It is said to have been Grallon Meur who brought the name of Cornouailles from Great Britain and founded the bishopric, first held by St. Corentin about 495. Hoel, count of Cornouailles, united the countship with the duchy of Brittany. Quimper suffered in the local wars of succession. In 1344 it was sacked by Charles of Blois.

Monfort failed to take the town in 1345, but it opened its gates to his son John IV in 1364 after the victory at Auray. Remains of the town walls (15th century) are preserved in the terrace of the episcopal palace and near the college. Quimper is the seat of a bishopric in the province of Rennes. The cathedral of St. Corentin (13th to 16th centuries), with a fine façade (*c.* 1425), is a splendid example of the Gothic style in granite. Breton pottery is made here.

QUIMPERLÉ, a town of western France, in the department of Finistère, at the confluence of the Isole and the Ellé which unite to form the Laita, 28 mi. E.S.E. of Quimper by rail. Pop. (1946) 10,679. Quimperlé grew up round the abbey of Ste. Croix, founded in the 11th century, the restored romanesque basilica of which still remains. The church of St. Michel (14th and 15th centuries), with a fine tower, crowns the hill above the town.

QUIN, JAMES (1693–1766), Irish actor, was born in London Feb. 24, 1693. He first appeared on the stage as Abel in Sir Robert Howard's *The Committee* at the Smock Alley Theatre, Dublin. Quin's first London engagement was in small parts at Drury Lane, and his first triumph was as Bajazet in Nicolas Rowe's *Tamerlane* (Nov. 8, 1715). The next year he appeared as Hotspur at Lincoln's Inn, where he remained for 14 years. On July 10, 1718, he was convicted of manslaughter for killing Bowen, another actor, in a duel. The affair was regarded as an accident. In 1721 a drunken nobleman reeled on to the stage of the theatre and assaulted the manager, Rich, whose life was saved by Quin's prompt armed interference. This resulted in a riot, and thereafter a guard was stationed in all theatres. In 1732 Quin appeared at Covent Garden, returning to Drury Lane from 1734 to 1741, and in 1742 was again at Covent Garden, where he remained until the close of his career. On Nov. 14, 1746, Quin played Horatio and Garrick Lothario to the Calista of Mrs. Cibber in Rose's *Fair Penitent* to an enthusiastic audience. Quin was a serious rival of Garrick.

His Richard III was pronounced inferior to Garrick's; but his Falstaff was preferred.

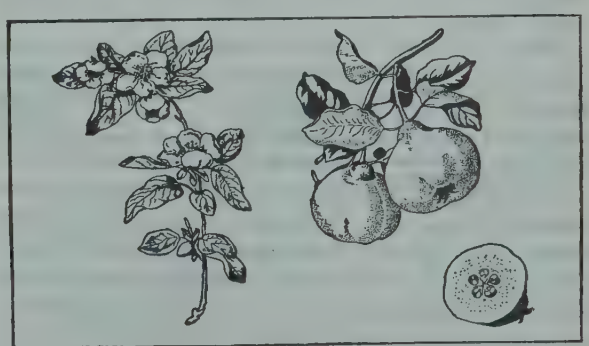
Quin's last regular appearance was May 15, 1757, as Horatio in the *Fair Penitent,* though in 1758 he twice played Falstaff for the benefit of friends. He retired to Bath, where he lived a gay life. Quin died on Jan. 21, 1766. He was buried in the abbey church at Bath. Quin's character is summarized by Smollett in *Humphrey Clinker.*

See *The Life of Mr. James Quin, Comedian,* 1766.

QUINAULT, PHILIPPE (1635–1688), French dramatist and librettist, was born in Paris on the 3rd of June 1635. By 1670 he had written some 16 or 17 comedies, tragedies, and tragi-comedies. In 1671 he contributed to the singular miscellany of *Psyché,* in which Corneille and Molière also had a hand, and which was set to the music of Lulli. Here he showed a remarkable faculty for lyrical drama, and from this time till just before his death he confined himself to composing libretti for Lulli's work. His libretti are among the few which are readable without the music, and which are yet carefully adapted to it. Coming at the time when opera became fashionable out of Italy, he had much to do with establishing it as a permanent European *genre.* His first piece after *Psyché* was a kind of classical masque, *Les Fêtes de l'Amour et de Bacchus* (1672). Then came *Cadmus* (1674), *Alceste* (1674), *Thésée* (1675), *Atys* (1676), one of his best and *Isis* (1677). All were classical in subject, as was *Proserpine* (1680), which was superior to any of them. *The Triumph of Love* (1681) is a mere ballet, but in *Persée* (1682) and *Phaeton* (1683) Quinault returned to the classical opera. Then he finally deserted it for romantic subjects, in which he was even more successful. *Amadis de Gaule* (1684), *Roland* (1685), and *Armide* (1686) are his masterpieces, the last being the best. Quinault died Nov. 26, 1688.

The best edition of his works is that of 1739 (Paris, 5 vol.).

QUINCE, a fruit tree concerning which botanists differ as to whether or not it is entitled to take rank as a distinct genus, *Cydonia,* or as a section of the genus *Pyrus* (family Rosaceae, *q.v.*). The name *Cydonia oblonga* is to be preferred to *Pyrus cydonia.* Bailey gives five varieties of *C. oblonga,* namely, vars. *lusitanica, maliformis, pyriformis, marmorata* and *pyramidalis.* The quinces are much-branched shrubs or small trees with entire leaves, small stipules, large solitary white or pink flowers like those of the pear



QUINCE (CYDONIA OBLONGA); SHOWING BLOSSOM IN FULL BLOOM (LEFT), PEAR-SHAPED QUINCE SHOWING SEED BOX (RIGHT)

or apple, but with leafy calyx lobes and a many-celled ovary, in each cell of which are numerous horizontal ovules. The fruits may be round and flattened or somewhat pear-shaped, with large leafy calyx persisting on the mature fruit.

The common quince is a native of Persia and Anatolia, and perhaps also of Greece and the Crimea. By Franchet and Savatier *C. oblonga* is given as a native of Japan, with the native name "maroumerou." It is certain that the Greeks knew a common variety upon which they grafted scions of a better variety from

Cydon in Crete, whence it was obtained and from which the later names have been derived. The fragrance and astringency of the fruit of the quince are well known, and the seeds formerly were used medicinally for the sake of the mucilage they yield when soaked in water. The quince is but little cultivated in Great Britain; in Scotland it seldom approaches maturity, unless favoured by a wall. The fruit has a strong aroma and in the raw state is astringent; but it makes an excellent preserve, and is often used to give flavour and sharpness to stewed or baked apples.

The Japanese quince, formerly considered in the genus *Cydonia* but now known as *Chaenomeles lagenaria,* has been widely used as an ornamental plant in gardens as a shrub, particularly because of the beauty of its flowers that appear on the stems before the leaves open fully in late winter and early spring months. Some of the small shrubs bear large green fragrant fruits that are quite inedible in the fresh state but have been used in making preserves.

The quince was formerly grown in home fruit gardens and commercial plantings in the northeastern United States but later became the least esteemed of all tree fruits for orchards in that area. The fruit is almost inedible in the uncooked state, and other fruits are preferred in the fresh state for the diet. It thrives under the same systems of cultivation as do apples and pears and does fairly well along fence rows, where it may be given little care. The quince is susceptible to a bacterial disease called fire blight, which is also a serious hazard to pear growing in the United States. Trees that are not forced into strong vegetative growth by pruning and fertilization are less susceptible to the fire blight disease. The trees are subject to the same scale insects that attack apples and pears and should receive the same dormant spray treatment for the control of these pests. The fruits are golden yellow in colour and the flesh takes on a pink colour when cooked, giving an attractive colour to jellies and conserves made from this fruit. Orange is the most commonly grown variety. Champion is another of the more important varieties. Quince stocks are used on which to graft the pear to dwarf the tree and hasten early bearing. The Angers variety, imported from France, is the most important stock used for dwarfing pears. (F. P. C.)

See W. W. Robbins, *Botany of Crop Plants* (Philadelphia, 1924); L. H. Bailey, *Standard Cyclopedia of Horticulture* (1914–27) and *Manual of Cultivated Plants* (1924).

QUINCKE, GEORGE HERMANN (1834–1924), German physicist, was born at Frankfurt on the Oder on Nov. 19, 1834. He was appointed "privat-docent" at Berlin university in 1859. Between 1860 and 1872 he held various teaching posts. He was professor of physics at Würzburg (1872–75) and at Heidelberg from 1875 until he retired in 1907. He died on Jan. 13, 1924.

Quincke carried out a number of observations on surface tension. He also wrote papers on the reflection of light at metal surfaces, on the penetration of light into the second medium in the case of total reflection, and on elliptic polarization. Quincke also devised methods of measuring the magnetic permeability of liquids and the dielectric constants for non-conductors.

QUINCY, JOSIAH (1744–1775), American patriot, son of Josiah Quincy (1709–84), was born in Boston on Feb. 23, 1744. Between 1767 and 1770, he contributed several papers to the Boston *Gazette* that were flaming tirades against British oppression. After the "Boston massacre," he and John Adams defended Capt. Preston and the accused soldiers and secured their acquittal. From this time on he wrote repeated letters to the Boston *Gazette* and published several books in which he urged opposition to England. In Sept. 1774 he left for England where he consulted with leading Whigs as to the political situation in America; on March 16, 1775 he started back, but he died on April 26 in sight of land.

See the *Memoir of the Life of Josiah Quincy, Jr., of Massachusetts* (Boston 1825, 2nd ed., 1874), by his son.

Josiah Quincy (1772–1864), son of the above named, American lawyer and author, was born in Boston on Feb. 4, 1772. He graduated from Harvard in 1790, studied law and was admitted to the bar in 1793, but was never a prominent advocate. He served in the Massachusetts senate in 1804–05; and was a member in 1805–13 of the national House of Representatives. After leaving Congress, he held various political offices until in 1823 he became mayor of Boston. As mayor he brought about municipal reform, and in 1829 resigned to become president of Harvard college. He remained president until 1845 during which time he made many reforms in grading, finances, etc. His last years were spent on his farm in Quincy, where he died on July 1, 1864.

He wrote a *Memoir* of his father (1825); a *History of Harvard University* (1840), the *Journals of Mayor Samuel Shaw* (1847); *The History of the Boston Athenaeum* (1851); *The Municipal History of the Town and City of Boston* (1852); a *Memoir of the Life of J. Q. Adams* (1858); and many practical contributions to agriculture. *See* Edmund Quincy, *Life of Josiah Quincy* (Boston, 1867).

Josiah Quincy (1802–1882), son of the last named, was mayor of Boston in 1845–49; his brother Edmund (1808–77) was a prominent abolitionist and author. Josiah Quincy (1802–82) had two sons—Josiah Phillips (1829–1910), a lawyer and author; and Samuel Miller, who became a brigadier-general in the Union army. Josiah Quincy (1859–1919), a son of Josiah Phillips Quincy, was mayor of Boston in 1895–99. (B. B. K.)

QUINCY, a city of western Illinois, U.S., on the Mississippi river, 110 mi. N.W. of St. Louis; the county seat of Adams county. It is on federal highway 24 and is served by the Burlington Route and the Wabash railways, and by river barges and steamers. Pop. (1950) 41,402; 40,469 in 1940 by the federal census. The city is built on a picturesque bluff above the river and is surrounded by rich farm lands. It has beautiful parks covering 300 ac., one of which embraces prehistoric Indian mounds, and is the seat of the Illinois State Soldiers' and Sailors' home (1887). Industrial products include air compressors, centrifugal pumps, rock drills and other equipment for mine and oil-field operation, metal wheels, trailer truck bodies, poultry equipment, screw fittings, stoves, furnaces, pulpboard, garments, hosiery and shoes, soybean oil and meal, poultry and dairy products, mineral feeds and livestock preparations. In 1822 John Wood, the first white settler, built a log cabin there; and on March 4, 1825, the day of the inauguration of John Quincy Adams, the hamlet of ten inhabitants was made the county seat. In honour of the new president the county was named Adams, the town Quincy, and the public square (now Washington park) was called John's square. The town was incorporated in 1834 and was chartered as a city in 1839.

QUINCY, a city of Norfolk county, Mass., U.S., on Massachusetts bay, just south of Boston, occupying 16.77 sq.mi. between the Neponset river on the north and Fore river on the south. It is served by the New York, New Haven and Hartford railroad. The population was 83,190 in 1950, and in 1940 it was 75,810 by federal census. It is a beautiful residential suburb of great historic interest and has distinctive manufacturing industries. The Quincy granite quarries have been celebrated since the middle of the 18th century. The first freight railway in the United States was established there in 1825.

On Fore river are shipyards (established 1900) in which were built many of the modern vessels of the U.S. navy. The city has 2,600 ac. of parks and playgrounds. A settlement known as Merry Mount or Mt. Wollaston was established within the present bounds of Quincy in 1625 by Thomas Morton (*q.v.*), but was abandoned after his arrest; and in 1634 a second settlement was made by Puritans. In 1792 Quincy was set off from Braintree and incorporated as a town (named in honour of John Quincy, 1689–1767) and in 1888 it was chartered as a city. It was the home of the Hancocks and the Adamses, the birthplace of the first governor of Massachusetts and of two presidents of the United States. The houses in which John Adams and John Quincy Adams were born (built in 1681 and 1716) and the Edmund Quincy homestead (1685) are colonial museums, open to the public. The granite for King's chapel, Boston, 1749–54, and for the Bunker Hill monument, 1825–42, was quarried in Quincy.

QUINET, EDGAR (1803–1875), French historian and man of letters, was born at Bourg-en-Bresse (Ain), on Feb. 17, 1803. His first publication, the *Tablettes du Juif Errant,* appeared in 1823. He obtained considerable credit from his translation (1827) of Herder's *Philosophie der Geschichte.* At this time he met Michelet, and also Cousin, who procured him a post on a Gov-

ernment mission to the Morea in 1829. On his return he published *La Grèce Moderne* in 1830. His reputation for speculative Republicanism ruined his hopes of employment after the February revolution, but he joined the staff of the *Revue des deux Mondes*. The most remarkable of the numerous essays which he contributed to it was on *Les Epopées françaises du XIIème siècle*. In 1839 he was appointed professor of foreign literature at Lyons, and in 1841 was transferred to the chair of southern literature at the Collège de France. The *Génie des religions*, embodying his brilliant lectures at Lyons, appeared in 1842. In 1846 the Government put an end to his lectures, because he introduced into them polemic against Ultramontanism.

Quinet took part in the revolution of 1848, and was returned for Ain to the Constituent and then to the Legislative Assembly, where he figured among the extreme radical party. He wrote many pamphlets during the Second Republic, attacked the Roman expedition and was an uncompromising opponent of Prince Louis Napoleon. He was banished from France after the *coup d'état* and settled at Brussels, where he lived for seven years, and published *Les Esclaves* (1853) and *Marnix de Sainte-Aldégonde* (1854). Quinet was restored to his chair after the fall of the Empire, and during the siege of Paris wrote vehemently against the Germans. As deputy for the department of the Seine (1871) he opposed the terms of peace between France and Germany. He died on March 27, 1875.

BIBLIOGRAPHY.—In addition to the works mentioned above, Quinet wrote *Les Révolutions d'Italie* (1848); *Histoire de mes idées* (1858); *Le Siège de Paris et la defense nationale* (1871); *La République* (1872); *Le Livre de l'exilé* (1875 and later). Three volumes of letters and some other works were published posthumously. A complete edition of his works was published in 28 volumes in 1877–79. His second wife, in 1870, published certain *Mémoires d'exil*, and *Lettres d'exil* followed in 1885. In that year Prof. George Saintsbury published a selection of the *Lettres à sa mère* with an introduction. *See* also E. Paris, *Libres penseurs religieux* (1905); R. Heath, *Early Life and Writings of Edgar Quinet* (1881).

QUININE, the most important alkaloid contained in cinchona bark (*see* CINCHONA BARK, ALKALOIDS OF).

Quinine is used chiefly for its antimalarial action; the manner of its highly specific action on the malaria parasite was still not clearly understood at mid-20th century. It does not prevent the establishment of the infection after innoculation by the mosquito (prophylaxis), nor does it cause a complete eradication of the parasites (parasitic cure). Its only action is in suppressing the infection, thus allowing time for the development of the processes of immunity.

Quinine has long been popular as a remedy for fever and pain. Its relief of fever is due to dilation of blood vessels in the skin and to haemoconcentration (increase in red corpuscles), while its analgesic effect is probably due to a central depressant action located in the optic thalami. It has a local anaesthetic effect caused by necrosis and subsequent regeneration of the axis cylinders of sensory nerves. It may cause considerable irritation, however, and its only virtue is its prolonged action.

Small amounts of quinine stimulate the uterus, especially during the late pregnancy, and the drug is used to some extent in labour. Quinine has a curarelike action on smooth muscle, interfering with the transmission of nerve impulses. It, therefore, intensifies the muscular weakness of myasthenia gravis but relieves the muscular spasm of myotonia congenita and of torticollis. Because of its bitter taste, quinine is used as a tonic to increase the appetite. It is also a common ingredient of hair tonics where its use is entirely irrational.

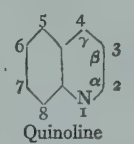
Cinchonism is the name applied to the toxic symptoms which follow the prolonged administration of quinine, but may appear after one small dose in certain persons. The symptoms closely resemble those of salicylism. The patient is deaf, but complains of ringing in the ears. Vision may be disturbed, rashes appear frequently, and there may be marked gastrointestinal upsets. In persons who display a pronounced tendency toward cinchonism, desensitization may be effected by repeated small doses.

QUINNAT (*Oncorhynchus tschawytscha*), most important salmon (*q.v.*) of North American Pacific coast, frequently weighing upward of 50 lb. It has been naturalized in New Zealand.

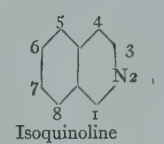
QUINOA (*Chenopodium quinoa*), a small annual herb of the goosefoot family (Chenopodiaceae), very similar to the common lamb's quarters (*q.v.*), native to Bolivia, Chile and Peru, where it has long been cultivated as a food plant by the native peoples of the Andean plateau. The plant produces a great profusion of very small seeds, which are ground into meal and made into cakes or gruel or boiled like rice; the green parts are used as a pot herb like spinach.

(*See* CHENOPODIUM.)

QUINOLINE is an organic compound of formula C_9H_7N which in general chemical behaviour resembles pyridine (*q.v.*) very closely. It is, in fact, a benzopyridine, bearing the same relation to pyridine as naphthalene does to benzene. The benzene and pyridine rings are fused together in the 2,3 position, the other possibility, fusion in the 3,4 position, giving isoquinoline which is discussed below.



Quinoline



Isoquinoline

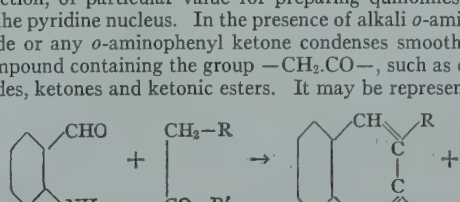
The positions of substituents in derivatives of the two compounds are indicated by numbers as shown above. The prefixes N, α, β and γ were also used formerly for the pyridine ring of quinoline.

Quinoline itself was first isolated from coal tar by F. F. Runge in 1834. The modern commercial product is obtained from that source or is made synthetically. It also occurs in bone oil. C. F. Gerhardt in 1842 obtained quinoline by heating the alkaloid cinchonine with potassium hydroxide and this was the first evidence of the occurrence of the quinoline nucleus in certain of the natural alkaloids; quinine similarly heated gives 6-methoxyquinoline. The first synthesis of quinoline was achieved by W. Koenigs in 1879 by passing the vapour of allylaniline over hot lead oxide. This is clear evidence that the nitrogen atom is directly attached to the benzene ring. A large number of synthetical methods are known for the preparation of quinoline and its derivatives; important examples are:

1. The Skraup reaction (1880) is of exceedingly wide application and gives quinoline or derivatives substituted in the benzene ring. A primary aromatic amine is heated with glycerol, sulphuric acid and a mild oxidizing agent, nitrobenzene or arsenic acid being often used. The reaction is a condensation of acrolein, $CH_2{:}CH.CHO$, formed by dehydration of the glycerol, with the amine to give a dihydroquinoline which is oxidized by the oxidizing agent. Aniline is converted into quinoline in good yield by this method which can also be applied to practically all aromatic amines.

2. The Doebner-Miller reaction (1883) consists of heating an aromatic amine and an aldehyde with hydrochloric acid or zinc chloride. The product is a quinoline substituted in the 2 position; thus aniline and acetaldehyde give quinaldine (2-methylquinoline) and though the yield is not high, the reaction is useful for obtaining certain quinoline derivatives of commercial interest.

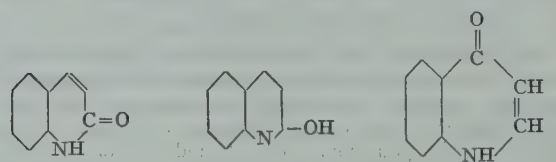
3. The Friedländer synthesis (1883) is, as opposed to the Skraup reaction, of particular value for preparing quinolines substituted in the pyridine nucleus. In the presence of alkali *o*-aminobenzaldehyde or any *o*-aminophenyl ketone condenses smoothly with any compound containing the group $-CH_2.CO-$, such as certain aldehydes, ketones and ketonic esters. It may be represented thus:



Isatin can be used in place of the less accessible *o*-aminobenzaldehyde; this gives the 4-carboxylic acid derivative from which the carboxyl group can be removed if necessary.

Quinoline is a colourless, highly refractive oil boiling at 239° C. and with a characteristic smell. It is almost insoluble in water but miscible with organic solvents, and it behaves as a weak mono-

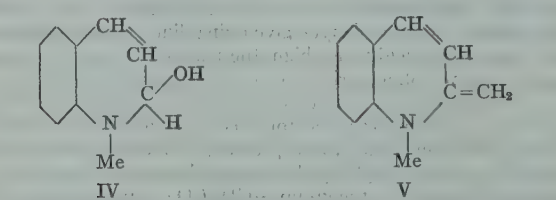
acidic base. Its salts are readily soluble in water except the bichromate which is sparingly soluble in the cold and can be used for the purification of quinoline. Sodium reacts with quinoline, which is best dried with barium oxide. Since the pyridine ring is deactivated by the presence of the nitrogen atom, a substituting reagent such as nitric acid attacks the benzene ring and gives a mixture of the 5- and 8-substituted compounds. Further nitration gives the 5,7- and 6,8-dinitro derivatives. These nitro compounds can be reduced to amines which behave as true aromatic amines and can be diazotized and converted into other derivatives. As with pyridine, the 2- and 4-amino compounds are anomalous in this respect. Anionoid substituting reagents, such as sodamide, react with the pyridine nucleus in the 2 and 4 positions, and 2-aminoquinoline can be obtained directly by the action of sodamide. Of the hydroxy compounds, 8-hydroxyquinoline, which is often called oxine, is of interest as an organic analytical reagent for the detection and estimation of certain metals, notably aluminum, magnesium and zinc with which it forms insoluble complexes; because of their space arrangement the metal can unite both with the phenolic hydroxyl group and, by co-ordinate bond formation, with the nitrogen atom. 2-Hydroxyquinoline is usually called carbostyril and, like the corresponding pyridine derivative, behaves more like the lactam I than as a hydroxy compound II. Similarly the structure of the 4-hydroxy compound



I II III

(γ-quinolone, kynurin) is usually taken to be III; the 2-carboxylic acid of this compound occurs in the urine of dogs. In quinaldine (2-methylquinoline) and lepidine (4-methylquinoline) the methyl groups are reactive and condense readily with aldehydes; the 3-methyl compound does not.

Quinoline and its homologues are tertiary bases and thus react with alkyl halides to give quaternary ammonium salts which show the normal behaviour of strong electrolytes. The quaternary hydroxides derived from these salts are not stable and tend to pass more or less completely into un-ionized forms, as with many other cyclic bases. In quinoline and those of its derivatives in which there is no alkyl group in the 2 or 4 position this un-ionized form is the pseudo base IV in which the hydroxyl group is extremely reactive. With quinaldine and lepidine and their homologues it is the anhydro-base (methylene base) V, which is also very reactive. These forms are derivatives of a 1,2- or 1,4-dihydroquinoline.



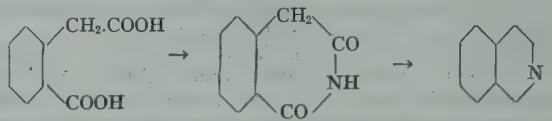
IV V

The reactivity of these compounds is the basis for the preparation of dyestuffs of the cyanine class (isocyanines, pseudocyanines and carbocyanines) which are of great value as sensitizers of the photographic emulsion to wave lengths in the red and infra-red.

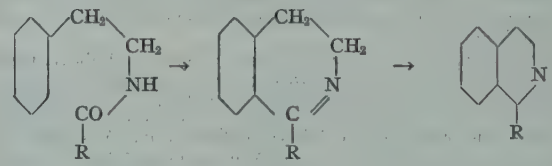
On reduction the pyridine ring of quinoline is more readily attacked than the benzene ring and the first product obtained with nearly all reducing agents is 1,2,3,4-tetrahydroquinoline which behaves as a monoalkylaniline. Complete reduction by vigorous catalytic methods gives decahydroquinoline; this exists in two geometrically isomeric forms because both rings are now multiplanar and no longer aromatic. As demanded by stereochemical theory, both these forms have been resolved into optical antimers.

When quinoline is oxidized, the benzene ring is attacked first and with alkaline permanganate the product is quinolinic acid, which is pyridine-2, 3-dicarboxylic acid.

Isoquinoline is found in coal tar and crude quinoline from that source contains about 4% of isoquinoline. It is a solid melting at 24° C. and boiling at 240° C. and with a smell quite different from that of quinoline. It is more strongly basic than the latter, since the nitrogen atom is not directly attached to the benzene ring, and its sulphate is not very soluble in cold water; separation from quinoline is based on these facts. The structure is established as that given above by a variety of syntheses, such as the reduction of the imide of homophthalic acid.

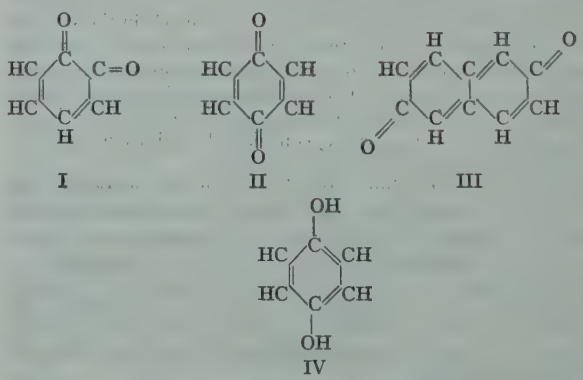


The isoquinoline nucleus is found in a number of important alkaloids; *e.g.*, papaverine, berberine, hydrastine and narcotine. A valuable reaction for synthesizing this nucleus is that of A. Bischler and B. Napieralski (1893). Acyl derivatives of β-phenylethylamines when heated with powerful dehydrating agents in boiling xylene or tetralin give 3,4-dihydroisoquinolines which can be dehydrogenated to isoquinolines with permanganate or catalytically with palladium.



Many of the isoquinoline alkaloids have been synthesized by means of this reaction. (T. W. J. T.)

QUINONES, a group of coloured cyclic organic compounds containing two carbonyl groups, C=O (*see* KETONES) either adjacent (orthoquinone, I) or separated by a vinyl group, C=C, (paraquinone, II) in a usually six-membered unsaturated ring. All quinones have these features except a few in which the carbonyl groups are located in different rings: *e.g.* amphinaphthoquinone, III. The term quinone usually refers to the specific compound, parabenzoquinone (*p*-benzoquinone), II, but may also apply to some other compound having the required structural features. A similar ambiguity exists also for the terms hydroquinone and quinhydrone (*see* below). The general reactions of quinones are entirely analogous to the specific reactions of *p*-benzoquinone.



I II III IV

p-Benzoquinone is easily and quantitatively reduced to its corresponding hydroquinone, IV, by a variety of reducing agents. This change is readily reversed by oxidizing agents.

$$\underset{p\text{-Benzoquinone}}{C_6H_4O_2} + 2H^+ + 2e \rightleftharpoons \underset{p\text{-Benzohydroquinone}}{C_6H_6O_2}$$ where e is an electron.

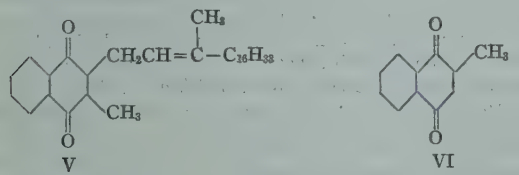
If a platinum electrode is put into a solution which contains equivalent amounts of some quinone and its hydroquinone, and which is saturated with respect to the addition compound of the two (the so-called quinhydrone), an electric potential is produced which is dependent on the hydrogen-ion concentration. By mak-

ing connection through a suitable conducting solution with a reference half cell, this potential can be measured. A device, the quinhydrone electrode, was developed to make use of the above principle in measuring the hydrogen-ion concentration of an unknown solution. (*See* HYDROGEN-ION CONCENTRATION: *Quinhydrone Electrode.*)

The ring of atoms in a quinone is said still to have a quinonoid (or quinoid) character if one of the sets of doubly bonded carbon and oxygen atoms is replaced by another doubly bonded atom pair, or even if both of those sets are so replaced. Quinonoid structures are important in theories concerning the relationship of chemical constitution to colour. Many quinones, among which one of the most important is anthraquinone (*see* ANTHRAQUINONE), are used as dyestuff intermediates. All vat dyes have quinonoid structures. An important feature in the use of vat dyes is the fact that the dye is placed on the cloth while in the hydroquinone state, and the oxidation to the quinone state takes place on exposure to air.

Many quinones occur in natural products. One of the most important of these is vitamin K_1, which possesses the structure V and is the antihaemorrhagic agent found in certain green plants. (*See* VITAMINS: *Vitamin K.*) Synthetic quinones, in particular 2-methyl-1,4-naphthoquinone, VI, have similar properties and are used in medical practice.

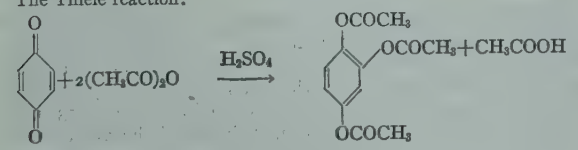
A number of interesting naturally occurring quinones is listed in *Organic Chemistry* by L. F. Fieser and M. A. P. Fieser, pp. 746 to 758 (1944).



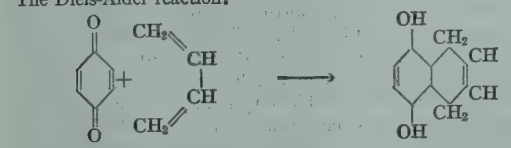
V VI

In scientific research, quinones are of importance because of their manifold chemical reactivity stemming from the fact that they contain carbonyl groups and activated double bonds. Frequently these functions act in a complementary way, giving rise to special reactions peculiar to the quinones. A few examples are illustrated below:

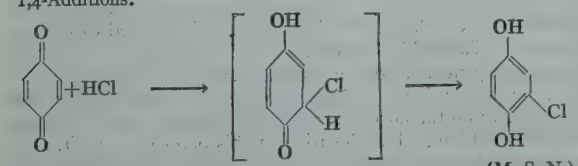
The Thiele reaction:



The Diels-Alder reaction:



1,4-Additions:



(M. S. N.)

QUINSY, a common term for an abscess which develops around the tonsil, usually following acute tonsillitis (*q.v.*).

QUINTAIN, an instrument used in the age of chivalry in practising for the tournament (O. Fr. *quintaine,* from Lat. *quintana,* a street between the fifth and sixth maniples of a camp, where warlike exercises took place). An early form consisted of the wooden figure of a Saracen armed with shield and sword; the object being to strike the figure on the forehead between the eyes.

As late as the 18th century running at the quintain survived in English rural districts.

QUINTANA ROO, a federal territory of Mexico on the eastern side of the Yucatán peninsula, bounded by British Honduras and Guatemala. Pop. (1950) 26,996, predominantly Maya Indians; area, 19,435 sq. mi., formed in 1931 from parts of the states of Yucatán and Campeche. The territory is hot, humid and heavily forested, with 50 to 60 in. of rain annually. Like the rest of the peninsula, Quintana Roo is a level, porous limestone plain through which water percolates to form underground grottos, caverns and wells. The area is populated chiefly by descendants of Maya Indians who in 1847 rebelled against whites in Yucatán and were eventually driven into these fastnesses by continuous military campaigns. Distrustful of Yucatecan Mexicans, they carry on sporadic trade in chicle with British Honduras, and main contacts with the outside world lie along the narrow-gauge railway that connects Felipe Carrillo Puerto (Santa Cruz de Bravo), to Vigía Chico on Ascension bay. Another slight penetration from the coast inland is represented by a similar line in the northern section from Leona Vicario (Santa María) to Puerto Morelos. Air strips at various points, and regular service to Belize, Brit. Hond., and Mérida lessened some of the characteristic isolation of the territory, which for many years was used as a dumping ground for political prisoners. Chicle and a small amount of copra, produced on the coast near Cozumel Island, are the main products. The small Mayan hamlets are nearly self-sufficient. The capital is Chetumal.

The territory contains numerous important archaeological remains of the earlier pre-Spanish Mayan empire, notably those at Tulum. (HD. C.)

QUINTESSENCE, in ancient and scholastic philosophy, the name given to the fifth immaterial element, over and above the four material elements, air, water, earth and fire, which Aristotle assumed to be permeating the whole world, and called *οὐσία*; in mediaeval philosophy this was called *quinta essentia,* the fifth essence.

QUINTILIAN [MARCUS FABIUS QUINTILIANUS] (*c.* A.D. 35–95), Roman rhetorician, was born at Calagurris in Spain. The years from 61 to 68 he spent in Spain, probably in the retinue of the future emperor Galba, with whom he returned to the capital. For at least 20 years after the accession of Galba he was at the head of the foremost school of oratory in Rome. Vespasian created for him a chair of rhetoric. About the year 88 Quintilian retired from teaching and from pleading, to compose his great work on the training of the orator (*Institutio Oratoria*). After two years' retirement he was entrusted by Domitian with the education of two grand-nephews, whom he destined as successors to his throne. Quintilian gained the titular rank of consul, and probably died not long before the accession of Nerva (A.D. 96). A wife and two children died early. His great work, the *Institutio Oratoria,* is in form a manual on the training of a public speaker; in fact it is the outline of a liberal education. As an orator, a teacher and an author, Quintilian set himself to stem the current of popular taste which found its expression in what we are wont to call silver Latin; but apparently he did not attempt to modify the primary cause of it—the excessive concentration on poetry in the early stages of literary training. In his youth the influence of the younger Seneca was dominant. But the chief teacher of Quintilian was a man of another type, one whom he ventures to class with the old orators of Rome. This was Domitius Afer, a rhetorician of Nîmes, who rose to the consulship. His great model was Cicero, of whom he speaks at all times with unbounded eulogy, and whose faults he could scarce bring himself to mention; nor could he well tolerate to hear them mentioned by others. The reaction against the Ciceronian oratory which had begun in Cicero's own lifetime, had acquired overwhelming strength after his death. Quintilian failed to check it, as another teacher of rhetoric, equally an admirer of Cicero, had failed—the historian Livy. The great movement for the poetization of Latin prose which was begun by Sallust ran its course till it culminated in the monstrous style of Fronto. The teachers and audiences in the schools of declamation, and in the courts the judges, juries and audiences alike, demanded the startling, quaint or epigrammatic, and the speakers practised a thousand tricks to satisfy the demand.

Starting with the maxim of Cato the Censor that the orator is "the good man who is skilled in speaking," Quintilian takes his future orator at birth and shows how this goodness of character and skill in speaking

may be best produced. The scheme followed is the standard division into three periods, supervised by the *litterator*, the *grammaticus*, and the *rhetor* respectively. Under the first the child receives elementary instruction, under the second he is grounded in literary criticism and scholarship generally as well as in what we call grammar, especial emphasis being laid on poetry; the third stage studied much the same authors, though more attention was given to prose, but with a direct view to the practice of oratory. The parts of the work which relate to general education are of great interest and importance. Quintilian postulates the widest culture; there is no form of knowledge from which something may not be extracted for his purpose; and he is fully alive to the importance of method in education. Yet he develops all the technicalities of rhetoric with a fulness to which we find no parallel in ancient literature. Even in this portion of the work the illustrations are so apposite and the style so dignified and yet sweet that the modern reader, whose initial interest in rhetoric is of necessity faint, is carried along with much less fatigue than is necessary to master most parts of the rhetorical writings of Aristotle and Cicero. The passages which review Greek and Latin literature are the most famous of all. There is a considerable traditional element in these, greater on the Greek than on the Latin side; but substantially posterity has concurred in his judgment. In the divine government of the universe he seems to have had a more than ornamental faith, though he doubted the immortality of the soul. As to politics Quintilian, like others of his time, felt free to eulogize the great anti-Caesarian leaders of the dying republic, but only because the assumption was universal that the system they had championed was gone for ever.

The Latin of Quintilian is not always free from the faults of style which he condemns in others. It also exhibits many of the usages and constructions which are characteristic of the silver Latin. But no writer of the decadence departs less widely from the best models of the late republican period. The language is on the whole clear and simple, and varied without resort to rhetorical devices and poetical conceits.

Besides the *Institutio Oratoria*, there have come down to us under Quintilian's name 19 longer (ed. Lehnert, 1905) and 145 shorter (ed. Ritter, 1884) *Declamationes*, or school exercitations on themes like those in the *Controversiae* of Seneca the elder. The longer pieces are certainly not Quintilian's. The shorter were probably published, if not by himself, at least from notes taken at his lessons. Editio princeps, Campames (Rome, 1470). Of the editions of the whole works the chief is that by Burmann (1720); of the *Institutio Oratoria* that by Spalding, completed by Zumpt and Bonnell (1798–1834, 5th ed., Meister, 1882).

QUINTUS SMYRNAEUS, Greek epic poet, probably flourished in the latter part of the 4th century A.D. He is sometimes called Quintus Calaber, because the only ms. of his poem was discovered at Otranto in Calabria by Cardinal Bessarion in 1450. According to his own account (xii, 310), he tried his hand at poetry in his early youth, while tending sheep at Smyrna. His epic in 14 books, known as Τὰ μεθ' Ὅμηρον, or *Posthomerica*, takes up the tale of Troy at the point where Homer's *Iliad* breaks off (the death of Hector), and carries it down to the capture of the city by the Greeks, their departure and dispersal in the storm. The poet has no originality; in conception and style his work is closely modelled on Homer.

Editio princeps by Aldus Manutius (1504); Köchly (ed. major with elaborate prolegomena, 1850; ed. minor, 1853); Z. Zimmermann, author of other valuable articles on the poet (1891); *see* also Kehmptzov, *De Quinti Smyrnaei Fontibus ac Mythopoiia* (1889); C. A. Sainte-Beuve, *Etude sur . . . Quinte de Smyrne* (1857); F. A. Paley, *Quintus Smyrnaeus and the "Homer" of the tragic Poets* (1879); G. W. Paschal, *A Study of Quintus Smyrnaeus* (Chicago, 1904).

QUIPUS. The Peruvian quipus consists of a number of thongs or cords hanging from a top-band or cross-bar, generally forming groups, often with an equal number of cords in each group, with cords from these and again from the last. Knots occur rarely on the main cord. In its simplified form, knots are merely tied upon the individual cords. In its more elaborate forms the cords are of different colours, and are knotted together so as to form open loops of various shapes. In the *Antiguedades Peruanas*, we are told that the knots of the quipus in all probability indicated only numbers originally, but that as time went on the skill of the makers became so great that historical events, laws and edicts could thus be communicated. In every place of any importance there was an official whose business it was to interpret quipus received from a distance, and to make quipus himself. If, however, the quipus came from a distant province, it was not intelligible without an oral explanation. The art of interpretation of quipus is lost, so that it is impossible to ascertain how far the knots were merely a mnemonic for the messenger, and how far they were intelligible without explanation to a stranger. Recent examination of a series of complete quipus suggests knowledge of an astronomical nature, similar to that of the Mayas, and the use of these devices for magical purposes. Similar mnemonics were used among the Chinese, the Tibetans and other peoples of the Old World. (*See* Knots.)

Bibliography.—*See* Leland Locke, *The Ancient Quipus* (1923); E. Nordenskiöld, *The Secret of the Peruvian Quipus* (1925).

QUIRINUS (*kwĭ-rī'nus*, Lat. *kwĭ-rē'nŏŏs*) was the third (after Jupiter and Mars) of the purely Roman gods. The name Quirinus is adjectival in form, and it would seem to mean "he of *quirium*," a word generally taken since Niebuhr to signify a very ancient Sabine settlement which united with the Palatine community to form the original Rome; but (*see* Kretschmer in *Glotta*, x, 147 *et seq.*) it may well mean "assembly" (*covirium*), and therefore the god may be "he of the assembly or assembled host." The identification, in the last century of the republic, of Quirinus with the deified Romulus has greatly obscured his real nature, but we know he resembled Mars (*q.v.*), had a flamen, the third in rank of the greater flamines, and a college of Salii. His temple lay on the *collis Quirinalis*, and his festival, the Quirinalia, was on Feb. 17. Associated with him in cult were a goddess, Hora, and certain minor deities, the Virites Quirini. *See* Wissowa, *Relig. u. Kultus* (2nd ed.), p. 153, and Roscher's *Lexikon*.

QUIRITES (*kwĭ-rī'tēz*), earliest name of the burgesses of Rome (*see* Quirinus). In the phrase *"populus Romanus Quirites* (or *Quiritium*)," it denoted the individual citizen as contrasted with the community. Hence *ius Quiritium* in Roman law denotes full Roman citizenship. Whether the word ever had military associations is a point much debated, but if so it lost them at an early date and came to designate Roman citizens in their civil, as distinct from their military, capacity, and referred solely to Romans concerned in domestic affairs. Thus Caesar is said to have quelled a mutiny among his legionaries by the device of addressing them as "Quirites" (citizens). (*See* Roman Law.)

QUITMAN, a city of southern Georgia, U.S.A., the county seat of Brooks county; on federal highway 84, and served by the Atlantic Coast Line and the South Georgia railways. Pop. 4,769 in 1950; 4,450 in 1940. It has mills and factories, and is a shipping point for melons, tobacco, garden truck, cattle and other agricultural produce. The city was founded in 1858 and incorporated in 1859.

QUITO, the capital of the republic of Ecuador, and of the province of Pichincha, situated in lat. 0° 14′ S., long. 79° 45′ W., about 114 mi. from the Pacific coast and 165 mi. in a direct line northeast of Guayaquil, with which it is connected by a railway completed in 1908. The population of Quito was 212,873 in the census of 1950. It occupies a small basin of the great central plateau formed by the volcano Pichincha on the west, the Puengasi ridge on the east, and ridges north and south formed by spurs from the eastern side of Pichincha. The ground upon which the city is built is uneven and is traversed from west to east by two deep ravines (*quebradas*), one of which is arched over to preserve the alignment of the streets. The city is in great part laid out in rectangular squares, the streets running nearly with the cardinal points of the compass. The houses of Quito are chiefly of the old Spanish or Moorish style. The building material in general use is sun-dried bricks, which in the better houses is covered with plaster or stucco. The public buildings are of the heavy Spanish type. Facing the principal square (*plaza mayor*), and occupying the whole south side, is the cathedral; on the west side is the government palace; on the north the archbishop's palace; and on the east the municipal hall. The elevation of this plaza is 9,343 ft. above sea level. The finest building in the city is the Jesuits' church, the façade of which is covered with elaborate carving. Among public institutions are the university, which occupies part of the old Jesuit college, an astronomical observatory, and 11 large monastic institutions, six of which are for nuns. One of the convents, that of San Francisco, covers a whole block, and ranks among the largest institutions of its kind in the world. A part of it is in ruins, and another part has been for some time used as military barracks by the government. The university has faculties of theology, law

and medicine. The botanist and chemist, William Jameson (1796–1872), was a member of its faculty for many years. There are a number of retail and wholesale firms. The city exports include hides and forest products from the wooded mountain slopes near by. Religious paintings of a mediaeval type are produced in large numbers and exported. The native manufactures include tanned leather, saddles, shoes, ponchos, woollen and cotton cloth, fibre sandals and sacking, blankets, coarse matting and woollen carpets. Quito artisans show much skill in wood and ivory carving and in gold and silver work. The women excel in fine needlework.

Quito derives its name from the Quitus, who inhabited the locality a long time before the Spanish conquest. In 1533 Sebastián Benalcázar took peaceful possession of the native town and in 1541 it was elevated to the rank of a Spanish city. Its full title was San Francisco del Quito, and it was capital of the province or presidency of Quito down to the end of Spanish colonial rule. It has suffered repeatedly from earthquakes.

QUIT RENT, a yearly payment, a relic of the feudal system, made by the copyholders or freeholders of an English manor to its lord. It is a customary payment based on immemorial usage. It is called quit rent because it acquits the tenant of all dues and obligations to the lord. When paid by a freeholder, quit rent is called chief rent. This form of rent has its origin in the feudal services due to the manor, compounded for an annual payment (*see* RENT).

In the United States the term quit rent is used to describe a perpetual rent reserved upon the conveyance of a fee simple, more commonly known as a fee-farm rent, a ground rent, or rent charge.

QUIXOTE, DON (in Spanish Don Quijote), the hero of Cervantes' (*q.v.*) romance (part 1, 1605: part 2, 1615), which was originally conceived as a satire of farcical incident directed against the romances of chivalry. (*See* SPANISH LANGUAGE AND LITERATURE.) He has given his name in all European languages to a type of character which misses practical success by supposing that common humanity is governed by ideals as exalted or as imaginative as its own.

QUM, a district and city in north central Iran. The district lies between Tehran, north (*c.* 95 mi.), and Kashan, south, producing abundant grain, and cotton of a very long staple. The revenue amounted to 342,088 krans in 1926–27 (about £7,602). Qum, the administrative headquarters, in 34° 39′ N. and 50° 55′ E., has an elevation of 3,100 ft. Population about 40,000. It is a stronghold of the Shiah faith and has many tombs of saints and pious persons including the shrine of Fatima, sister of the Imam Riza; and the town is visited by large numbers of pilgrims. Besides Fatima, at least ten kings and some 400 saints are interred in Qum and its precincts. Shah Abbas II, whose piety won him high favour with the ecclesiastical authorities, is buried in the shrine in a special mausoleum which is sumptuously furnished with a set of 14 remarkably fine silk rugs, dated 1666. Along with other important works of art, they can be seen in an excellent little museum attached to the shrine. On the south side of the city is a group of five superb mausolea (four of them of the 14th century) all distinguished by quite remarkable polychrome stucco ornament. The chief industries are glass, pottery and shoemaking.

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QUOIN, in architecture, originally any vertical external corner of a building; more generally applied, at present, to large cut stones used either to form an accurate corner in a wall of rough rubble or brick or else to furnish a decorative termination to a wall surface of any material. Projecting stone quoins, frequently rusticated, or with the edges slightly recessed or bevelled, are common decorative features in the high Renaissance work in Italy, the early 17th century work in France and the Palladian style in England; in these styles they are used not only at the corners of a building, but also often at the edges of windows and doors. In much 18th century work in Scandinavia, England and America, projecting quoin shapes are formed with brick.

QUOITS or **HORSESHOES.** Quoits goes back to the ancient Greeks as a sport, while horseshoe pitching can be traced in the United States to the time of the American Revolution, although it has probably been a pastime since shoes for horses were developed in their present shape. The chief objective in both games involves the tossing of quoits or shoes in an endeavour to encircle or "ring" a stake anchored in the ground, usually from a distance of about 40 ft. The chief difference is that the quoit is a circular iron ring without an opening, while the horseshoe has an opening.

The rules of quoits seem to have varied greatly in different localities. With the increasing popularity of the game of horseshoes, quoits has virtually died out. The important rules of horseshoe pitching are as follows: A court shall consist of two pitchers' boxes, with a stake in the centre of each, and shall cover an over-all area 10 ft. wide and 50 ft. long. The pitching distance shall be 40 ft. between stakes; ladies' distance 30 ft. The pitcher's box shall be filled to a depth of 6 in. with potter's clay. The stakes shall be of iron or steel, extending 12 in. above the clay surface, and inclining 3 in. toward each other. No horseshoe shall exceed the following dimensions: 7½ in. in length, 7 in. in width, 2½ lb. in weight. A regulation game shall consist of 50 points. Under the cancellation system of scoring, the closest shoe to the stake scores one point; two shoes closer than opponent scores two points; one ringer, three points; two ringers, six points; one ringer and closest shoe of same player, four points; two ringers against one for opponent, three points; all equals count as ties and no points are scored. In case each contestant has a ringer, the next closest shoe, if within 6 in. of the stake, shall score one point. A leaning shoe has no value over one touching the stake. Under the non-cancellation method of scoring, any shoe within 6 in. of the stake counts one point, and equals do not cancel. Matches may be played between individuals or teams. The first record of a world's horseshoe tournament, without distinction between professional or amateur, was held in 1910, and since then world's championship tournaments have been conducted virtually every year. The Amateur Athletic Union of the United States conducts local and district competitions, and an annual national amateur championship tournament.

Horseshoes is one of the leading outdoor pastimes in the U.S., and the game branched out to other countries, especially during World War II, when the men of the armed forces of the U.S. carried it to the far corners of the world.

QUORUM, in its general sense, a term denoting the number of members of any body of persons whose presence is requisite in order that business may be validly transacted by the body or its acts be legal. The term is derived from the wording of the commission appointing justices of the peace which appoints them all, jointly and severally to keep the peace in the county named. It also runs—"We have also assigned you, and every two or more of you (of whom [*quorum*], any one of you the aforesaid A, B, C, D, etc., we will shall be one) our justices to inquire the truth more fully," whence the justices so named were usually called justices of the *quorum*. The term was afterwards applied to all justices, and subsequently, by transference, to the number of members of a body necessary for the transaction of its business.

QUOTA. Quotas, in the field of international trade, are a special kind of quantitative control of exports or imports. Quantitative controls are measures which directly limit the quantity—in exceptional cases the value—of goods (or services) that may be exported or imported. The opposite to quantitative controls are controls which operate by making imports or exports more expensive without fixing a limit on the quantity; of these, tariffs, which put a special tax on exports or imports, are the main type.

The principal quantitative trade controls are the quota, licensing and monopoly systems. Under the monopoly system a governmental agency has an exclusive monopoly for the import or export of the restricted commodities. The distinction between the quota and licensing system is not so clear-cut, but there is a

tendency to speak of quotas when the quantities are determined in advance and the rules for the distribution of the quota among countries of origin and traders are more or less clearly formulated; and of a licence system when the granting of import licences is left to the discretion of the administrative organs. From now on we shall refer chiefly to quotas, but much of what will be said holds of the licensing and monopoly systems as well.

Quotas are fixed either by autonomous action of a country or in agreement with other countries ("autonomous" *vs.* "contractual" quotas). Another distinction is between import and tariff quotas. By a "tariff quota" is meant a regulation which permits the import of a certain quantity ("quota") of a commodity duty free (or at a specially low duty), while quantities exceeding the quota are subjected to a (higher) duty. An "absolute" or "import quota" restricts imports absolutely. Another type is "milling or mixing quotas"; this is a rule which requires that imports of, say, barley must be milled or mixed in a certain proportion with home-grown grain. In the following, reference will be made chiefly to absolute import quotas.

Throughout the last quarter of the 19th century and up to 1914 the predominant method of trade control was the tariff. In the 20th century quantitative restrictions on trade were first imposed on a large scale during and immediately after World War I. During 1914–18 such controls were an integral part of war economics. After the armistice quotas were fairly rapidly abolished, except in central and eastern Europe. There the dislocations produced by the war were much more serious than elsewhere. Trade was resumed, first, on the basis of intergovernmental barter and, then, on that of general prohibitions modified by licences. During the 1920s quotas were progressively abolished and replaced by tariff protection. The next great wave of quota protection of trade came with the great depression in the early 1930s. Especially after 1931 one country after another introduced quantitative restrictions, first on cereals and certain other foodstuffs and then on a great variety of agricultural and industrial products. France was the first large country to introduce a comprehensive quota system (1931), but it was followed by practically all European countries. In 1935–36 there was a slight relaxation, but this movement towards somewhat freer trade soon came to an end. Everywhere economies were being geared for the approaching war; and a tightly controlled trade is an integral part of a war economy. The United States was the only important country that made very little use of quotas during the 1930s. The only important U.S. quota was on sugar.

Why have quotas become so popular and how does quota protection differ from tariff protection? The increasing use made of quantitative trade controls is a phase in the trend towards autarchy and protection which has been observable ever since 1870 or so. Tariffs have gone higher and higher, the last free-trade countries (Great Britain, the Netherlands, Denmark) introduced protective measures and eventually quantitative restrictions were piled on top of tariffs. But quotas are a much more effective device for restricting trade than tariffs and much more disturbing to the international trade mechanism. Under the tariff system volume and value of trade, although restricted, are still flexible. The flow of goods changes according to changes in demand and supply at home and abroad. Despite an import duty imports can rise, if cost of production and prices fall abroad and rise at home. Thus the effect of a tariff can be offset by a depreciation of the foreign currency, or an export subsidy, while a quota constitutes a rigid bar to imports. This is one of the main reasons why during the great depression of the 1930s one country after the other switched from tariffs to quotas. Tariffs were no longer regarded a sufficient protection in the face of violently changing prices, unstable currencies and extensive utilization of export subsidies. Another related reason was that tariffs could in many cases not be increased at short notice without violating international treaties, while such treaties did not mention, and therefore were thought not to prohibit, the imposition of quotas. Quotas are a more powerful weapon of discrimination between individual countries and traders. This makes them popular with economic nationalists and protectionists in all countries. In fact, it has been found practically impossible to find a method of quota allocation which could be called nondiscriminatory and in accordance with the most favoured nation principle, while under the tariff system nondiscrimination has a precise, generally accepted meaning.

There is still another extremely important characteristic of the mode of operation of quotas which differentiates them sharply from tariffs. If a quota is effective, *i.e.*, if it is smaller than the quantity which would be imported in the absence of the quota, it creates a price differential between the importing and exporting country which is not covered by transportation cost plus duty. Under the tariff system, too, the price of the taxed commodity will be higher in the importing than in the exporting country, but (except if the tariff becomes prohibitive and imports cease altogether) the price difference tends to be equal to transportation cost plus duty; if it were greater, imports would increase; if it were smaller, imports would fall until the price differential was again equal to transportation cost plus tax. Under the quota system this mechanism is eliminated. It follows that the importation of the quota-restricted commodities becomes a very lucrative business. Under the tariff system the price difference flows into the coffers of the treasury; under the quota system it flows into private pockets, and in all countries with extensive quota systems fortunes have been made by importers. The consequence is that the government is forced to distribute the quota among individual traders. When quotas were first introduced in 1931, many countries made the mistake of fixing only global quotas and of letting everybody import until the quota was exhausted. Naturally everybody tried to import at once as much as possible, and the quota was exhausted within the first few days of the period (usually a month or a quarter of a year) for which it was fixed. Distribution of the licences to import within the quota must be made according to some principle. It should be remembered that the granting of an import licence under the quota system is equivalent to the granting of an unearned income. While under the tariff system the selection of the actual importers is left to the automatic mechanism of the market and is no concern of the government, under the quota system the authorities have to decide how much each trader is allowed to import. The import function ceases to be a business activity where success depends on commercial efficiency and imagination, but becomes a sinecure handed out by government agencies. In the 1930s, the usual procedure was to distribute quotas among countries of origin and individual traders (usually importers but sometimes also foreign exporters) in proportion to the imports from the respective countries effected by the individual traders in some base period which was considered as "normal." It is easy to see that this is not a satisfactory solution and that it becomes less and less satisfactory as time goes on and the underlying situation changes. But the fact that quotas give rise to large profits made in connection with imports and exports has made the system popular with importers and exporters. This popularity is enhanced by the fact that quota restriction, much more than tariffs, facilitates monopolistic price policies by domestic producers.

All these unavoidable abuses, inefficiencies and inconveniences make it unlikely and undesirable that the quota system will replace the tariff system. The development is likely to go either beyond the quota system and to lead to its replacement by outright government monopolies which would eliminate the unearned incomes flowing to private individuals; or quotas will again be replaced by tariffs. In some cases a workable combination may be found in a method by which the unearned income resulting from the price spread is effectively taxed away. One method would be to sell the import licences in an auction market to the highest bidder. *See* TARIFFS; MOST FAVOURED NATION CLAUSE.

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QUO WARRANTO, in English law, the name given to an ancient prerogative writ calling upon any person usurping any office, franchise, liberty or privilege belonging to the crown, to show "by what warrant" he maintained his claim, the onus being on the defendant. It lay also for non-user or misuser of an office, etc. If the crown succeeded, judgment of forfeiture or ousterlemain was given against the defendant. (*See* OUSTER.) The procedure was regulated by statute as early as 1278 (the statute of *Quo Warranto*, 6 Edw. I ch. 1), which was superseded by the modern form of an information in the nature of a quo warranto, exhibited on behalf of the crown or a private person called the relator. The information will not be issued except by leave of the court on proper cause being shown. It lies where the office is of a public nature and created by statute, even though it is not an encroachment upon the prerogative of the crown. Where the usurpation is of a municipal office the information is regulated by 9 Anne ch. 25 (1711). Such an information must, in the case of boroughs within the Municipal Corporations Act, 1882, be brought within 12 months after disqualification (s. 225); in the case of other boroughs, within six years after the defendant first took upon himself the office. Though nominally a criminal it has long been really a civil proceeding, and has recently been declared to be so.

In the United States, quo warranto is the proper remedy under the statutes of the various states to ascertain the right of a person to an office of a public nature, or one in a corporation. It also is used to test the validity of a franchise held by a municipality or a public service corporation. Some states have substituted by statute information in the nature of quo warranto and other remedies, and where such substitution has been made, quo warranto is improper.

THE letter corresponding to modern R in the ancient Semitic alphabet was 𐤓 (*resh*). Greek *rho* is found in a form practically unchanged in the early inscriptions from the island of Thera. The same form also occurs in early inscriptions from Attica and Corinth and in the Chalcidic alphabet. The most usual Greek form was rounded Ρ and this is the form in which the letter occurs in the Lydian alphabet. A form Ⅾ in which the loop is extended to the bottom of the vertical stroke also occurs in both the eastern and western alphabets. This was the form of the letter in the Umbrian and Oscan alphabets of Italy, although it is not found in Etruscan, the form in which is Ρ or Ϙ. In the latter, however, the loop reaches nearly to the ground. In the Chalcidic alphabet a form Ꝑ with an additional oblique stroke occurred, and this was taken over into Latin and

NAME OF FORM	APPROXIMATE DATE	FORM OF LETTER
PHOENICIAN	B.C. 1,200	𐤓
CRETAN	1,100-900	𐤓
THERAEAN	700-600	𐤓
ARCHAIC LATIN	700-500	Ρ
ATTIC	600	𐤓
CORINTHIAN	600	𐤓
CHALCIDIAN	600	Ρ
IONIC	403	𐤓
ROMAN COLONIAL	PRE-CLASSICAL AND CLASSICAL TIMES	R R R R
URBAN ROMAN		R
FALISCAN		𐤓 ꟽ ꟽ
OSCAN		◁ D D
UMBRIAN		D D
CLASSICAL LATIN AND ONWARDS		R

THE DEVELOPMENT OF THE LETTER "R" FROM THE EARLIEST TIMES TO THE PRESENT DAY

exaggerated, so that we find the forms R, Ꝛ and R. The last of the three survived.

The minuscule form has been subject to many variations. In cursive Latin of the 6th century occurred a form ⅄ in which the loop has disappeared, the three right-hand oblique strokes, or the loop and oblique stroke, being reduced to a single stroke. The Irish form in the 7th century was ꝛ in which a similar process had taken place, but the remnants of the loop and oblique stroke had become extended in a horizontal direction. On the basis of this was formed the Carolingian ꝛ, in which the vertical stroke was not extended below the line. The Carolingian form is the minuscule r of modern printing, but in handwriting it still contends with the form ɾ, resembling the Latin cursive tradition.

The sound represented by the letter has been the liquid, formed by contact between the tip of the tongue and the palate. The tip of the tongue is sometimes also rolled. In certain continental countries the sound is pronounced farther back in the mouth than in England. In southern England the sound is a very weak one, and when final is completely dropped (*e.g.*, in the words *mother, steamer*, etc.). The ancients recognized a difference in the sound as pronounced by the Greeks and Romans. The Greek Ρ was probably unvoiced or whispered, a fact expressed by placing the rough breathing over the letter when initial and by spelling Greek words containing this letter, when they were borrowed into Latin and the modern languages, by the combination *rh*.

(B. F. C. A.)

RA, the Egyptian solar god, one of the most important figures in the Pantheon. *See* EGYPT: *Religion.*

RABA BEN JOSEPH BEN HAMA (*c.* 280–352), Babylonian rabbi or amora. He is closely associated in his studies with Abaye. The latter was head of the academy at Pumbeditha. Raba founded a new school at Maḥuza, which eventually became so long as Raba lived the only academy in Babylonia (Persia). The development of Talmudic law (or *Halakkah*) was much indebted to this rabbi, whose influence in all branches of Jewish learning was supreme. His friendship with the King Shapur II enabled Raba to secure a relaxation of the oppressive laws enacted against the Jews of Persia. .

See Graetz, *History of the Jews* (Eng. trans., vol. ii, ch. xxi); Bacher, *Agada der Babyl. Amoräer,* p. 108, etc., and 114–133.

RABAH ZOBEIR (d. 1900), the conqueror of Bornu (an ancient sultanate on the western shores of Lake Chad, included since 1890 in British Nigeria), was a half-Arab, half-Negro chieftain. He was originally a slave or follower of Zobeir Pasha (*see* ZOBEIR RAHAMA), and is said to have formed one of the party which served as escort to Alexandrine Tinne (*q.v.*) in her journeys in the Bahr-el-Ghazal in 1862–64. In 1879, Zobeir being in Egypt, his son Suleiman and Rabah were in command of Zobeir's forces in the Bahr-el-Ghazal. They persisted in slave-raiding, and denied the khedive's authority, and Gordon sent against them Romolo Gessi Pasha. Gessi captured Suleiman and routed Rabah, who in July 1879 fled westward with some 700 Bazingirs (black slave soldiers).

He made himself master of Kreich and Dar Banda, countries to the south and southwest of Wadai. He finally established himself in Bagirmi, a state southeast of Lake Chad. In 1893 Rabah overthrew the sultan of Bornu. In his administration of the country he showed considerable ability and a sense of public needs. To the British, represented by the Royal Niger company, Rabah gave comparatively little trouble. Early in 1897 he began an advance in the direction of Kano, the most important city in the Fula empire. The news of the crushing defeat by Sir George Goldie of the Fula at Bida, induced Rabah to return to Bornu. He now turned his attention to the French. Émile Gentil had in this same year (1897) reached Lake Chad, via the Congo and Bagirmi, and had installed a French resident with the sultan of Bagirmi. As soon as Gentil had withdrawn, Rabah again fell upon Bagirmi, and forced sultan and resident to flee. In 1899 the French sent an expedition to reconquer the country, but it was only after a third encounter (April 22, 1900) that Rabah was slain and his host defeated. The chieftain's head was cut off and taken to the French camp. In this battle Major Lamy, the French commandant, also lost his life.

The French continued the campaign against Rabah's sons, two of whom were killed. Rabah had left instructions that if his army was finally defeated by the French, his successor should return to Bornu and make friends with the British. Rabah's third son, Fader-Allah, accordingly threw himself entirely upon British protection. But, in the later part of 1901 Fader-Allah, who

had 2,500 riflemen, again made aggressive movements against the French. In retaliation, Captain Dangeville pursued him into British territory. A battle was fought at Gujba, Fader-Allah being defeated. He fled mortally wounded and died the same night.

Connected accounts of Rabah's career are contained in É. Gentil's *La Chute de l'empire de Rabah* (Paris, 1902) and in M. von Oppenheim's *Rabeh und das Tschadseegebiet* (Berlin, 1902).

RABAT (*Ribàt*), a city on the Atlantic coast of Morocco, in 34° 3′ N., 6° 46′ W., 130 mi. S. of Cape Spartel, on the southern side and at the mouth of the Bu-Regreg, which separates it from Salé on the northern bank, administrative capital of the French protectorate, seat of the general residency of France in Morocco. The native town and the *mellah* form a trapezium, protected from the open winds by a rise of land occupied by vast cemeteries. It is defended on the north by the Kasba of the Oudaïa, built on the cliff which rises at the mouth of the Bu-Regreg; a fine gateway (12th century) gives access to it; there is a museum in the neighbouring *medresa* (university). About 2 mi. south of Rabat is the Hassan tower, a magnificent minaret of the Almohade period, and still further to the south the necropolis of Chella, which contains the tombs of the Merinides dynasty. The Dar-el-Makchzen (palace of the sultan) rises to the southwest. Important European quarters, with gardens, have been arranged outside, and at a certain distance from, the native town. The general residency and the administrative offices are situated in the Touargas quarter. The harbour, impeded by a bar, is difficult of access; works were undertaken with a view to improving the channel, but Rabat, situated between Port Lyautey and Casablanca, does not seem called to a great commercial future, and will remain an elegant residential town, as the seat of the protectorate government and the habitual residence of the sultan. Pop. (1936 census) 83,379, including 57,123 natives and 26,256 Europeans. In 1913 there were only 300 Europeans. Several towns have followed one another at the mouth of the Bu-Regreg. The most ancient settlement was at Chella, which, under the Romans, was called *Sala Colonia*. There was on the same spot a Berber town, which was succeeded, in the 12th century, by Salé on the right bank of the river. About the same time the Almohade sultan, Abd-el-Mumen, founded *Rabat-el-Fath*, the camp of victory, from which the town of Rabat takes its name; it was there that assembled the contingents of the holy war destined against Spain; it was also called Sala-el-Djedid, Salé the New, in opposition to Sala-el-Khedim, Salé the Old. In the 17th century Rabat received numerous Andalusians expelled from Spain, and became an independent republic of famous corsairs, at first rival, then vassal, of Salé. The Alauit dynasty endowed it with many monuments. But the real rise of Rabat dates from the French protectorate (1912).

See *Rabat et sa région (Villes et Tribus du Maroc)*, 4 vols. (Paris, 1918–20); L. Mercier, *Notes sur Rabat et Chella (Archives Marocaines*, tome v. to viii. (1905–08); Henri Basset et Levi-Provençal, *Chella: une nécropole Mérinide (Hesperis*, 1922); H. de la Casinière, *Les municipalités marocaines* (Casablanca, 1924).

RABAUT, PAUL (1718–1794), French pastor of "the Church of the Desert" (*see* HUGUENOTS), was born at Bédarieux, near Montpellier, on Jan. 29, 1718. In 1738 he was admitted as a preacher, and after a year's study (1740–41) at the Lausanne Seminary, received charge of the church of Nîmes. In 1744 he was vice-president of the general synod. During the persecution of 1745–1752 Rabaut went into hiding, and in 1753 a price was put on his head. During the years that followed he sought, with Antoine Court and others, to place French Protestantism on a solid basis and to improve their legal position. In 1785, when he was visited by General La Fayette, it was arranged that Rabaut's son, Rabaut Saint-Étienne, should go to Paris on behalf of the Reformed Church. In November 1787 Louis XVI.'s edict of toleration was signed, though it was not registered until Jan. 29, 1788. Two years later liberty of conscience was proclaimed by the National Assembly, of which Rabaut Saint-Étienne was chosen vice-president, and it was declared that non-Catholics might be admitted to all positions. After the fall of the Girondists, however, in which Rabaut Saint-Étienne was involved, Paul Rabaut, who had refused to renounce his title of pastor, was arrested, dragged to the citadel of Nîmes, and kept in prison seven weeks (1794). He died Sept. 25, 1794, soon after his release.

See J. Pons de Nîmes, *Notice biographique sur Paul Rabaut* (1808); Charles Dardier, *Paul Rabaut, ses lettres à Antoine Court* (1884) and *Paul Rabaut, ses lettres à divers* (1891).

RABAUT SAINT-ÉTIENNE, JEAN PAUL (1743–1793), French revolutionary, was born at Nîmes, the son of Paul Rabaut (*q.v.*), the name of Saint-Étienne being assumed from a property near Nîmes. In the Constituent Assembly he worked on the framing of the constitution, spoke against the establishment of the republic, and voted for the suspensive veto, as likely to strengthen the position of the crown. In the Convention he sat among the Girondins and was proscribed with his party. He went into hiding, but was discovered and guillotined Dec. 5, 1793.

See J. A. Dartique, *Rabaut St.-Étienne à l'Assemblée Constituante* (1903).

RABBAN BAR SAUMA (*fl.* 1280–1288), Nestorian traveller and diplomatist, was born at Peking about the middle of the 13th century. He started on a pilgrimage to Jerusalem, and travelling by way of Tangut, Khotan, Kashgar, Talas in the Syr Daria valley, Khorasan, Maragha and Mosul, arrived at Ani in Armenia. Warnings of the danger of the routes to southern Syria turned him from his purpose; and his friend Rabban Marcos suggested Bar Sauma's name to Arghun Khan, sovereign of the Ilkhanate or Mongol-Persian realm, for a European embassy, then contemplated, to conclude an anti-Muslim alliance with the chief States of Christendom. Bar Sauma set out in 1287, with Arghun's letters to the Byzantine emperor, the pope and the kings of France and England. He went first to Constantinople, then to Rome. The papacy being then vacant, a definite reply to his proposals was postponed, and Bar Sauma passed on to Paris, where he visited Philip IV. In Gascony he met King Edward I. of England, probably at Bordeaux. On returning to Rome, he was cordially received by Pope Nicolas IV., who gave him communion on Palm Sunday, 1288, allowed him to celebrate his own Eucharist in the capital of Latin Christendom, commissioned him to visit the Christians of the East, and entrusted to him the tiara which he presented to Mar Yaballaha. His narrative is of unique interest as giving a picture of mediaeval Europe at the close of the crusading period, painted by a keenly intelligent, broad-minded and statesmanlike observer.

See J. B. Chabot's translation and edition of the *Histoire du Patriarche Mar Jabalaha III. et du moine Rabban Cauma* (from the Syriac) in *Revue de l'Orient latin*, 1893, pp. 566–610; 1894, pp. 73–143, 235–300; O. Raynaldus, *Annales Ecclesiastici* (continuation of Baronius), A.D. 1288, ss. xxxv.–xxxvi.; 1289, s. lxi.; C. R. Beazley, *Dawn of Modern Geography* (1897, etc.) ii. 15, 352; iii. 12, 189–190, 539–541.

RABBI, a Jewish title (Hebr. רַבִּי, My teacher or master; διδάσκαλε, John I., 38) or *Rab* (master) or *Rabbēnu* (our master; Hebrew) or *Rabbān* (our master: Aramaic) are titles applied to Jewish scholars or doctors of the Law, but not used by them in speaking of themselves. They spoke of themselves as *Talmidhē Hakhāmim* (disciples of the wise); in later days a spiritual head of a congregation would style himself קצור or קקטן (*cf.* title page of S. Singer's *Authorized Daily Prayer Book*). Rab in biblical Hebrew means "great" and in later Hebrew "master" as opposed to *'ebhedh* or servant. These titles must be differentiated and the *locus classicus* is the famous letter of Sherira (*see* GĀON) from which it is clear that *Rab* is a Babylonian and Rabbi a Palestinian title. In *Rabbi* and *Rabbēnu* the pronominal suffixes "my" and "our" soon lost all force. Rabban was reserved for the Patriarchs, the first to bear the title being Gamaliel I. (*haz-Zāqen*), who presided alone over the Sanhedrin. Sherira emphasizes the fact that the earlier authorities (*e.g.*, Hillel) bore no titles. As regards the relative rank of the variants he says, "Rabbi is higher than Rab and Rabban is higher than Rabbi: higher than Rabban is the simple name." This means that the earliest untitled authorities are the most distinguished: these are followed by the Patriarchs and then by the Palestinian Tannaites (*see* GĀON) and Babylonian scholars successively. It is clear that in the days of Jesus titles were not used and some modern scholars therefore consider Matthew xxiii., 7, 8: Mark x., 51: John xx., 16 as anachronisms. The

Tosefta to *'Eduyōth* (end) maintains that Rabbi denotes a teacher with at least two generations of disciples: in process of time antiquity makes him regarded as Rabban and by the time the second generation of disciples is forgotten he is styled by his own name alone. On the other hand Judah I., the redactor of the Mishnah is often known as Rabbi κατ' ἐξοχήν, while the *Amora Abba Arika* was generally styled Rab. The title of Rabbi was later conferred by ordination (*Ṣemīkhah* or laying on of hands): a still later term is *hattārath hōra'ah* or *facultas docendi.* The Qaraites in the tenth century who rejected Rabbinic tradition designated their opponents as Rabbanites. In mediaeval times Rabbēnu was used of distinguished scholars. In modern days Rabbi or Rab is often a courtesy title.

RABBIT, a well-known rodent, formerly called cony. The rabbit, *Oryctolagus cuniculus,* is a member of the family Leporidae (*see* RODENTIA). From the hare (*q.v.*) the rabbit is distinguished by its smaller size, shorter ears and feet, absence of black on the ears and gray colour; by the facts that the young are born naked and blind and that it lives in burrows in the ground. It breeds from four to eight times a year, a litter comprising three to eight young. It begins to breed at the age of six months and lives seven or eight years.

Originally inhabiting the western half of the Mediterranean basin, the rabbit spread, partly by the agency of man, throughout temperate Europe, and it is still extending its range. Introduced into New Zealand and Australia, where natural enemies were few, it increased beyond bounds until it became an unmitigated nuisance. The name rabbit is loosely used to include many members of the family Leporidae, especially in North America (*see* HARE).

The rabbit has long been domesticated, and the variations produced are greater than in any other mammal except the dog (*q.v.*). For not only has the weight been quadrupled and the structure of the skeleton modified, but the proportionate size of the brain has been reduced (*cf.* the domestic duck) and the colour and texture of the fur remarkably altered. The old English lop-eared breed may have ears 23 in. from tip to tip and 6 in. in width. The hardy and prolific Belgian hare resembles the true hare in colour and form, while a similar but larger variety is the (so-called) Patagonian rabbit. The Angora rabbit has very long fur, which is of commercial value; the most valued variety is the albino. The Dutch breed is small and particoloured, being dark posteriorly and white anteriorly. The silver grey is much esteemed for its skin, while the Flemish giant is the biggest of all breeds.

Modern dressing and dyeing methods have developed rabbit fur (known to the fur trade as "coney") into the most satisfactory of low priced furs for wearing qualities. Because it lends itself readily to dyeing it is used in great quantities in imitation of such furs as squirrel, seal, beaver, nutria, Chinchilla, musk-rat, ermine, leopard and still others.

BY COURTESY OF THE AMERICAN MUSEUM OF NATURAL HISTORY

LESSER ARIZONA COTTONTAIL

Various tame varieties of rabbits, which are heavier, and have a fur stronger and less liable to shed, are raised especially in Belgium and France, to supply the demand. Because of the excellent felting properties of rabbit fur it now forms the largest proportion of fur going into the manufacture of felt hats. Forty to fifty rabbit skins furnish material for a dozen hats. Rabbit fur is also in demand for upholstery purposes. The supply of rabbits for the hat industry comes chiefly from Australia (which for some years averaged 70,000,000 skins annually), New Zealand, Belgium, France and England.

RABBŪLĀ, a distinguished bishop of the Syrian church early in the 5th century. He was a native of Kenneshrīn, a town some few miles south of Aleppo and the seat of a bishopric. He resided for some time in a monastery, and then passed to a life of greater hardship as a solitary hermit. On the death of Diogenes, bishop of Edessa, in the year 411–412, Rabbūlā was chosen his successor. On one occasion he visited Constantinople and there preached before Theodosius II. (who was then favourable to Nestorius) and a great congregation a sermon in denunciation of Nestorian doctrine, of which a portion survives in the Syriac version. He became the friend of Cyril of Alexandria, with whom he corresponded, and whose treatise *De recta fide* he translated into Syriac. The version survives in a British Museum ms.; *see* Wright's *Catalogue* p. 719. He died in August 435.

RABELAIS, FRANÇOIS (*c.* 1495–1553), French author, was born at Chinon on the Vienne in the province of Touraine. The date of his birth is uncertain: it has been put by tradition, and by authorities long subsequent to his death, as 1483, 1490 and 1495. Most 17th-century authorities give the earliest date, and this also accords best with the age of the eldest of the Du Bellay brothers, with whom Rabelais was (perhaps) at school. In favour of the middle date, the testimony of Guy Patin (1601–72), a witness of some merit and not too far removed in point of time, is invoked. The only contribution which need be made here to the controversy is to point out that if Rabelais was born in 1483 he must have been an old man when he died, and that scarcely even tradition speaks of him as such. It is said that he had four brothers and no sisters, that his father had a country property called La Devinière, and was either an apothecary or a tavern-keeper. An indistinct allusion of his own has been taken to mean that he was tonsured in childhood at seven or nine years old; and tradition says that he was sent to the convent of Seuilly. From Seuilly at an unknown date tradition takes him to the convent school of La Baumette near Angers, where he is supposed to have been at school with the brothers Du Bellay, with Geoffroy d'Estissac and others. He certainly entered the Franciscan monastery of Fontenay le Comte some time before April 5, 1519, by which date he held a position sufficiently senior to sign deeds for the community. The letters of the well-known Greek scholar Budaeus, together with some notices by André Tiraqueau, a learned jurist, to whom Rabelais rather than his own learning has secured immortality, show what manner of life the future author of *Gargantua* led in his convent. The letters of Budaeus show that an attempt was made by the heads of the convent or the order to check the studious ardour of these Franciscans; but it failed, and there is no positive evidence of anything like actual persecution. Papers were seized as suspicious, then given back as innocent; but Rabelais was in all probability disgusted with the cloister—indeed his great work shows this beyond doubt. In 1524 his friend Geoffroy d'Estissac procured from Clement VII. an indult, licensing a change of order and of abode for Rabelais. From a Franciscan he became a Benedictine, and from Fontenay he moved to Maillezais, of which Geoffroy d'Estissac was bishop. But even this learned and hospitable retreat did not apparently satisfy Rabelais. In or before 1530 he left Maillezais, abandoned his Benedictine garb for that of a secular priest, and, as he himself puts it in his subsequent *Supplicatio pro Apostasia* to Pope Paul III., *per seculum diu vagatus fuit.* For a time the Du Bellays provided him with an abode near their own château of Langey, but on Sept. 17, 1530, he entered the faculty of medicine at the University of Montpellier, becoming bachelor on Nov. 1, a remarkably short interval, which shows what was thought of his acquirements. Early in 1531 he lectured publicly on Galen and Hippocrates, and his stay at Montpellier, which lasted rather more than a year at first, was renewed at intervals for several years.

In 1532, however, he had moved from Montpellier to Lyons. He was appointed before the beginning of November physician to the Hôtel Dieu, with a salary of 40 livres per annum, and lectured on anatomy with demonstrations from the human subject. He edited for Sebastian Gryphius, in the single year 1532, the medical *Epistles* of Giovanni Manardi, the *Aphorisms* of Hippocrates, with the *Ars Parva* of Galen, and an edition of two supposed Latin documents, which, however, happened unluckily to be forgeries.

At this time Lyons was the centre of an unusually enlightened

society, and indirectly it is clear that Rabelais became intimate with this society. A manuscript distich, which was found in the Toulouse library, deals with the death of an infant named Théodule, whose country was Lyons and his father Rabelais, but we know nothing more about the matter. What makes the Lyons sojourn of the greatest real importance is that at this time probably appeared the beginnings of the work which was to make Rabelais immortal. There is no doubt that both Gargantua and Pantagruel were popular names of giants in the Middle Ages, though no mention of the former in French literature much before Rabelais's time has been traced. In 1526, however, Charles de Bordigné, in a satiric work of no great merit, entitled *la Légende de Pierre Faifeu*, has the name Gargantua with an allusion, and in 1532 (if not earlier) there appeared at Lyons *les Grandes et inestimables chroniques du grand et énorme géant Gargantua*. This is a short book on the plan of the later burlesques and romances of the Round Table. Arthur and Merlin appear with Grandgosier, as he is here spelt, Galemelle (Gargamelle), Gargantua himself, and the terrible mare. But there is no trace of the action or other characters of *Gargantua* that was to be, nor is the manner of the piece in the least worthy of Rabelais. No one supposes that he wrote it, though it has been supposed that he edited it and that in reality it is older than 1532, and may be the direct subject of Bordigné's allusion six years earlier. What does, however, seem probable is that the first book of *Pantagruel* (the second of the whole work) was composed with a definite view to this chapbook and not to the existing first book of *Gargantua*, which was written afterwards, when Rabelais discovered the popularity of his work and felt that it ought to have some worthier starting-point than the *Grandes chroniques*. The earliest known and dated edition of *Pantagruel* is of 1533, of *Gargantua* 1535, though this would not be of itself conclusive; but the definite description of Gargantua in the title as "Père de Pantagruel," the omission of the words "second livre" in the title of the first book of *Pantagruel* while the second and third are duly entitled "tiers" and "quart," the remarkable fact that one of the most important personages, Friar John, is absent from book ii., the first of *Pantagruel*, though he appears in book i. (*Gargantua*), and many other proofs show the order of publication clearly enough. Besides this, 1533 saw the publication of an almanac, the first of a long series which exists only in titles and fragments, and of the amusing *Prognostication Pantagrueline* (still, be it observed, Pantagrueline, not Gargantuine). Both this and *Pantagruel* itself were published under the anagrammatic pseudonym of "Alcofribas Nasier," shortened to the first word only in the case of the *Prognostication*.

On Oct. 23, 1533, *Pantagruel* was condemned by the Sorbonne, and in Jan. 1534 Jean du Bellay, passing through Lyons on an embassy to Rome, engaged Rabelais as physician. The visit did not last very long, but it left literary results in an edition of a description of Rome by Marliani, which Rabelais published in Sept. 1534.

In the spring of 1535 the authorities of the Lyons hospital, considering that Rabelais had twice absented himself without leave, elected Pierre de Castel in his place; but the documents do not imply any blame, and the appointment of his successor was once definitely postponed in case he should return. In the summer of 1535 Rabelais once more accompanied Jean du Bellay, now a cardinal, to Rome, and stayed there till April in the next year. To this period belong letters to Geoffroy d'Estissac, the already-mentioned *Supplicatio pro Apostasia*, and the bull of absolution which was the reply to it. This bull freed Rabelais from ecclesiastical censure, and gave him the right to return to the order of St. Benedict when he chose, and to practise medicine. He took advantage of this bull and became a canon of St. Maur. In 1537 he took his doctor's degree at Montpellier and lectured on the Greek text of Hippocrates, and in July 1538 he was present in the capacity of *maître des requêtes* at the conference between Francis I. and Charles V. at Aigues-Mortes. In 1540 we find him for the third time in Italy in the service of Guillaume du Bellay-Langey, elder brother of Jean, who was governor of Piedmont; and according to the letters of Pellicier, bishop of Montpellier and ambassador to Venice, Rabelais was then employed by him to collect mss. for the king's library. In Dec. 1540 he was compelled to return to France to clear himself of a charge of having revealed diplomatic secrets, but he rejoined Guillaume du Bellay at Turin in the following spring, and remained in his service until he died on Jan. 9, 1543. Rabelais wrote a panegyrical memoir of Guillaume, which is lost, and the year before saw the publication of an edition of *Gargantua* and *Pantagruel*, book i., together (both had been repeatedly reprinted separately), in which some dangerous expressions were cut away. Nothing at all is known of his life, whereabouts, or occupations till the publication of the third book, which appeared in 1546, "avec privilège du roi," which had been given in Sept. 1545.

Up to this time Rabelais, despite the condemnation of the Sorbonne referred to above, had experienced nothing like persecution or difficulty. Even the action of Dolet, who in 1542 reprinted the earlier form of the books which Rabelais had just slightly modified, seems to have done him no harm. But the storm of persecution which towards the end of the reign of Francis I. was fatal to Dolet himself and to Des Périers, while it exiled and virtually killed Marot, threatened him. It is certain that he passed nearly the whole of 1546 and part of 1547 at Metz in Lorraine as physician to the town at the salary of 120 livres, and Sturm speaks of him in a contemporary letter as having been "cast out of France by the times," and says that he himself in another letter gives a doleful account of his pecuniary affairs and asks for assistance. At Francis's death on March 31, 1547, Du Bellay went to Rome, and at some time not certain Rabelais joined him. He was certainly there before June 1548, and he was still there in Feb. 1549, when he dates from Du Bellay's palace a little account of the festivals given at Rome to celebrate the birth of the second son of Henry II. and Catherine de' Medici. This account, the *Sciomachie* as it is called, is extant. In the same year a monk of Fontevrault, Gabriel du Puits-Herbault, made in a book called *Theotimus* the first of the many attacks on Rabelais. It is, however, as vague as it is violent, and it does not seem to have had any effect. Rabelais had indeed again made for himself protectors whom no clerical or Sorbonnist jealousy could touch. The *Sciomachie* was written to the cardinal of Guise, whose family were all-powerful at court, and Rabelais dedicated his next book to Odet de Châtillon, afterwards cardinal. Thus Rabelais was able to return to France, and in 1550 was presented to the livings of Meudon and St. Christophe du Jambet. There is very little ground for believing that the "curé of Meudon" ever officiated or resided there. He certainly held the living for less than three years, resigning it in Jan. 1553 with his other benefice, and at the episcopal visitation of 1551 he was not present.

Some chapters of Rabelais's fourth book had been published in 1548, but the whole did not appear till 1552. The Sorbonne censured it and the parlement suspended the sale, taking advantage of the king's absence from Paris. But it was soon relieved of the suspension. He died, it is said, on April 9, 1553, but actual history is quite silent save on the point that he was not alive in May of the next year, and the legends about his deathbed utterances—"La farce est jouée," "Je vais chercher un grand peut-être," etc.—are altogether apocryphal. The same may be said of the numerous silly stories told of his life, such as that of his procuring a free passage to Paris by inscribing packets "Poison for the king," and so forth.

Ten years after the publication of the fourth book and nine after the supposed date of the author's death there appeared at Lyons 16 chapters entitled *l'Ile sonnante par maistre François Rabelais*, and two years later the entire fifth book was printed as such. In 1567 it took place with the others, and has ever since appeared with them. But from the beginning of the 17th century there have been disbelievers in its authenticity. The opponents of the book rely (1) on the testimony of a certain Louis Guyon, who in 1604 declared that the fifth book was made long after Rabelais's death by an author whom he knew, and who was not a doctor, and on the assertion of the bibliographer Du Verdier, about the same time, that it was written by an "écolier de Valence"; (2) on the fact that the anti-monastic and even anti-Catholic polemic is much more accentuated in it; (3) on the

arguments that parts are apparently replicas or rough drafts of passages already appearing in the four earlier books and (4) that some allusions are manifestly posterior to even the farthest date which can be assigned for the reputed author's decease. On the other hand, it is urged that, though Guyon and Du Verdier were in a sense contemporaries they wrote long after the events, and that the testimony of the former is vitiated, not merely by its extreme vagueness, but by the fact that it occurs in a *plaidoyer*, tending to exculpate physicians from the charge of unorthodoxy; that Du Verdier in another place assigns the *Prognostication Pantagrueline* to this same unknown student of Valence and had therefore probably confused and hearsay notions on the subject; that the rasher and fiercer tone, as well as the apparent repetitions, are sufficiently accounted for on the supposition that Rabelais never finally revised the book, which indeed dates show that he could not have done since the fourth was not finally settled until just before his death and that it is perfectly probable, and indeed almost certain, that it was prepared from his papers by another hand, which is responsible for the anachronous allusions above referred to. But the strongest argument, and one which has never been attacked by authorities really competent to judge, is that the "griffe de l'aigle" is on the book, and that no known author of the time except Rabelais was capable of writing the passage about the *Chats fourrés*, the better part of the history of Queen Whims (La Quinte) and her court and the conclusion giving the oracle of the bottle.

Gargantua and *Pantagruel* are, unfortunately, so little read that some sketch of their contents is necessary. The first book, *Gargantua*, describes the birth of that hero (a giant and the son of gigantic parents), whose nativity is ushered in by the account of a tremendous feast. In this the burlesque exaggeration of the pleasures of eating and drinking, which is one of the chief exterior notes of the whole work, is pushed to an extreme. Early, however, the author becomes serious in contrasting the early education of his hero—a satire on the degraded schools of the middle ages—with its subsequent and reformed stage, in the account of which all the best and noblest ideas of the humanist Renaissance in reference to pedagogy are put with exceptional force. Gargantua is recalled from Paris, whither he had been sent to finish his education, because of a war between his father, Grandgosier, and the neighbouring king, Picrochole. This war is described at great length, the chief hero of it being the monk Friar John, an unclerical cleric in whom Rabelais greatly delights. Picrochole defeated and peace made, Gargantua establishes the abbey of Thelema in another of Rabelais's most elaborate literary passages, where all the points most obnoxious to him in monastic life are indicated by the assignment of their exact opposites to this model convent. The second book introduces the principal hero of the whole, Pantagruel, Gargantua's son, who goes through something like a second edition of the educational experiences of his father. Like him, he goes to Paris, and there meets with Panurge, the principal triumph of Rabelaisian character-drawing, and the most original as well as puzzling figure of the book. Panurge has almost all intellectual accomplishments but is totally devoid of morality. This book, like the other, has a war in its latter part; Gargantua scarcely appears in it and Friar John not at all. It is not till the opening of the third book that the most important action begins. This arises from Panurge's determination to marry—a determination, however, which is half-hearted and which leads him to consult a vast number of authorities, each giving occasion for satire of a more or less complicated kind. At last it is determined that Pantagruel and his followers (Friar John has reappeared in the suite of the prince) shall set sail to consult the oracle of the *Dive Bouteille*. The book ends with the most obscure passage of the whole, an elaborate eulogy of the "herb pantagruelion," which appears to be, if it is anything, hemp. Only two probable explanations of this have been offered, the one seeing in it an anticipation of Joseph de Maistre's glorification of the executioner, the other a eulogy of work, hemp being on the whole the most serviceable of vegetable products for that purpose. The fourth and fifth books are entirely taken up with a description of the voyage. Many strange places with stranger names are visited, some of them offering obvious satire on human institutions, others, except by the most far-fetched explanations, resolvable into nothing but sheer extravaganza. At last the Land of Lanterns, borrowed from Lucian, is reached, and the oracle of the bottle is consulted. This yields the single word "Trinq," which the attendant priestess declares to be the most gracious and intelligible she has ever heard from it. Panurge takes this as a sanction of his marriage, and the book ends abruptly. This singular romance includes the most bewildering abundance of digression, burlesque amplification, covert satire on things political, social and religious, miscellaneous erudition of the literary and scientific kind. Everywhere the author lays stress on the excellence of "Pantagruelism," and the reader who is himself a Pantagruelist (it is perfectly idle for any other to attempt the book) soon discovers what this means. It is, in plain English, humour, which may be said to consist in the extension of a wide sympathy to all human affairs, together with a comprehension of their vanity. Moroseness and dogmatism are as far from the Pantagruelism of Rabelais as maudlin sentimentality or dilettantism. Perhaps the chief things lacking in his attitude are, in the first place, reverence, of which, however, from a few passages, it is clear he was by no means totally devoid and, secondly, an appreciation of passion and poetry.

For a general estimate of Rabelais's literary character and influence the reader may be referred to the article FRENCH LITERATURE.

However, there are three questions without the discussion of which this notice of one of the foremost writers of the world would not be worthy of its present place. These are—What is the general drift and purpose of *Gargantua* and *Pantagruel*, supposing there to be any? What defense can be offered, if any defense is needed, for the extraordinary licence of language and imagery which the author has permitted himself? What was his attitude toward the great questions of religion, philosophy and politics? These questions succeed each other in the order of reason, and the answer to each assists the resolution of the next.

According to some expositors, Rabelais is a sober reformer, an apostle of sound education, of rational if not dogmatic religion, who wraps up his morals in a farcical envelope partly to make them go down with the vulgar and partly to shield himself from the consequences of his reforming zeal. According to others, Rabelais is all this but with a difference. He is not religious at all; he is more or less antireligious and his book is more or less of a general protest against any attempt to explain supernaturally the riddle of the earth. According to a third class, the Rabelaisian legend does not so much err in principle as it invents in fact. Rabelais is the incarnation of the "esprit Gaulois," a jovial, careless soul, not destitute of common sense or even acute intellectual power, but first of all a good fellow, rather preferring a broad jest to a fine-pointed one and rollicking through life like a good-natured undergraduate. But it is impossible to think that any unbiased judge reading Rabelais can hold the grave-philosopher view or the reckless-goodfellow view without modifications and allowances which practically deprive either of any value. Those who identify Rabelais with Pantagruel strive in vain to account for the vast ocean of pure or impure laughter and foolery which surrounds the few solid islets of sense and reason and devotion. Those who identify Rabelais with Panurge can never explain the education scheme, the solemn apparition of Gargantua among the farcical and fantastic variations on Panurge's wedding and many other passages; while, on the other hand, those who insist on a definite propaganda of any kind must justify themselves by their own power of seeing things invisible to plain men.

No one reading Rabelais without *parti pris*, but with a good knowledge of the history and literature of his own times and the times which preceded him, can have much difficulty in appreciating his book. He had evidently during his long and studious sojourn in the cloister acquired a vast stock of learning. He was, it is clear, thoroughly penetrated with the instincts, the hopes and the ideas of the Renaissance in the form which it took in France, in England and in Germany—a form, that is to say, not

merely humanist but full of aspirations for social and political improvement, and above all for a joyous, varied, and non-ascetic life. He had thoroughly convinced himself of the abuses to which monachism lent itself. Lastly, he had the spirit of lively satire and of willingness *desipere in loco* which frequently goes with the love of books. It is in the highest degree improbable that in beginning his great work he had any definite purpose or intention. The habit of burlesquing the *romans d'aventures* was no new one, and the form lent itself easily to the two literary exercises to which he was most disposed—apt and quaint citation from and variation on the classics and satirical criticism of the life he saw around him. Here and there persons are glanced at, but for the most part the satire is typical rather than individual, and it is on the whole a rather negative satire. In only two points can Rabelais be said to be definitely polemic. He certainly hated the monkish system in the debased form in which it existed in his time; he as certainly hated the brutish ignorance into which the earlier systems of education had suffered too many of their teachers and scholars to drop. At these two things he was never tired of striking, but elsewhere, even in the grim satire of the *Chats fourrés*, he is the satirist proper rather than the reformer. It is in the very absence of any cramping or limiting purpose that the great merit and value of the book consist. It holds up an almost perfectly level and spotless mirror to the temper of the earlier Renaissance. The author has no universal medicine of his own (except Pantagruelism) to offer, nor has he anybody else's universal medicine to attack. It is not indeed possible to deny that in the Oracle of the Bottle, besides its merely jocular and fantastic sense, there is a certain "echo," as it has been called, "of the conclusion of the preacher," a certain acknowledgment of the vanity of things; but it is little more than a suggestion, and is certainly not strengthened by anything in the body of the work. Rabelais is, in short, if he be read without prejudice, a humorist pure and simple, feeling often in earnest, thinking almost always in jest. He is distinguished from the two men who alone can be compared with him in character of work and force of genius combined—Lucian and Swift—by very marked characteristics. He is much less of a mere mocker than Lucian, and he is entirely destitute, even when he deals with monks or pedants, of the ferocity of Swift. He neither sneers nor rages; the *rire immense* which distinguishes him is altogether good-natured; but he is nearer to Lucian than to Swift, and Lucian is perhaps the author whom it is most necessary to know in order to understand him.

If this general view is correct it will probably condition to some extent the answer to be given to the two minor questions stated above. The first is connected with the great blemish of *Gargantua* and *Pantagruel*—their extreme coarseness of language and imagery. Rabelais's errors in this way are of course, looked at from an absolute standard, unpardonable. But judged relatively there are several, we shall not say excuses, but explanations of them. In the first place, his comparative indecency has been much exaggerated by persons unfamiliar with early French literature. The form of his book was above all things popular, and the popular French literature of the middle ages as distinguished from the courtly and literary literature, which was singularly pure, can hardly be exceeded in point of coarseness. Moreover, Rabelais's coarseness, disgusting as it is, has nothing of the corruption of refined voluptuousness about it, and nothing of the sniggering indecency which disgraces men like Pope, like Voltaire, and like Sterne. The general taste having been considerably refined since, Rabelais has in parts become nearly unreadable—the worst and most appropriate punishment for his faults. As for those who have tried to make his indecency an argument for his laxity in religious principle, that argument hardly needs discussion. It is notoriously false as a matter of experience.

This brings us to the last point—what his religious opinions were. He has been claimed as a free-thinker of all shades, from undogmatic theism to atheism, and as a concealed Protestant. The last of these claims has now been very generally given up, but the accusation of free-thinking, if not of directly anti-Christian thinking, has always been more common. Those who hold this opinion, however, never give chapter and verse for it, and it may be said confidently that chapter and verse cannot be given. The sayings attributed to Rabelais which colour the idea are purely apocryphal. Even a jest at the Sorbonne couched in the Pauline phrase about "the evidence of things not seen," was removed by the author from the later editions. It must be remembered that the later middle age, which in many respects Rabelais represents almost more than he does the Renaissance, was, with all its unquestioning faith, singularly reckless and, to our fancy, irreverent in its use of the sacred words and images. On the other hand, there are in the book expressions which either signify a sincere and unfeigned piety of a simple kind or else are inventions of the most detestable hypocrisy. For these passages are not, like many to be found from the Renaissance to the end of the 18th century, obvious flags of truce to cover attacks—mere bowings in the house of Rimmon to prevent evil consequences. They are always written in the author's highest style, a style perfectly eloquent and unaffected; they can only be interpreted (on the free-thinking hypothesis) as allegorical with the greatest difficulty and obscurity, and it is pretty certain that no one reading the book without a thesis to prove would dream of taking them in a non-natural sense. There is absolutely nothing within the covers of Rabelais's works incompatible with an orthodoxy which would be recognized as sufficient by Christendom at large, leaving out of the question those points of doctrine and practice on which Christians differ. Beyond this no wise man will go, and short of it hardly any unprejudiced man will stop.

Bibliography.—The first complete edn. of R. was publ. by J. Martin (Lyons, 1567). It is computed that 60 edns. were printed before the close of the 16th century (P. P. Plan, *Biblio. rabelaisienne*, 1532–1711, 1904). The first critical edn. of importance is that of Le Duchat (Amsterdam, 1711). Since the elaborate edn. of E. Johanneau (9 vols., 1823) there have been many edns., M. Marty-Laveaux in the Collection Lemerre (6 tom., 1868–1903), R. Lefranc, and others. There have been many commentaries independent of edns., from J. Bernier's *Jugement et Nouvelles Observations sur les oeuvres . . . de M. F. Rabelais* (1697), onwards.

See monographs by E. Noel (1850); A. Mayrargues (1868); J. Fleury (1876); P. Stapfer (the best) (1889); H. Hatzfield (Leipzig, 1923); J. Plattard, *La Vie de Fr. R.* (1929); also L. Saineanu, *La Langue de R.* (2 tom., 1922–23), and *Le cinquème livre de R.* in Problèmes Littéraires du seizième siècle (1927); P. Villey, *Les grands écrivains du XVI siècle, R. et Marot*, in Bibl. Littéraire de la Renaissance, Tom. XI. (1923); J. Boulenger, *R. à travers les ages*, bibl. (1925); W. Nicati, *R. notre maître; son oeuvre, sa doctrine, le Pantagruelisme* (1926); *see* also *Revue des Études Rabelaisiennes* (1903–12), contd. as *Revue du seizième siècle* (1913, in prog.).

Rabelais was very early popular in England, and Sir T. Urquhart trans. the earlier books in 1653; Motteux finished it with an extensive commentary in 1694. In 1893 there was a new trans. (2 vols.) by W. F. Smith. For English criticism *see* A. F. Chappell, *The Enigma of R., an essay in Interpretation* (1924); N. H. Clement, *The Infl. of the Arthurian Romances on the five books of R.* (Univ. of California, 1926). *See* also S. P. Putnam, *Rabelais: Man of the Renaissance* (1929).

RABIES: *see* Hydrophobia.

RABIRIUS, a Latin epic poet of the age of Augustus. Among the papyrus fragments discovered at Herculaneum in the early part of the 19th century were sixty-seven (mutilated) hexameters, referring to the final struggle between Antony and Octavian and the death of Cleopatra, generally supposed to be part of a poem by Rabirius, since Seneca (*De Benef.* vi. 3, 1) informs us that he wrote on those subjects. If genuine, they justify the qualified commendation of Quintilian rather than the exaggerated praise of Velleius Paterculus (ii. 36, 3), who couples Rabirius and Virgil as the two most eminent poets of his time.

Fragments in E. Bährens, *Fragmenta Poetarum Romanorum* (1885); W. Scott, *Fragmenta Herculanensia* (Oxford, 1885); O. Ribbeck, *Geschichte der römischen Dichtung*, ii. (1889); M. Schanz, *Geschichte der römischen Litteratur*, ii. 1 (1899); Teuffel, *Hist. of Roman Literature* (Eng. trans., 1900), 252, 9.

RABIRIUS, GAIUS, a Roman senator, who was defended (63 B.C.) by Cicero in a speech still extant. Nearly forty years after the death of Saturninus, Titus Labienus was put up by Caesar to accuse Rabirius of the murder. The obsolete accusation of *perduellio* was revived, and the case was heard before Julius and Lucius Caesar as commissioners specially appointed (*duoviri perduellionis*). Rabirius was condemned, and the people were on the point of ratifying the decision on appeal when Metellus Celer dissolved the assembly.

A nephew known as C. RABIRIUS POSTUMUS, was also defended by Cicero (54 B.C.) in the extant speech *Pro Rabirio Postumo*, when charged with extortion in Egypt and complicity with Aulus Gabinius (*q.v.*).

See Cicero, *Pro Rabirio*, ed. W. E. Heitland (1882); Dio Cassius, xxxvii. 26–28; H. Putsche, *Über das genus judicii der Rede Ciceros pro C. Rabirio* (Jena, 1881); O. Schulthess, *Der Prozess des C. Rabirius* (Frauenfeld, 1891).

RACAN, HONORÉ DE BUEIL, MARQUIS DE (1589–1670), French poet, became page at the court of Henry IV. and then entered the army, seeing some active service. In 1625 he published his most important work, *Bergeries*, a dramatic pastoral. Racan was a follower of Malherbe, and was one of the original members of the French Academy. He died in February 1670.

His *Oeuvres complètes* which include versions of the Psalms and sacred odes, were edited by Tenant de Latour in 1857, and the edition includes a biographical notice. *See* Sainte-Beuve, *Causeries du lundi.*

RACCONIGI, a town of Piedmont, Italy, in the province of Cuneo, 24 mi. S. of Turin, and 31 mi. N. of Cuneo by rail, 837 ft. above sea-level. Pop. (1936) 6,552 (town), 8,209 (commune). It has a royal château (1570), which in 1900 became the summer residence of the king of Italy.

RACCOON, the typical representative of a family (Procyonidae) of American arboreal Carnivora (*q.v.*). The raccoon has a curious habit of washing its food in water before eating it. The typical raccoon (*Procyon lotor*) is a thickly built animal about 3 ft. long, of which the tail is 10 in., with a coat of long coarse grayish-brown hairs, short ears and a bushy black-and-white-ringed tail. It extends over the whole of the United States and reaches northward to southern Canada and southward into Mexico where it attains its maximum size. The following are from Dr. C. Hart Merriam's *The Mammals of the Adirondacks:*

THE RACCOON OR "COON" (PROCYON LOTOR), OF NORTH AMERICA

> Raccoons are omnivorous beasts and feed upon mice, small birds, birds' eggs, turtles and their eggs, frogs, fish, crayfish, molluscs, insects, nuts, fruits, maize, and sometimes poultry. Excepting alone the bats and flying-squirrels, they are the most strictly nocturnal of all our mammals. . . . They haunt the banks of ponds and streams, and find much of their food in these places, such as crayfish, mussels, and fish, although they are unable to dive and pursue the latter under water. . . . They are good swimmers. . . . The raccoon hibernates during the severest part of the winter. . . . It makes its home high up in the hollow of some large tree, preferring a dead limb to the trunk itself. . . . From four to six young are . . . born at a time. . . . The young remain with the mother about a year.

The South-American species, *P. cancrivorus*, the crab-eating raccoon, differs by its shorter fur, larger size, more powerful teeth, and other minor characters. It extends over most of South America, as far south as northern Argentina.

RACCOON-DOG (*Nyctereutes procyonoides*), a small wild dog, found in China, Japan and Amurland. The total length is about 32in. The prevailing hues are black and dusky yellow. In habit these dogs are nocturnal. In winter they feed on fish, and in summer on mice, forming small packs to hunt their prey.

RACEME, in botany, an inflorescence in which the main stem continues onwards, bearing the flowers on lateral branches, as in the wallflower (*see* CRUCIFERAE). A compound raceme is called a panicle. (*See* FLOWER.)

RACES OF MANKIND. The study of the varieties of the human race has occupied the attention of thinkers from early times. Two entirely different forms of classification have been employed, one based on the study of the skull, the second, and more generally used method, on superficial characters, such as skin and hair, which may be observed on the living man. To some extent these two methods have been combined in modern times.

Cranial Form.—Apart from Sergi, who elaborated a method of classification based on *cranial form*, the shape being estimated by viewing the skull from on top, most anthropologists have preferred to take measurements, especial importance being attached to the cephalic index—the percentage ratio of the length to the breadth—but numerous other measurements have been made, mostly of little value for classification. W. L. H. Duckworth suggested the combination of three characters on the skull, the cranial capacity, the cephalic index and the degree of prognathism (measured by taking the angle which the most projecting part of the jaw makes with the forehead). On the basis of the possible combinations of these criteria Duckworth divided mankind into seven groups.

Coefficient Method.—Karl Pearson devised a method, termed the coefficient of racial likeness, which aims by a method of averaging at including a very large number of measurements in a single figure. The method is complex, and depends on the difference between a series of measurements taken on a set of skulls belonging to one race, and those taken on a second set. There is less difference in those closely allied than in those more distantly related, and the coefficient is correspondingly smaller or bigger. The rather complex mathematical processes involved are the chief disadvantage of the coefficient method.

Colour Groups.—The oldest grouping of mankind, still in popular use, is that of skin colour. It has been suggested that the degrees in pigmentation of the human skin are due to the effects of environment, either to sunlight or humidity or a combination of both, the evolutionary changes which took place at an earlier date having become part of the heritage of the races we know to-day. Although the darkest skins are to be found in the tropics, whereas the fairest occur in the temperate climate of western Europe, attempts to correlate skin colour and environment break down when specific cases are considered. Some exceptions can be explained by recent immigration, others again, especially in the individual, by racial admixture, for where races are mixed we may find members of the same family who are very differently pigmented. On the whole the average value of the skin colour in various groups is correlated with other criteria, which appear to be good bases for classification.

One of the most important of these is the cephalic index. Taking the length as 100, the proportion of the breadth seldom falls below 70 or over 90, and it is usual to describe those peoples with an index below 75 as *dolichocephalic* (long-headed), those above 80 as *brachycephalic* (short-headed), the intermediate group being *mesocephalic*. Taken by itself, either in the individual or the race, the cephalic index is by no means a certain guide. We find brachycephalic, mesocephalic and dolichocephalic groups in all the greater divisions of mankind. In the individual, a series of 6,000 Japanese contained one man with an index of 69, and one of 96, and in a continuous series between these two extremes over 700 (about 12%) having indices between 80 and 81, the average being just under the latter figure.

Of the characters generally in use, however, the cephalic index shows most consistently the lowest *relative* variation within small groups. It is therefore of great value for classifying smaller units within the wider divisions, but deductions can only be drawn from the average of a reasonably large number of individuals, at least 50 of the same sex. The practice of artificial deformation may to a certain extent obscure the true head form, and where it occurs the cephalic index is often of little value.

Usually long heads are associated with long faces and vice versa, the face being then termed harmonic. A certain use of this fact has been made for classificatory purposes. There are other features of facial form which appear to be characteristic of different races, but are difficult to measure exactly.

Stature and Nose Form.—The *average* stature is a useful criterion. The form of the nose is estimated by an index formed by taking the length from the root to the junction with the upper lip as 100 and expressing the breadth across the nostrils as a percentage. Professor Thomson, to whom the idea was due, and Buxton have shown that the nasal index tends to be high in those countries where the air is moist and hot and low where it is cold and dry, the various combinations of these two factors being associated with corresponding nasal indices. The correlation is high with certain very marked exceptions, of which the most

important is the Australian aborigines. It seems probable that they migrated from a hot, moist climate, and that they have retained the form of nose most appropriate to such a climate. The evolution of any character needs the time factor, especially when, as in this case, evolution by elimination has played an important part.

Hair Form.—On the basis of the form of the hair, mankind may be divided into straight-haired (*leiotrichous*), woolly-haired (*ulotrichous*) and an intermediate group of wavy or curly-haired (*cymotrichous*). Certain types are difficult to define, but usually the distinction is clear-cut. All types of hair may occur in the same population, where racial admixture has taken place, but normally the variation is slight in the same group.

In section the woolly hair is flat and ribbon-like, straight hair is round, wavy and curly hair showing an elliptical form. Here also there may be a certain correlation with environment. The woolly hair occurs for the most part in the Tropics and may form a protection against the sun, being associated with special sweat-glands. The period at which the evolution of the hair form took place is uncertain, but it remains the most convenient basis for the ultimate classification of the great groups of man, the other criteria being subordinated to it. In this classification physical criteria alone have been used; all cultural or linguistic terms have been avoided. Owing to historical reasons certain peoples have been named after the languages they speak, and subsequently these terms have been applied to physical types. Terms like Malay, Dravidian, Mongol and Bantu are used as if they could be applied to races and not merely to peoples speaking certain groups of languages.

Other Classifications.—The classification given below is based on the anatomical characters already discussed; attention has, however, been recently directed towards certain physiological characters as a basis of racial differentiation. Several criteria have been put forward, amongst them the different reactions of the blood sera in divergent races and the effect of the ductless glands on the macroscopical anatomical characters. Although great stress has been laid on the latter, especially by Sir Arthur Keith, neither this nor other physiological criteria have to the present time been sufficiently investigated to form a basis for a novel classificatory method.

Straight-haired Groups.—The straight-haired peoples correspond to a large extent to the races called by some writers Mongol or Mongoloid, or "the Yellow-Brown Race." All these peoples possess cheek-bones of a greater or lesser degree of prominence. In most cases the face is flattened, often markedly so. The skin is usually yellow, shading into a coppery yellow or brown on one side, and on the other, especially in women, a pale almost white yellow tinge. In Asia the cephalic index tends to vary between mesocephaly and brachycephaly, with some marked cases of the latter form. In America the Eskimo are dolichocephalic and a wide range of mesocephaly and brachycephaly occurs among the other tribes.

While Haddon divides this race into three groups on the basis of a cephalic index, it is probably more convenient to adopt a primary geographical division and to separate the Leiotrichi into an Asiatic and American group, since the latter have been separated from their kinsmen in Asia for a long time and have to a certain extent specialised.

Asiatic Groups.—There are three groups in Asia, a northern or Arctic group, a central group, the Pareoeans (the Dwellers beside the Dawn) and a southern or Proto-Malay, it being possible that the two latter groups, formerly included under the term Southern Mongoloid, should be classed together.

The northern group is rather indeterminate, and includes a number of tribes living in the circumpolar regions of Asia and extending even as far west as northern Scandinavia, where they are represented by the Lapps. Most of these peoples have mixed with other races, to which fact their diversity is due, but they certainly include a mesocephalic and a round-headed subdivision. In eastern Asia at least there is a more northerly group, living in the most easterly extension of the continent and a more southerly group, but the difference is probably due to racial admixture, consequent on the intrusion of the peoples who brought in the Turko-Mongol culture from the west and thus divided the northern and central groups of the straight-haired peoples.

In Korea there is a narrow belt which forms a connecting link between the northern and the Pareoean peoples. The latter differ most strikingly from their northern neighbours in having less prominent cheek-bones and a broadish nose. In the north of China they are often tall; in the south, where the type is found in greater purity, they are short and more stockily built. The Japanese represent a special variety of this type; they have mixed considerably with the Ainu, and this, at least in some cases, has altered their physical type.

The southern extension of these peoples, the Proto-Malays, are widely spread in south-eastern Asia and in the islands. They have been mixed with the various other peoples of this region and it is often difficult to distinguish them except by their broader heads.

The straight-haired peoples also extend into Central Asia, where they are known as Turks and Mongols. These terms are cultural and linguistic, and cannot be used in a racial sense. Great racial admixture has undoubtedly taken place in this region and much of the population is closely connected with the peoples of the west, but types occur with straight hair and other characters which show affinities with the Arctic group.

Most remote from the straight-haired peoples and showing certain relationships to them are the Polynesians, who live on the islands of the Pacific from Samoa to Easter I. and Hawaii to New Zealand. They probably represent an old mixture between the Proto-Malays and a group of the curly-haired people called Nesiots (islanders, *see* below), but other admixture has taken place and their position is difficult exactly to determine.

The Amerinds.—As regards the American aborigines, for whom the term *Amerind* has become conventionalised, it has been disputed whether they should be considered to belong to one race or not. The Eskimo, who to-day inhabit the Arctic coast of America, with a western extension into Asia, and an eastern into Greenland, once lived as far south as the coast of Massachusetts, and survived near Quebec till comparatively recent times. They differ from the other inhabitants of America in many respects notably in having extremely long skulls (the western Eskimo differ somewhat in this respect), which are compressed laterally and are very high-pitched. They have broad faces, an unusual feature in people with a long skull, and very narrow noses. The jaws are exceptionally well-developed and the individual teeth are very large, possibly owing to the nature of their food.

The Amerinds themselves vary considerably in most of those characters usually considered to be of racial significance. Hrdlicka, however, believes that they all belong to the same race. Verneau has recently affirmed the concurrence of types akin to the Melanesians, a view previously held by others also. Haddon suggests with every degree of probability that side by side with the straight-haired peoples there is a cymotrichous type, which he has called Palaeo-Amerinds.

The subdivisions of the true straight-haired Amerinds are somewhat complicated and need not be discussed in great detail. The best basis for division is the cephalic index, but stature and other features must be taken into consideration. The nasal index, it should be noted, increases towards Central America.

The peoples of the north-west coast are most closely allied to the inhabitants of Asia, and are distinguished from the other Amerinds by their lighter skin colour. East of the Rockies and extending over the great plains and into the woodland area there is a group of tall tribes with mesocephalic heads, of whom the Sioux are a typical example. On the east coast in ancient times there was a different type with longer, narrower heads. On the American plateau and extending into central and southern America there is a round-headed type, of short stature and with straight noses, to whom the Maya of ancient times were akin. The Aztecs were more long-headed and their relationship with the more northerly peoples can be traced through some of the inhabitants of northern Mexico to-day.

The ethnology of South America is as yet not fully estab-

lished, but several types can be distinguished, one akin to the Maya peoples and a different type, with a round head and tall stature, in Patagonia, of whom the Fuegians are a branch. Side by side with these straight-haired peoples there exist traces of a curly-haired race, both in ancient deposits and also among some modern tribes. With the exception of the Palaeo-Amerinds the distribution of the straight-haired peoples is continuous, the Bering Strait dividing the Asiatic and American branches.

Woolly-haired Groups.—The woolly-haired people have an extremely discontinuous distribution, namely, an eastern habitat which stretches from the continent of Asia to Fiji, and a western, the greater part of Africa. Attempts have been made to bridge this gap. Hüsing believes that in ancient times short dark curly-haired peoples occurred on the Persian Gulf in localities where negroes are still found. These negroes are, however, the descendants of imported slaves, and there is no information of a definite character to support Hüsing's contention. Some of the jungle tribes of south India are said to have negroid characters, but at present no evidence has been collected to bridge the gap between the two groups, and the characters which link them may be due not to community of ancestry but to the effects of a tropical environment. While the original centre of dispersion of these peoples is at present uncertain, there are almost certainly secondary centres of dispersion in north-east Africa and eastern Asia.

In addition to woolly hair all these peoples have the following characters in common: dark skins sometimes almost black, broad noses, usually a rather small brain in relation to their size, especially among the taller members of the group, with forearms and shins proportionately long. In the skeleton there is a smoothness of contour which even in adults often recalls the bony form of a child, and among some members of the group the forehead has that prominent and smooth form which is so characteristic of the infant of our own race. In both eastern and western groups there is a division which includes some very small or pygmy peoples and another of medium or tall-statured tribes.

Eastern Group.—The eastern group may be divided on this basis into the pygmy Negritos and the taller Papuans and Melanesians. The former are all dark-skinned and have heads which are slightly rounded, the cephalic index varying from just under 80 to about 83. There are slight local differences due to the extreme isolation to which these peoples have been subjected. Four separate geographical groups occur, one in the Andaman Islands (the Andamanese), one in the central regions of the Malay Peninsula and eastern Sumatra (the Semang), a third in various parts of the Philippine Is., usually called after a well-known tribe, the Aeta and a fourth group called after a tribe in the western mountains of Dutch New Guinea, the Tapiro, who have left traces in other parts of New Guinea and probably also in parts of Melanesia. All these groups are isolated from one another and occupy as it were almost the circumference of a circle. The Andamanese occupy a very special position, both racially and geographically; they have been isolated for a long period and until recently were not in contact with any other race. Such measurements as have been taken indicate that these people are remarkably true to type and show little variation from the average. They are probably the one human group which can be considered a "pure" race.

The Papuans and Melanesians are distinguished from the Negritos by their greater stature and narrower heads; the former probably represent the original stock. At one time they had a wide distribution throughout all Melanesia, probably to Australia, and the extinct Tasmanian aborigines seem to have been a variety of this stock. To-day Papuans are found in New Guinea and in some of the most easterly of the Indian Archipelago islands. They may be distinguished from their kinsfolk by their retreating forehead, prominent brow-ridges and the form of their noses, which are often prominent and rounded, with a down-turned tip.

The Melanesians are extremely variable and include a variety of racial elements, though the basis of the stock is Papuan. The racial mixing which has taken place will account for the fact that, although they are usually woolly-haired, all varieties of hair are found. Stature is equally variable, although the average height is under 5 ft. 3 inches. The prominent brow-ridges so characteristic of the Papuans is not common and the nose is usually smaller than in these peoples. The Melanesians have a wide distribution from the coastal regions of New Guinea and the neighbouring islands to the Pacific from New Caledonia to the Admiralty Is., and as far eastwards as Fiji; formerly they seem to have extended over most of the Pacific.

The Bushmen.—The Bushmen, who belong to the second group of the woolly-haired peoples, are also short, though not of pygmy stature; they differ from the other Ulotrichi in having yellowish skins. Now restricted to the Kalahari desert, they formerly ranged over the whole of south Africa and possibly over a much wider area. Their hair is short and curls into little tufts like pepper-corns, giving the appearance of bald patches. The head is small and low and there is little or no forward projection of the jaw. The most distinctive character of the Bushmen is a great development of the buttocks (*steatopygia*); this feature is specially developed in the women. The Hottentots are closely allied to the Bushmen and possess most of the characters already described. They represent a cross between the latter and other negroid stocks.

True Negroes.—The true negroes inhabit the Guinea Coast, but their original range seems to have been over most of tropical Africa. They are tall with black or dark brown skins, long narrow heads and retreating foreheads and prominent jaws. The lips are thickened and everted and the nose is very broad. They have mixed with other elements and have produced hybrid stocks. In the upper Nile valley numerous tribes, called Nilotes, are to be found; they are characterised by a very tall stature, a slender build and extremely narrow heads. There is also a more round-headed strain, due probably to an early admixture with some curly-haired people. Most, if not all, of the Nilotes have been considerably altered by contact with other non-negro peoples. In central and southern Africa there are numerous negroid tribes characterised by a variety of physical form, due no doubt to racial admixture. The majority are long-headed with considerable variation in stature.

The Pygmies.—In the equatorial forests certain pygmy tribes live. These Negrillos differ from the tall negroes not only in their stature but also in the lighter colour of their skin, which is often yellowish and covered by a light down, and in the more rounded form of the head; the nose is broader even than that of the negro.

Curly-haired Groups.—The third great division of the human race, the curly-haired or Cymotrichous, occupies in many ways an intermediate position between the other two groups. Its distribution is world-wide, and it includes both undifferentiated and highly differentiated groups of mankind. The white races belong to this class. The centre of dispersion of the group was probably somewhere in Asia, but the precise limits of this cradle land have not yet been determined.

The hair varies from wavy to curly, and, whereas in other races it is, with but few exceptions, black or dark brown, in this group every shade occurs from a dead black to a fair straw colour; the brown, however, predominates. The skin colour is equally variable. Most members of this race have a fairly large brain in relation to their body size, but some of the more primitive members are extremely small-brained. The forehead in the males has usually a well-marked prominence over the eyes, the so-called "bar of Michael Angelo." The face is never flattened nor are the lips everted. The stature is very variable, but no pygmy types are found.

Every degree of cephalic index is found, and this still remains the most convenient method of simple classification. The race, however, contains certain sub-races which appear to be more primitive than others and the division into primitive and more advanced groups brings out certain points which may otherwise be overlooked. The primitive which survive are the Proto-Nordics, the Proto-Indics and the Australian aborigines. The Palaeo-Amerinds also probably belong to this class. The more advanced peoples include a dolichocephalic group, a mesoce-

phalic and a brachycephalic group.

Proto-Nordics.—The Proto-Nordics appear at one time to have had a wide distribution over northern Asia. Some of the present inhabitants of the Turkoman steppes present this type in an undifferentiated form, namely the Ainu, who have within comparatively recent times been driven out of the main islands of Japan, and who still inhabit the northern island (Hokkaido) Saghalien, and to the south the Riukiu islands. This curious people are of medium stature, very stockily built, with large heads and a marked bar across the forehead. They have an abundance of hair on the head and body and long, wavy beards. Their eyes are straight as in Europeans and their general appearance contrasts very strongly with the Japanese who to-day live amongst them.

Proto-Indics.—The Proto-Indics may be classed geographically into three, possibly four, divisions: first, the jungle tribes of southern India (some of the more primitive tribes of northern India also have affinities with this stock); secondly, the Vedda, the most primitive of the inhabitants of Ceylon; and thirdly, some of the more primitive peoples of the southern part of the Malay Peninsula, of whom the best-known are the Sakai and Senoi. In Sumatra and Celebes and possibly elsewhere in the Malay Archipelago there survive tribes who may be considered as a fourth division of the Proto-Indics, but here they have for the most part been mixed with other stocks. In much of southeastern Asia there is a racial background of Proto-Indics who have been overlaid by other invaders, but the stock has survived in a relatively pure state in the places enumerated above. The Proto-Indics have curly hair, very dark and often nearly dead black skins, a short stature and extremely broad noses.

The Australian Aboriginal.—The Australian aborigines almost certainly belong to the same stock, but they possess some special characteristics which may be due to the length of time they have been isolated from the parent stem. The skin is usually of a dark chocolate brown, the hair, which is somewhat variable but usually curly, is frequently very abundant on the face and body. The stature is medium, the nose very broad, and their most distinctive feature is the great bony development of the skull, including a great massing of bone over the eyes and a big development of the jaws and teeth. Whereas the Proto-Indics, notably the Veddas, have extremely small skulls, those of the Australians, though often containing an extremely small braincase, are always massively built, and the beetling brows, low forehead and projecting lower part of the face give the males a very characteristic appearance.

Advanced Long-headed Types.—The long-headed peoples of less primitive type can be divided into several groups, but it seems extremely probable that all belong to the same stock; most of them can be distinguished from the Proto-Indics by their greater stature, and all by the narrower form of the nose. Local groups of these peoples have become separated into sub-races which breed true.

Eastern Groups.—The most easterly representatives of these stocks in Asia are the *Nesiots,* who are found mixed with the straight-haired, round-headed Proto-Malays in the Malay Archipelago, in the Philippines, sporadically in southeastern Asia and in the interior of southern China; the exact extension of these peoples is not yet fully known. In southern India a large proportion of the population belongs to a second group, *Chersiots* (mainlanders, as opposed to *Nesiots, islanders*). They are here much mixed with Proto-Indics and round-heads. In the northern part of India the proportion of the round-heads is much greater, and in the northwest the round-headed element predominates. In Rajputana and in the Punjab there is another group of long-heads, to be distinguished from the Chersiots by their taller stature, fairer skins and narrower noses. These Haddon terms Indo-Afghans.

Western Groups.—Further west, in the horn of Africa and the desert between the Nile and the Red Sea, this stock is dominant in the population, though frequently mixed with negroes. These tribes represent the modern descendants of the Proto-Egyptian population. Among the groups of this stock with a white complexion several varieties may be distinguished: one, the *Eurafrican,* seems only to occur in isolated spots in north Africa and western Europe, including part of the British Isles, another is met with among the Bedouin Arabs, while the third or Mediterranean race forms the fringing population of the Mediterranean sea and the western Atlantic seaboard of Europe. In the eastern Mediterranean it is inextricably mixed with the Armenoid peoples.

Among the Mesocephals Haddon includes three groups; two, however, the Pyrenean and the Atlanto-Mediterranean are probably hybrids. The third, the Nordic, is more clearly marked and is characterised by fair skin and hair, blue eyes and a tall stature. To-day they form one element in the population of the British Isles and northern France, Belgium and Holland, and northern Germany. They predominate in Scandinavia.

The Round-headed Group.—The great round-headed branch of the Cymotrichi is conveniently called Eurasiatic. It extends all along the great mountain chain from the central plateau of France on the west to the Himalayas on the east. The Alpine branch of the family is distributed along the central massif of Europe into central and even Eastern Asia, the Armenoid or Illyrio-Anatolian has a more limited range in southeastern Europe and western Asia. They may be distinguished by the extreme flatness and height of the head. In the Pamirs, in Persia, and extensively in central Asia and in India, a separate branch of this race, the Pamiri, is found, while locally in western Europe isolated examples of two early groups, the Prospectatores and the "Beaker Folk" still survive. They probably resulted from early crossing of round-heads with Mediterranean and Nordic man respectively. All these peoples are marked by the roundness of their heads, their brown, auburn or black hair and somewhat sallow or olive skins. The eyes vary from brown to hazel, but blue eyes are found.

Most of the migratory movements which resulted in the present distribution of mankind took place too far back in history for us to estimate their exact course, but in all probability human stocks were evolved near the places where we first find them recorded in historic times. Some migrations belong to the domain of ancient history, but it is very doubtful how far these movements have actually affected the physical type. In all probability ethnological history has consisted chiefly of the gradual extension of dominant types. (*See* A. C. Haddon, *Races of Mankind,* 1924.)

(L. H. D. B.)

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RACHEL (1821–1858), French actress, whose real name was Elizabeth Felix, the daughter of poor Jewish pedlars, was born on Feb. 28, 1821, at Mumpf, in the canton of Aargau, Switz. At Reims she and her elder sister, Sophia, afterwards known as Sarah, joined a troupe of Italian children who made their living by singing in the cafés, Sarah singing and Elizabeth, then only four years of age, collecting the coppers. In 1830 they came to Paris, where they sang in the streets, Rachel giving such patriotic songs as the *Parisienne* and the *Marseillaise* with a rude but precocious energy which evoked an abundant shower of coppers. Étienne Choron undertook to give the two sisters gratuitous instruction, and after his death in 1833 they were received into the Conservatoire. Rachel made her first appearance at the Gymnase in Paul Duport's *La Vendéenne* on April 4, 1837, with only mediocre success. On June 12, 1838, she made her *début* at the Théâtre Français, as Camille in Corneille's *Horace,* when her remarkable genius at once received general recognition. In the same year she won a great triumph as Roxane in Racine's *Bajazet,* but it was in *Phèdre,* which she first played on Jan. 21, 1843, that her peculiar gifts were most strikingly manifested. Her range of characters was limited, but within it she was unsurpassable. She excelled in the impersonation of evil or malignant passion, in her presentation of which there was a majesty and

dignity which fascinated while it repelled. By careful training her voice, originally hard and harsh, had become flexible and melodious, and its low and muffled notes under the influence of passion possessed a penetrating quality that was irresistible. Perhaps her most successful appearance in plays by contemporary authors was in 1849 in Scribe and Legouvé's *Adrienne Lecouvreur*, which was written for her. In 1841 and in 1842 she visited London, where her interpretations of Corneille and Racine were the sensation of the season. In 1855 she made a tour in the United States with comparatively small success, but her powers had begun to deteriorate. She died of consumption at Cannet, near Nice, on Jan. 4, 1858, and was buried in the Jewish part of the cemetery of Père Lachaise in Paris. Rachel's third sister was Lia Felix.

See Jules G. Janin, *Rachel et la tragédie* (1858); Mrs. Arthur Kennard, *Rachel* (Boston, 1888); A. de Faucigny-Lucinge, *Rachel et son temps* (1910); L. Barthou, *Rachel* (1926); J. Agate, *Rachel* (1928).

RACHILDE (Mme. Alfred Vallette, née Eymery) (1862–1938). Rachilde made her name by a series of powerful, sensational novels, dealing in many cases with abnormal personalities. She was an admirable critic, and was for many years one of the principal critics of the *Mercure de France*.

Her works include *Monsieur Vénus* 1889, latest ed. 1926); *La Tour d'Amour* (1899); *La Maison Vierge* (1920); *Les Rageac* (1921); *Le Grand Seigneur* (1922). *See* André David, *Rachilde* (1924).

RACHMANINOFF, SERGEI VASSILIEVITCH (1873–1943), Russian composer and pianist, was born on his father's estate Oneg, near Ilmen Lake, Government of Novgorod, on April 2, 1873. At nine he became a pupil of Demjansky's at the St. Petersburg Conservatoire, going three years later to the Moscow Conservatoire, where he studied piano under his cousin, Siloti, and composition under Taneiev and Arensky. In 1892 he won a gold medal with his opera *Aleko*, which was favourably received when produced at Moscow, 1893. Concert tours in Russia and elsewhere followed. In 1899 he appeared in London as pianist, conductor and composer, and in 1902 he had great success in Vienna. In 1903 he went back to Moscow where he remained for three years as piano professor at the Maryinsky Institute, also conducting at Imperial opera. Subsequently he lived for several years in Dresden where he devoted himself mainly to composition, varied by occasional concert tours. In 1909 he paid his first visit to the United States; while in 1912–13 he conducted the Moscow Philharmonic Symphony orchestra. After the Russian revolution he escaped to Sweden, with his family, and in 1918 took up his permanent residence in the United States.

Among Rachmaninoff's many compositions, particularly notable are the *Second Symphony in E Minor*, his piano concertos, opp. 1, 18 and 30, *Rhapsody on a Theme by Paganini*, and *Etudes Tableaux*. His *Recollections*, dictated to his editor, Oskar von Riesmann, was published in 1934. He was internationally known for his creative ability as a composer, and for his technique and interpretation as a pianist. He died in Beverly Hills, Calif., March 28, 1943.

RACINE, JEAN (1639–1699), French tragic dramatist, was born at La Ferté-Milon (Aisne), and was christened on Dec. 22, 1639. His father was a solicitor, and held the office of *controleur au grenier à sel* at La Ferté. Racine's mother died when he was little more than a year old and his father married again but himself died soon afterwards, whereupon the poet went to his grandparents, who had strong Jansenist leanings. He was sent to the grammar school at Beauvais, and in Oct. 1655 was transferred to the school which the "Solitaires" had established at Port Royal. He was a diligent student, and wrote verse both in Latin and French, his Port Royal odes being far from despicable. In 1658 he was entered at the Collège d'Harcourt, and it is clear from his correspondence, which, as we have it, begins in 1660, that he was not at all of an austere disposition at this time, and that he was already given up irrevocably to literature. The marriage of Louis XIV. was the occasion of an ambitious ode, *La nymphe de la Seine*, which earned 600 livres, and in 1660 Racine finished one piece, *Amasie*, and undertook another, *Les Amours d'Ovide*, for the theatre. The first, however, was rejected by the actors of the Marais, and it is not certain that the other was ever finished. Racine's letters show that he was intimate with more than one actress at this time; he also made acquaintance with La Fontaine, and the foundations of the legendary "society of four" (Boileau, La Fontaine, Molière and Racine) were thus laid. In Nov. 1661 he went to Uzès in Languedoc to live with his uncle the Père Sconin, vicar-general of that diocese, whose attempts to secure a benefice for him were, however, in vain. Racine was back in Paris before the end of 1663, and an ode on the recovery of Louis XIV. from a slight illness secured him another grant of 600 livres in the summer of 1664. The ode in which he thanked the king for his presents, *La Renommée*, is said to have introduced him to Boileau, to whose censorship he was deeply indebted. Unfortunately there is a break in his correspondence after Nov. 1663, and from this time forward the gossip of the period, and the *Life* by his son Louis, who was only six years old when his father died, are our main sources.

The first but the least characteristic of the dramas by which Racine is known, *La Thébaide*, was played by Molière's company at the Palais Royal theatre on June 20, 1664. In Feb. 1665 the greater part of his second acted play, *Alexandre le Grand*, was read before a distinguished audience at the Hôtel de Nevers, and Molière's company played it on Dec. 4. But a fortnight afterwards *Alexandre* was played, "de complot avec M. Racine," says La Grange, by the rival actors at the Hôtel de Bourgogne, and Racine's friendship with Molière ended in consequence. If, however, *Alexandre* was the occasion of showing the defects of Racine's character as a man, it raised him vastly in public estimation as a poet. He was now for the first time proposed as a serious rival to Corneille, and the contrast between the two was accurately apprehended and put by Saint Evremond in his masterly *Dissertation sur l'Alexandre*, still the best criticism of the faults of Racine, though not of the merits, which had not yet been fully seen. It may be added that in the preface of the printed play the poet showed the extreme sensitiveness to criticism which often accompanies a tendency to criticize others. These defects of character showed themselves still more fully in another matter. The Port Royalists detested the theatre, and in Jan. 1666 Nicole, their chief writer, spoke of dramatic poets as "empoisonneurs publics." Racine immediately published a letter to the author, which, though very smartly written, is full of savage personalities. He had written a second pamphlet and was about to publish it when fortunately Boileau, who had been absent from Paris, returned and protested against the publication. It remained accordingly unprinted till after the author's death, and in later years he expressed bitter regret for having published the first.

After this disagreeable episode Racine's life, for ten years and more, becomes simply the history of his plays, if we except his liaisons with the actresses Mademoiselle du Parc and Mademoiselle de Champmeslé, and his election to the Academy on July 17, 1673. The series of his unquestioned dramatic triumphs began with *Andromaque* (Nov. 1667), and this play may perhaps dispute with *Phèdre* and *Athalie* the title of his masterpiece. It is much more uniformly good than *Phèdre*, and the character of Hermione is the most personally interesting on the French tragic stage. Whatever may be thought of the *tragédie pathétique* (a less favourable criticism might call it the "sentimental tragedy"), it could hardly be better exemplified than in this admirable play, which owes its success to the application of the most delicate art to the conception of really tragic passion. *Andromaque* was succeeded, at the distance of not more than a year, by the charming comedietta of *Les Plaideurs* (printed on Dec. 5, 1668). At first it was a complete failure, though Molière is reported to have said on leaving the house, "Que ceux qui se moquoient de cette pièce meritoient qu'on se moquoient d'eux"; but the piece was suddenly played at court a month later; the king laughed, and its fortunes were restored. It was followed by a very different work, *Britannicus*, which appeared on Dec. 13, 1669. This was much less successful than *Andromaque*, and seems to have held its own but a very few nights. Afterwards it became very popular, and even from the first the exquisite versification was not denied. But the

complete nullity of Britannicus himself and of Junie, and the insufficient attempt to display the complex and dangerous character of Nero are not redeemed by Agrippina, who is really good, and Burrhus, who is solidly painted as a secondary character. Voltaire calls it "la pièce des connaisseurs," a double-edged compliment. The next play of Racine has, except *Phèdre,* the most curious history of all. Henrietta of Orleans proposed the subject of *Bérénice* to Corneille and Racine at the same time, and both plays, but especially Racine's, were successful. *Bajazet,* first played on Jan. 4, 1672, has great technical merit, but it is impossible to imagine anything less oriental than the atmosphere of the piece, which is scarcely saved by its ingenious scenario and admirable style. This charge is equally applicable with the same reservations to *Mithridate,* which appears to have been produced on Jan. 13, 1673, and was extremely popular. Racine's next attempt, *Iphigénie,* was a long step backwards and upwards in the direction of *Andromaque.* Greek tragedy gave examples which prevented him from flying in the face of the propriety of character as he had done in *Bérénice, Bajazet,* and *Mithridate.* The date of its appearance is very uncertain. It was acted at court on Aug. 18, 1674, but it does not seem to have been given to the public till the early spring of 1675.

The last and finest of the series of tragedies proper was the most unlucky. *Phèdre* was represented for the first time on New Year's Day 1677, at the Hôtel de Bourgogne. Within a week the opposition company launched an opposition *Phèdre* by Nicolas Pradon, who had been employed to write it by the duchess of Bouillon and other influential enemies of Racine. So well had their measures been taken that the finest tragedy of the French classical school was all but driven from the stage, while Pradon's was a positive success. The unjust cabal against his piece no doubt made a deep impression on Racine. But it is impossible to decide exactly how much influence this had on the subsequent change in his life. For 13 years he had been constantly employed on a series of brilliant dramas. He now broke off his dramatic work entirely and in the remaining 20 years of his life wrote but two more plays, and those under special circumstances and of quite a different kind. He had been during his early manhood a libertine in morals and religion; he now became irreproachably domestic and almost ostentatiously devout. No authentic account of this change exists; what is certain is that Racine reconciled himself with Port Royal, accepted their doctrine of the incompatibility of the stage and the Christian life, and on June 1 married Catherine de Romanet and definitely settled down to a quiet domestic life, alternated with the duties of a courtier. His wife had money, and he had possessed for some time the post of treasurer of France at Moulins. His annual "gratification" had been increased from 800 to 2,000 livres, and in the year of his marriage he and Boileau were made historiographers-royal with a salary of 2,000 crowns. Racine's labours brought him, in addition to his other gains, frequent special presents from the king, and in 1690 he further received the office of "gentilhomme ordinaire du roi," which afterwards passed to his son. He had two sons and five daughters.

The almost complete silence which Racine imposed on himself after the comparative failure of *Phèdre* was broken once or twice even before the appearance of his two last exquisite tragedies. The most honourable of these was the reception of Thomas Corneille on Jan. 2, 1685, at the Academy in the room of his brother. The discourse which Racine then pronounced turned almost entirely on his great rival, of whom he spoke even more than becomingly. But it was an odd conjunction of the two reigning passions of the latter part of his life—devoutness and obsequiousness to the court—which made him once more a dramatist. Madame de Maintenon had established an institution at Saint Cyr for the education of poor girls of noble family; the tradition of including acting in education was not obsolete, and the favourite asked Racine for a new play suited to the circumstances. The result was the masterpiece of *Esther,* with music by Moreau, the court composer and organist of Saint-Cyr. The beauty of the chorus, the perfection of the characters and the wonderful art of the whole piece need no praise. Almost immediately the poet was at work on another and a still finer piece of the same kind, and he had probably finished *Athalie* before the end of 1690. The fate of the play, however, was very different from that of *Esther.* The public cared very little for it, but the just judgment of posterity has ranked *Athalie,* if not as Racine's best work (and there are good grounds for considering it to be this), at any rate as equal to his best. Thenceforward Racine was practically silent, except for a brilliant *Histoire abrégée de Port Royal* and four *cantiques spirituels,* in the style and with much of the merit of the choruses of *Esther* and *Athalie.* The general literary sentiment was against him, and his weakness for spiteful epigrams cost him many friends. At last even the king withdrew his favour. He died April 21, 1699, and was buried at Port Royal.

Racine may be considered from two very different points of view,—(1) as a playwright and poetical artificer, and (2) as a dramatist and a poet. From the first point of view there is hardly any praise too high for him. Every advantage of which the Senecan tragedy adapted to modern times was capable he gave it. He perfected its versification; he subordinated its scheme entirely to the one motive which could have free play in it,—the display of a conventionally intense passion, hampered by this or that obstacle; he set himself to produce in verse a kind of Ciceronian correctness. The grammar-criticisms of Vaugelas and the taste-criticisms of Boileau produced in him no feeling of revolt, but only a determination to play the game according to these new rules with triumphant accuracy. The result is that such plays as *Phèdre* and *Andromaque* are supreme in their own way. But his greatest achievements in pure passion—the foiled desires of Hermione and the jealous frenzy of Phèdre—are cold, not merely beside the crossed love of Ophelia and the remorse of Lady Macbeth, but beside the sincerer if less perfectly expressed passion of Corneille's Cléopâtre and Camille. He had cut away from himself, by the adoption of the Senecan model, all the opportunities which would have been offered to his varied talent on a freer stage, though the admirable success of *Les Plaideurs* makes us regret that he did not experiment further in comedy.

BIBLIOGRAPHY.—The first collected edition of Racine's works appeared in 1675–76; the last appeared in the poet's lifetime (1697), perhaps revised by him. Among posthumous editions the most important is that of P. Mesnard in the *Grands écrivains* series, 8 vol. (1865–73). Louis Racine's *Life* was first published in 1747. Among English imitations are the *Distressed Mother* of Ambrose Philips (1712) and the *Phaedra and Hippolytus* of Edmund Smith (acted in 1707); and a complete verse translation by R. B. Boswell (1889–91). *See* Sainte-Beuve, *Portraits Littéraires,* vol. i, and for criticism the studies by G. Larroumet (1898) and J. Lemaître (1908), and the *Life* by Mary Duclaux (1925). The case for and against Racine has been concisely stated by G. Lytton Strachey in *Books and Characters* (1922) and J. C. Bailey in *The Claims of French Poetry* (1907).

RACINE, LOUIS (1692–1763), French poet, second son and seventh child of Jean Racine, was born in Paris on Nov. 6, 1692. *La Grace* (1720) and *Religion* (1742), his most important work, are inspired by a sincere piety, and are written in verse of uniform clearness and excellence. His other works include epistles, odes, among which the *Ode sur l'harmonie* (1736) should be mentioned, *Mémoires* (1747) of Jean Racine, and a prose translation of *Paradise Lost* (1755). Louis Racine died on Jan. 29, 1763.

His *Oeuvres complètes* were collected (6 vol.) in 1808. The *Lettres inédites de Jean Racine et de Louis Racine,* containing a notice on Louis Racine by the Abbé A. de La Rogue, were published in 1862.

RACINE, a city in southeastern Wisconsin, U.S., on Lake Michigan, at the mouth of the Root river, 65 mi. N. of Chicago and 25 mi. S. of Milwaukee. It is served by the Chicago and North Western, the Chicago, Milwaukee, St. Paul and Pacific, and the Chicago, North Shore and Milwaukee railways. Located on Wisconsin highways 11, 20, 38 and 42, it is served by numerous motor truck and bus lines. The population in 1950 was 70,749 by federal census, and 67,195 in 1940.

Racine is Wisconsin's second largest manufacturing city. In 1947 there were 211 establishments employing 19,152 and paying salaries and wages totalling $61,492,000. The value added by manufacture was $109,752,000. Principal products include farm machinery, iron and steel castings, automotive parts, heating equipment, household appliances, electrical machinery and ap-

paratus, printing and publishing, food products, apparel, luggage, and wax polishes.

Racine was settled in 1834 by a lake captain, Gilbert Knapp. First known as Port Gilbert, Racine adopted the French name of the Root river in 1837. It was incorporated as a village in 1841 and chartered as a city in 1848.

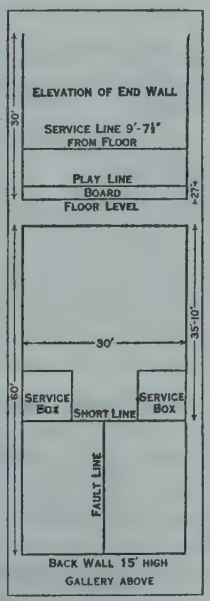
The Racine Zoological garden has a large collection of animals, birds and reptiles. Much of the park system is located along the shores of Lake Michigan and includes public golf courses.

RACKETS or **RACQUETS,** a game played in an enclosed court with a ball and an implement with which the ball is struck called a racket. This is about 2½ft. long and the head is tightly strung with cat-gut. No standard dimensions are laid down.

In the earliest days of the game, the head of the racket was inclined like a tennis racket. Later it was pear-shaped. In modern days it is nearly circular and some 7 or 8in. in diameter. The average weight of a racket is about 9 oz. and it is made of ash. Experiments have been made with metal frames but with no practical success. The balls are one inch in diameter and weigh one ounce. They are made of strips of cloth tightly wound over each other and then bound with twine, with a sewn covering of smooth white leather. In England the floor of courts is black or red in colour and the walls black.

In India and some other places in the East, where the floor and walls of the court are painted white, black balls are used. There has been no standard size laid down for a racket court but the great majority of courts are about 60ft. long by 30ft. broad. Both the single and the double or four-handed game are played in courts of this size nowadays. Formerly there were several courts as large as 80ft. by 40ft. built specially for the double game, but one or two of these alone now remain. Modern racket courts have four walls and a roof, but in India some courts are left unroofed for the sake of coolness.

The floor, which must be perfectly level and smooth, is made of cement. The floor cannot be too hard, since the faster the ball travels, the better the game; similarly the walls, which should be built of masonry faced with cement and most carefully smoothed, cannot be too hard and fast. The front and side walls are about 30ft. high, the back wall being about half that height, with a gallery for spectators (containing the marker's box) above it. The court is entered by a door in the centre of the back wall, which, when shut, must be perfectly flush with that wall, and without any projecting handle. The court is lighted from the roof. The diagram shows the divisions and the markings of the court. On the front wall is fixed a wooden board, the upper edge of which, 27in. from the floor, constitutes the "play-line," and which usually fills the whole space from that height to the floor; and at a height from the floor of 9ft. 7½in. is a second line, called the "cut-line" or "service-line," usually painted red or green. At a distance of 35ft. 10in. (in a court 60ft. by 30ft.) from the front wall and parallel to it, a line is painted on the floor, from wall to wall, called the "short-line"; and from the centre of the short-line to the centre of the back wall is the "fault-line," dividing into two equal rectangles the space between the back wall and the shortline. These lines again are usually red or green in colour.



PLAN AND ELEVATION OF RACKETS COURT

The rectangles are the service-courts and are called the right-hand and left-hand court respectively. Against the side walls outside these courts, but so that one side in each case is formed by the short-line, are squares called the service-boxes.

The Game.—Rackets is usually played either by two persons ("singles"), or four persons playing two against two ("doubles"); and the general idea of the game is the same as that in lawn tennis and fives, the object of the player in all these games being to score a point by striking the ball either before it reaches the ground or on its first bound, in accordance with the rules of the game, in such a way that his adversary may fail to make a "good," *i.e.*, a valid, stroke in return. In the four-handed game one of each set of partners takes the right-hand court and his partner the left. The game consists of 15 points called "aces." Aces can only be scored by the "hand-in" (the player, or side, having the service), and the "hand-out" must therefore win a stroke or strokes to obtain service before he or they can score an ace; in "doubles" each of the partners serves in turn, and both must therefore be ousted before "hand-out" obtains the service; but to this rule the first hand of each game affords an exception (*see* below). The right to serve first is determined by the spin of a racket and the service must be made in the following manner. The server, standing with one foot at least inside one of the service-boxes, must toss the ball from his hand, and while it is in the air he must hit it with his racket so that it strikes the front wall above the service-line and falls to the floor within the service-court on the opposite side; after striking the front wall the ball may, but need not, strike the side wall or back wall, or both, and it may do so either before or after touching the floor. The serve is a "fault" if the ball (1) strikes the front wall above the board but on or below the service-line, in which case it is called a "cut"; or (2) touches the floor on the first bound, outside the proper service-court, when it is called "short" or "fault" according to the position of its pitch (*see* below). If the "hand-out" player to whom the fault is served "takes" it (*i.e.*, if he plays at it), the fault is condoned and the play proceeds as if the serve had been good. If, however, the fault be not taken, the server must serve again from the same box; and if he serves a second fault he loses his "hand" or innings, and his partner or his opponent, as the case may be, takes his place. Two consecutive faults have thus the same result as the loss of a stroke in the rally by the "hand-in." A serve which makes the ball strike the board, or the floor before reaching the front wall, or which sends it "out-of-court" (*i.e.*, into the gallery or roof of the court), counts the same as two consecutive faults; it costs the server his innings. Skill in service is a most important part of proficiency in rackets; a player can seldom become first-rate unless he possesses a "strong service." A great deal of "cut" may be imparted to the ball by the stroke of the racket, which makes the ball in its rebound from the wall behave like a billiard ball carrying "side" when striking a cushion; and when this "cut" is combined with great pace in the bound of the ball off the side wall, the back wall, and the floor, at varying angles which the server has to a great degree under his control, it becomes exceedingly difficult for hand-out to "get up" the service (*i.e.*, to hit it on the first bound, sending it above the play-line on the back wall), and still more so to make a good stroke which will render it difficult for his adversary in his turn to get up the ball and thus continue the rally. Racket courts vary very much in pace and conditions and in some service is very much easier of return than in others, but it not infrequently happens that a long sequence of aces, sometimes the whole 15 aces of a game, are scored consecutively by service which hand-out is unable to return. A noteworthy instance of successful service occurred in the semi-final tie of the doubles Amateur Championship matches at the Queen's Club in 1897 when W. L. Foster opened service and scored all the aces in the first two games, and added six in the third, thus putting on a sequence of 36 aces before losing his "hand." To obtain first service is therefore an initial advantage, although in doubles it is limited by the rule that only one partner shall have a "hand" in the opening service.

The server may begin in either of the service boxes; but when he has started, the service must proceed from the two boxes alternately till the close of the innings of the side, whether singles or doubles. When the other side obtains the innings they may in like manner begin in either box, without regard to where the last service of their opponents was delivered. In singles, hand-out changes sides in the court after each serve, answering to the change over of the server; in doubles the serve is taken alternately

by the two hand-out players, who permanently occupy the right- and left-hand courts respectively, being allowed to change the order in which they receive the service at the end of any game or rubber. Except in the rare case of left-handed players most of the play in the left half of the court, including the taking of service on that side, is back-handed; and the stronger of the two partners in back-hand play usually, therefore, takes the left-hand court. The best position in the court for the hand-out about to take the serve depends entirely on the nature of the service, and he has to use his judgment the instant the ball leaves the server's racket in order to determine where it will strike the floor and at what precise point in its course it will be best for him to attempt to take it. A strong fast service, heavily cut, that sends the ball darting round the corner of the court, leaving the back wall at an extremely acute angle, or dropping almost dead off it, can only be got up by standing near the back wall a long way across the court and taking the ball by a wrist stroke at the last instant before it falls to the ground a second time. On the other hand, when the server avoids the side wall altogether and strikes the back wall direct and hard, whether he achieves a "nick" serve (*i.e.*, the ball striking precisely in the angle between the back wall and the floor) or hits the wall high up, hand-out will have little time to spare in changing position to get within reach of the ball. Many good players make a practice wherever possible, especially in the case of heavily cut service, of taking the service on the volley (*i.e.*, before the ball reaches the ground), sometimes of taking the ball after it leaves the side wall and before it reaches the back wall; practice alone enables the player to decide with the necessary promptitude how each stroke is to be played. In returning the service, or in playing any stroke during the rally, the ball may strike any of the other walls before the front wall. This "boasted" stroke is quite legitimate, often most valuable and sometimes indispensable. The tendency, however, in modern rackets is towards using it too frequently. Good play consists for the most part in hard low hitting, especially as close as possible along the side walls into the corners of the back wall. One of the most effective and beautiful but difficult strokes in rackets is the drop which occurs when the ball is hit so that it only just reaches the front wall and drops close to it. The "half-volley," in which the ball is struck at the moment of its contact with the floor and before it has had time to rise, is employed with great effect especially in hard play; it makes the return much quicker than when the ball is allowed to rise to the full length of the bound, and requires corresponding quickness on the part of the adversary.

If hand-out succeeds in returning the serve, the rally proceeds until one side or the other fails to make a good return. A good return means (1) that the ball is struck by the racket before its second bound on the floor, and without its having touched any part of the clothes or person of the striker or his partner; (2) that it is hit against the front wall above the board without first touching the floor or going out of court; and (3) that it returns off the front wall into play (*i.e.*, to the floor of the court or to an adversary's racket) without going out of court. If hand-in be the one to fail in making a good return, he loses his "hand," and (in singles) hand-out goes in and proceeds to serve; in doubles one of the hand-in partners loses his "hand," and the second partner goes in and serves till he in turn similarly loses his "hand," except that in the case of the opening service in the game there is (as already mentioned) only one "hand" in any event. If hand-out fails to make a good return to the serve or to any stroke in the rally, hand-in scores an ace, and the side that first scores 15 aces wins the game. When, however, the score reaches "13-all" (*i.e.*, when each side has scored 13 aces), hand-out may, before the next serve is delivered, declare that he elects to "set" the game either to five or three, whichever he prefers; and similarly when the score stands at "14-all," hand-out may "set" the game to three. He makes this declaration by calling "set-5!" or "set-3!" and it means that five aces, or three aces, as the case may be, shall be required to win the game. It is the player's first duty to give the opponent full room for his stroke, but in the confined space of a racket court it is not always easy and sometimes, especially in doubles, absolutely impossible not to obstruct him. The rules, therefore, carefully provide for "lets" (an old English word for impediment or hindrance) when in matches a "let" is claimed by any one of the players and allowed by the referee, or the referee and two umpires, as the case may be, the service or rally counts for nothing and the server shall serve again from the same service box.

In ordinary games, the marker makes the decision as to a let. It is the duty of the marker, who occupies a box in the gallery, to "call the game." As soon as the server serves the ball the marker calls "Play!" if the ball strikes the front wall above the service-line; and "Cut!" if it strikes below the service-line; if the ball falls in front of the short-line the marker calls "Short!"; if the wrong side of the fault-line he calls "Fault!"; but whether to be "cut," "short," or "fault," the serve counts as a fault in its effect. To every good return, as to every good serve, the marker calls "Play!" If a return is made after the second bound of the ball (called a "double") the marker calls "Double!" or "Not up!"; if the ball is hit into the gallery, or against its posts or cushions, or above the girders or cross-beams of the roof, he calls "Out-of-court!" At the end of every rally he calls the state of the game, always naming first the score of hand-in's—"One-love" (love being the term for zero) meaning that hand-in has scored one ace and hand-out nothing, "Two-love," "Five-all," "Five-ten," "Fourteen-eleven," when one player reaches 14 it is customary for the marker to call "game-ball," *e.g.*, "14–11 game-ball." When one side has scored 15, the marker calls "Game!" He then in similar fashion calls the state of the match—"Two games to one," or whatever it may be—before the beginning of the next game. The server in possession at the end of the game continues to serve in the new game, subject as before to the rule limiting the first innings of the game to a single "hand." The usual number of games in matches is five for singles, and seven for doubles. In matches where there are umpires and a referee, there is an appeal to them from the marker's decision except as regards questions relating to the service, on which the marker's decision is final.

Records.—Attempts have been made to trace rackets, like tennis, to an ancient origin; but although it is doubtless true that the striking of a ball with the hand or some primitive form of bat is one of the oldest forms of pastimes, and that rackets has been evolved from such an origin, the game as now known can hardly be said to have existed before the 19th century. The first school which took to rackets was Harrow in the 1820s. It was about the middle of the century that closed courts of the modern pattern began to be built, and the founding of Prince's club in 1853 increased the popularity and standing of the game immensely. Here there were a number of courts and the match court was a great favourite—"Old Prince's" came to an end in 1886 and the next year the Queen's club courts were built and were ready for play in 1888—the present Prince's club, Knightsbridge, which has a rackets court, was opened in 1889. Nowadays, largely because of the expense of the game, there is not so much play except at the British public schools as previously, and a number of courts went out of use in the 1930s. Several were converted into squash rackets courts including one of the two formerly existing at Queen's club, one of those at Prince's club and the one at Lord's.

See E. B. Noel and C. N. Bruce, *First Steps to Rackets* (1925).

(E. B. N.; A. Da.)

RACKHAM, ARTHUR (1867–1939), English illustrator, born Sept. 19, 1867. He studied at the Lambeth School of Art, London. His first publication was the illustrated *Rip van Winkle* (1905), followed by *Peter Pan* (1906), *Alice in Wonderland* and the *Ingoldsby Legends* (1907). In 1906 he gained a gold medal at Milan, and in 1911 at Barcelona. He was elected associate of the Société Nationale des Beaux-Arts in 1912, and in 1919 became master of the Art Workers' guild.

Later illustrations include those to *Undine, Grimm's Fairy Tales, Aesop's Fables,* Dickens' *Christmas Carol, Comus, The Tempest, The Compleat Angler,* Poe's *Tales of Mystery and Imagination* and *Peer Gynt.*

RADAR is an electronic device which provides man with the ability to detect and locate objects of a certain sort at distances and under conditions of lighting or obscuration which would render the unaided eye quite useless. Further, radar affords a means for extremely precise measurement of the range, or distance, to each of the objects it detects and locates—or "sees," for short. It can also measure the speed of such an object to-

ward or away from the observing station in a simple and natural way.

Radar is superior to the eye because it can see regardless of visibility conditions and because it affords an easy and accurate means for measuring target range and its rate of change. Radar is greatly inferior to the eye in respect of the detailed definition of the picture offered. Even the most modern radar equipment available in 1946 could show only the gross outlines of such an object as a ship; the eye can, if the ship is visible at all, pick out such details as the flags at the masthead. Largely because of this lack of detail in radar vision, the class of objects usefully seen by radar is smaller than the class of those distinguishable by the eye. Radar deals best with isolated targets in a relatively featureless background: aircraft in flight, ships on the open sea, islands and coast lines, and the like.

How Radar Works.—Radar is a coined word derived from the initial letters of the phrase "radio detection and ranging," Radio waves sent out from the powerful radar transmitter are reflected by objects in the vicinity. A tiny fraction of the outgoing energy returns as an echo to the radar receiver, which is usually located, for convenience, at the same place as the transmitter. The properties of the received echo are used to form a picture or to determine certain properties of the object which caused the echo. As we shall see later on, there are several different forms of radar system, making use of different properties of the received echo and involving different sorts of radio transmissions from the radar transmitter.

However, the form of radar which was used most during World War II, and the one which had reached the highest state of development at the end of that conflict, was pulse radar. When the word "radar" is used without qualification in this article, pulse radar will be meant.

Pulse radar is so called because the transmitter is keyed to send out short, very intense bursts or pulses of energy with a relatively long interval between pulses. The receiver is active during this interpulse interval. It receives echoes from the nearest objects soon after the transmission of the pulse, from objects at intermediate range later on, and from the most distant objects near the end of the interpulse interval. When sufficient time has elapsed to permit the reception of echoes from the most distant objects of interest, the transmitter sends another short pulse, and the cycle repeats.

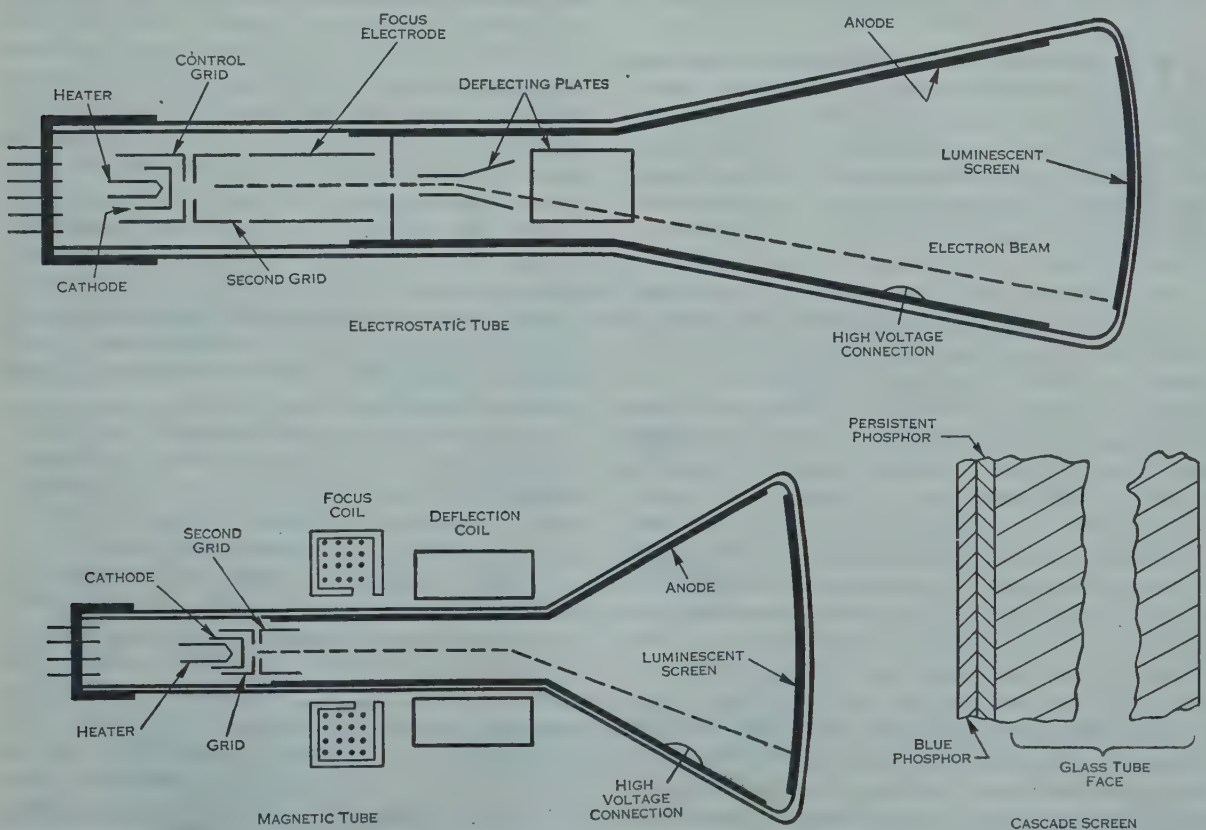
The delay between the transmission of the pulse and the reception of the echo is due to the fact that the radio waves used travel with the great but finite speed of light. In the units convenient in radar, the speed of light (about 186,000 miles per second, or 3×10^{10} cm./sec.) is 328 yd.[1] per millionth of a second, or microsecond (abbreviated μ sec.). Since the radio energy from the radar transmitter must travel the distance from the radar to the target twice, once out and once back as an echo, each μ sec. of delay between the transmission of a pulse and the reception of an echo corresponds to 164 yd. of range between radar set and target. If the delay corresponding to target range R is called T_R, it will be given by

$$T_R = \frac{2R}{c}, \qquad (1)$$

where c is the velocity of light.

This is the clue to the accuracy with which range can be measured by radar. Range measurement is reduced to the measurement of time, which can be performed more accurately than the measurement of any other basic quantity of physics. Very short intervals must be timed to get absolute precision in range, of course; if an error in range of only five yards can be tolerated, time intervals must be measured with an accuracy

[1] To fix in memory—this is about 1,000 ft. (984) in 1 μ sec.



FROM RADIATION LABORATORY SERIES, MCGRAW-HILL BOOK COMPANY, INC.

FIG. 1.—ELEMENTS OF A CATHODE-RAY TUBE

of one-thirtieth of a μ sec. Electronic timing and display techniques developed during World War II enabled such measurements to be made with great ease and convenience.

In 1945, for example, a serious map error was discovered by the use of bombing radar. This equipment enabled a bombing plane to find its position accurately by measuring the ranges to two fixed ground stations at which radar beacons (*see* below) were located. One beacon station was on the island of Corsica. A miss of about 1,000 yd., nearly 50 times the error expected, was scored on the first bombing mission carried out in Italy with this system. After an investigation of all possible sources of error, it was suggested that the reputed position of Corsica might be wrong. A correction of about 1,000 yd. in the position of the island was used on the next bombing run. The results, and those of later missions that used the corrected position of the island, were indistinguishable from those of optical bombing.

A cathode-ray tube (CRT) is almost always used for the display of radar signals. This device, shown schematically in fig. 1, has an "electron gun" at the base of its glass envelope, deflection plates or coils in the neck of the tube, and a luminescent screen on the inside of the large, nearly-flat face of the tube. The electron gun produces a narrow, accurately focused beam of electrons which is aimed toward the centre of the screen. This pencil of electrons can be deflected in its flight from gun to screen either by electric fields produced by voltages applied to deflection plates, or by magnetic fields produced by electric currents passing through deflection coils. A CRT using electrical deflection is referred to as an electrostatic CRT; one in which deflection of the electron beam is produced by magnetic fields is called a magnetic CRT. Means are almost always provided for producing two independent deflections of the beam at right angles to one another. When the beam of electrons strikes the screen covering the inner face of the tube, the impact of the electrons excites the luminescent material there and causes it to emit light.

Thus the CRT screen instantaneously displays a single small spot of light whose position depends on the deflecting voltages or currents effective at that instant. Because of the very small mass of an electron and the consequent small inertia of the electron beam, the spot can be deflected at very great rates of speed. "Writing speeds" (that is, speeds of CRT spot motion) of as much as 200 in. per μ sec. were practically used in laboratory test equipment during World War II. Writing speeds of 1/10 in. per μ sec. were common in service radar equipment. Not only the position of the spot can be controlled electrically, but also its intensity. The voltage applied to a "control grid" in the electron gun determines the electron beam current to which the light intensity produced at the screen is proportional.

One of the simplest ways of displaying radar signals is shown in fig. 1, Plate I. The beam of the CRT is swept across the face of the tube from left to right at a uniform rate of speed, beginning at the instant a pulse is sent out from the radar transmitter. Thus the distance the beam has travelled to the right from its initial position is a measure of the time which has elapsed after the transmission of the pulse, and the distance of an echo signal from the left end of the sweep is proportional to the range of the target causing the echo. The output signals of the radar receiver are applied to deflect the beam vertically, so that an echo appears as an upward deflection of the trace. To make sure that the weakest signals that are detectable at all are not missed, the over-all amplification of the receiver is great enough so that random electrical disturbances, called "noise," originating in the receiver, can be seen on the display. The two signals which rise perceptibly above this background of noise in fig. 1, Plate I, are, on the left, the "tail" of the transmitted pulse leaking into the receiver, and, on the right, the echo signals from a radar target. The target whose echo is shown in this figure is the earth's moon, 250,000 mi. away. The total time occupied by the sweep is thus some two and one-half seconds; the photograph is a time exposure which shows the whole path traced out during this time by the spot of light on the CRT face.

The type of indicator just described has come to be called an A-scope. Besides being simple, it affords an easy and straightforward way of measuring range. It makes no use of alterations in the intensity of the CRT spot.

In addition to finding target range, it is usually necessary to determine also the direction in which each target lies as viewed from the radar station. This could be done, in principle, by triangulation, using two or more simultaneous range readings on the same target as seen from separate radar stations. From the standpoint of simplicity, it is far preferable to measure both range and direction from a single radar station. This is possible if the radio energy sent out from the radar can be confined to a narrow beam, like that of a searchlight. Echoes will then be received only from targets which lie in the direction in which the beam is pointing. If the radar beam is swept, or scanned, around the horizon, the strongest echo will be received from each target when the beam is pointing directly toward it, weaker echoes when the beam points a little to one side or the other of the target, and no echo at all when the beam points in other directions. The bearing of a target can thus be determined by noting the direction in which the radar beam must be pointed to give the strongest signals from that target.

This can be done in several ways, some of which are highly precise. None is more graphic than the radar display called PPI, for plan position indication. The PPI shows the range and angular disposition of all targets seen by a radar set which is scanning around the horizon. Fig. 5, Plate III is a time exposure of a PPI indicator covering a full azimuth sweep. In the PPI, the radar echo signals from the receiver are applied to the control grid of the CRT indicator tube in such a way that the screen will be dark in the absence of a signal, and a bright spot will appear when a signal is received. The electron beam executes a sweep of uniform speed beginning at the instant each pulse is transmitted, just as in the A-scope, but in the PPI each of these sweeps commences at the centre of the tube and goes radially outward. Target bearing is indicated on the PPI by making the direction of each radial sweep on the indicator correspond to the geographical direction in which the antenna (and hence the radar beam) is pointing at that moment. North can be chosen to be at the top of the tube, for example; when the radar beam is pointing north, the radial sweep is executed from the centre upward. When the antenna has swung around to point east, the sweep on the PPI will take place from the centre to the right, and so on. The result is a map, on which the direction of each luminous spot marking a radar echo, measured from the centre of the tube, shows the bearing of the target causing the echo, and the distance of the spot from the centre of the tube face shows the target range.

Beside the A-scope and the PPI, many other forms of radar indicator have been devised for special purposes; some of these will later be catalogued.

The Basic Radar Set.—A radar set is shown schematically in fig. 2, separated into the major components fundamental to its action. The operation of these components is as follows.

A cycle of operation is begun by the firing of the modulator. This applies a high-power, high-voltage pulse to the magnetron, a type of transmitting tube developed specifically for radar use. For the brief duration of the modulator pulse, which may typically be 1 μ sec., the magnetron oscillates at a frequency of some thousands of megacycles per second (Mc./sec.)[1], transforming the D.C. power applied to it by the modulator into r-f (radio frequency) power with an efficiency usually larger than 50%. The r-f pulse thus produced travels down the r-f transmission line shown by double lines in fig. 2, and passes through the two switches marked TR and ATR. These are gas-discharge devices in which the discharge is initiated and maintained by the high-power r-f pulse produced by the magnetron. During this time, the TR (for transmit-receive) switch connects the transmitter r-f line

[1]The electromagnetic waves used in radar, like light and radio waves, can be characterized either by their wave length, λ, or by their frequency, ν. These two quantities are related, since their product is the velocity of propagation of light, c.

$$\lambda\nu = c$$

Numerically, a wave length of 10 cm. corresponds to a frequency of about 3×10^9 cycles/sec., or 3,000 Mc./sec.

to the antenna, and disconnects the mixer and the rest of the receiver, in order to prevent damage to these sensitive circuits by the high outgoing power. The ATR (for anti-TR) switch, when fired, simply permits the r-f pulse from the magnetron to pass through it with negligible loss. Between pulses, when these gas-discharge switches are in an unfired state, the TR switch connects the mixer to the antenna, and the ATR disconnects the magnetron in order to prevent any of the feeble received signals from being lost.

The r-f pulse, after passing through these two switches, travels down the r-f line to the antenna, where it is radiated. As is usual in radar, a single antenna is indicated in fig. 2 as being used both for transmitting and receiving; this requirement gives rise to the need for the duplexing arrangements involving the TR and ATR switches. The antenna design depends on the shape of radar beam required to meet the functional demands placed on the radar. It is almost always mounted on a scanner arranged to sweep the beam through space in the manner desired; simple azimuth rotation is indicated in fig. 2.

After the pulse has been transmitted, the discharges in the TR and ATR switches cease and the system is ready to receive echoes. These are picked up by the antenna and sent down the r-f line to the mixer. The mixer shown is identical with the usual mixer of a superheterodyne radio receiver; it is a non-linear device which, in addition to receiving the signals from the antenna, receives power from a c-w (continuous-wave) local oscillator operating at a frequency only a few tens of Mc./sec. away from the frequency of the radar transmitter. The difference frequency that results from mixing the echoes with the local oscillator signals contains the same intelligence as did the original echoes, but it is at a sufficiently low frequency (typically, 30 Mc./sec.) to be amplified by more or less conventional techniques in the intermediate frequency (i-f) amplifier shown. Output signals from the i-f amplifier are demodulated by a detector, and the resulting unipolar signals, still containing the echo intelligence, are further amplified by a video-frequency amplifier similar to those familiar in television receiver technique.

Output video signals are passed to the indicator for display. The indicator shown is a PPI which must, in addition to receiving echo signals from the indicator, receive a timing pulse from the modulator to indicate the instant for the start of each sweep. It must also receive from the scanner information on the direction in which the antenna is pointing, in order that the radial range sweep be executed in the proper direction from the centre of the tube. The necessary connections are indicated in fig. 2.

Each of the components shown in fig. 2 presented a series of difficult new problems of design during the period of radar development in the years 1935-45. Broad problems of component design are treated later in this article.

THE DEVELOPMENT OF RADAR

Early History.—Successful pulse radar systems were developed independently and nearly at the same time in the United States, England, France and Germany during the years 1935-40. In France and Germany the equipment was developed in commercial laboratories under military supervision; in Great Britain and the U.S. the pioneer development was in the laboratories of the armed services.

The independent occurrence of almost simultaneous and very similar radar developments in all these countries should not be surprising. The ideas basic to the radar art had been repeatedly enunciated during many years preceding the development of radar, and it is perhaps most surprising that practical radar systems were not developed at an earlier date.

Two ideas are basic to pulse radar: the echo principle and the method of using the travel time of pulses to determine target

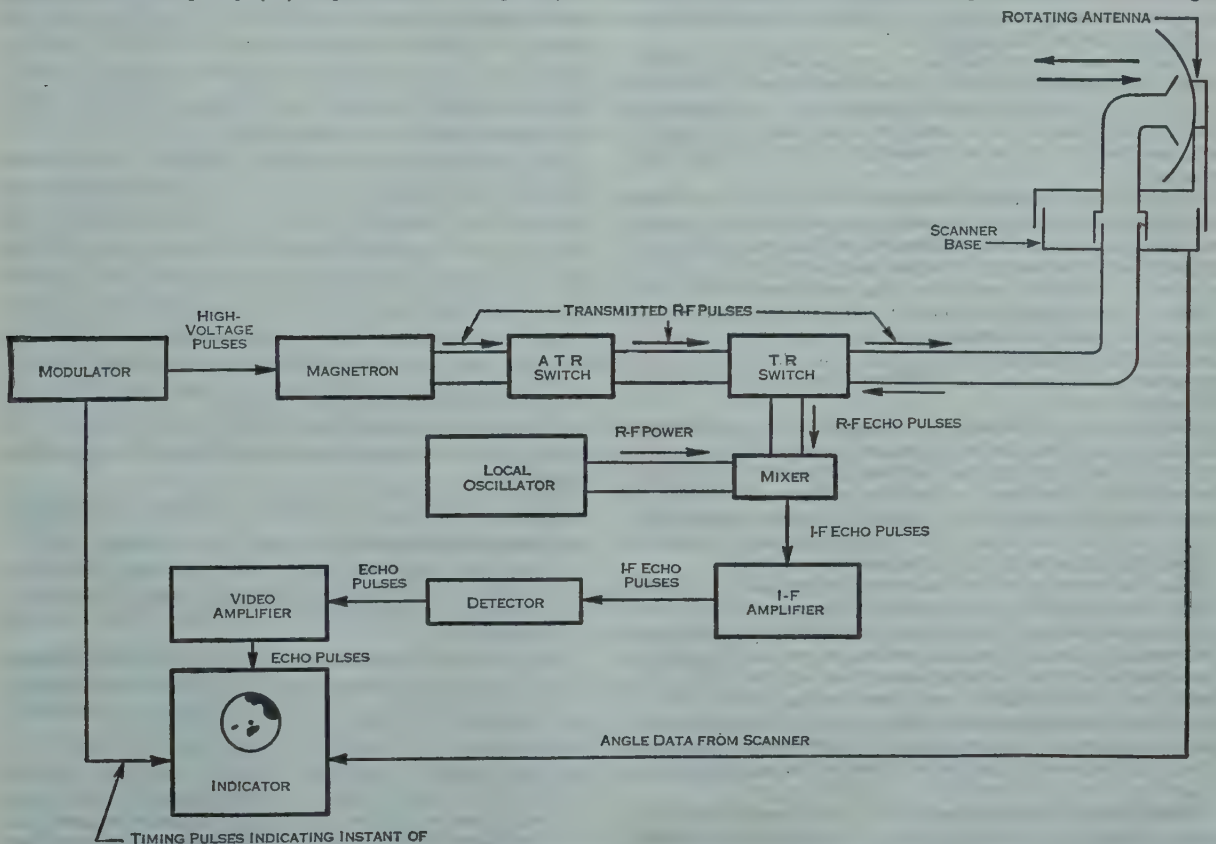


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FIG. 2.—BLOCK DIAGRAM SHOWING COMPONENTS OF A SIMPLE RADAR SET

range. The echo principle dates from the pioneer work of Heinrich Hertz on electromagnetic waves. Hertz found in 1887 that radio waves were reflected from solid obstacles, and this observation was repeatedly made in later years. It was even urged as a basis for a detection system; in 1904, a German engineer named Christian Hulsmeyer was granted patents in several countries on a radio-echo collision-prevention device. On June 20, 1922, Marchese Gugliemo Marconi was presented the medal of honour of the Institute of Radio Engineers at a dinner in New York city, N.Y. In the address he made on that occasion (from *Proceedings of the I.R.E.*, 1922) Marconi said:

> As was first shown by Hertz, electric waves can be completely reflected by conducting bodies. In some of my tests I have noticed the effects of reflection and deflection of these waves by metallic objects miles away.
>
> It seems to me that it should be possible to design apparatus by means of which a ship could radiate or project a divergent beam of these rays in any desired direction, which rays, if coming across a metallic object, such as another steamer or ship, would be reflected back to a receiver screened from the local transmitter on the sending ship, and thereby immediately reveal the presence and bearing of the other ship in fog or thick weather.

The pulse principle, almost exactly in the form in which it came to be used in radar, was employed in 1925 by Gregory Breit and Merle A. Tuve, of the Carnegie institution of Washington, D.C., in a series of experiments designed to measure the height of the ionosphere. The ionosphere is the layer of ionized gas near the top of the atmosphere which serves to reflect radio waves. The pulse-ranging method of Breit and Tuve was soon adopted by ionospheric investigators all over the world.

Research agencies of the U.S. army and navy have a long and complicated history of early experiment, total failure, and qualified success in the field of radio detection. The interested reader will find this dealt with fully in Dr. Henry Guerlac's history of radar cited in the bibliography.

The U.S. navy's first full success came in early 1939, when a radar set designed and built at the Naval Research laboratory was tested at sea during battle manoeuvres, mounted on the "U.S.S. New York." As a result of these trials, the first U.S. contract for the commercial manufacture of radar equipment was let.

In Nov. 1938, the coast artillery board of the U.S. army tested a radar position-finding equipment, designed for the control of anti-aircraft guns and searchlights, which had been built by the Signal Corps laboratories. This set, designed SCR-268, was also put into commercial production. An army long-range aircraft detection radar whose development had been requested in 1937 by the air corps was demonstrated to the secretary of war by the Signal Corps laboratories in Nov. 1939. A contract for the manufacture of this set, the SCR-270 (*see* fig. 2, Plate I), was let in Aug. 1940.

Development of British radar dates from the establishment by the air ministry, during the winter 1934-35, of a committee for the scientific survey of air defense. This committee received, among other suggestions, a carefully worked out plan for the radio pulse-echo detection of aircraft. This was proposed by a Scots physicist then heading the radio department of the National Physical laboratory, Sir Robert Watson-Watt.

The first experimental system of the type proposed by Watson-Watt was set up in the late spring of 1935 on a small island off the east coast of England. By the fall of 1935, the main features of a chain of warning stations to protect England had been worked out, and construction of the first five stations was begun in 1936. By March 1938 these stations, which protected the Thames estuary, were complete and in operation under royal air force personnel. A home chain of similar stations was erected about the borders of the United Kingdom in succeeding years. (*See* figs. 3 and 4, Plate I.)

Development emphasis then shifted to air-borne radar equipment. Two types were designed: (1) a set for the detection of surface vessels or surfaced submarines by patrol aircraft (called ASV, for air to surface vessel), and (2) an equipment to enable nightfighter aircraft to home on enemy aircraft (called AI, for aircraft interception). An experimental ASV system was successfully demonstrated during British fleet manoeuvres in Sept. 1938. Experimental AI equipment was demonstrated to the chief of R.A.F. fighter command in Aug. 1939.

The focusing of radar energy into sharp beams is especially important in the case of air-borne radar; for energy reflected when the radar beam strikes the ground or sea beneath the plane can mask entirely the much weaker echoes of the targets sought. Sharp beams can be obtained either by the use of very large antennas or very short radio wave lengths. Since large antennas cannot be carried in aircraft, short wave lengths are essential. The early British interest in military air-borne radar led to an intensive search for a type of radio transmitter which could give very high-power pulses at wave lengths of a few centimetres. By early 1940, the multicavity magnetron already mentioned had been developed to the point where it gave about ten kilowatts of pulse power. The invention of this tube made microwave radar practical for the first time, and the history of modern radar can be said to date from this device.

Wartime Radar Development in the U.S.—By the end of 1940, U.S. and British radar work was being carried out on a basis of full mutual exchange of information. A British technical mission visited the U.S. in Sept. and Oct. 1940, bringing full information on British radar developments, and samples of the newly-developed cavity magnetron. Arrangements were made for the continuing exchange of technical information and for the co-ordination of development effort.

In discussions with the Microwave committee of the U.S. National Defense Research committee, which had been set up a few month before, members of the British mission proposed that the U.S. undertake two specific microwave radar developments; (1) a microwave AI equipment, and (2) a microwave position finder for anti-aircraft fire control. To follow these suggestions, the Microwave committee of the N.D.R.C. made arrangements to set up a radar development laboratory staffed principally by physicists from a number of universities. The British had already established several highly successful civilian development agencies of a similar sort.

The Radiation laboratory, as the new N.D.R.C. establishment was named, opened its doors at the Massachusetts Institute of Technology, Cambridge, Mass., early in Nov. 1940. Its director throughout its 62 months of life was Dr. Lee A. DuBridge, on leave from the University of Rochester, later president of California Institute of Technology, Pasadena, Calif. The U.S. army and navy looked to the new Radiation laboratory for the development of microwave radar. Their own development agencies were already fully occupied with the many problems connected with getting the long-wave radar, already developed, through manufacture and into service use. At the end of 1940, the usefulness of microwave radar seemed highly speculative, and the army and navy laboratories quite properly felt it more important to concentrate their effort on radar techniques which had already been worked out.

During 1941, though not a single microwave radar equipment was delivered for service use, development work at the Radiation laboratory broadened far beyond the two specific projects which had been suggested by the British mission. Microwave equipment was showing great promise for many different wartime uses, and a considerable amount of army and navy interest was developing.

The tremendous expansion of the radar development program during the war years can be measured by the personnel figures of the various laboratories. The total personnel of the Radiation laboratory was about 40 at the beginning of 1941; by the middle of 1945 it had risen to its peak of nearly 4,000. The radar section of the Naval Research laboratory increased its personnel to about 600 in the same period. The radio position finding section of the Signal Corps laboratories grew into the Evans Signal laboratory, with a peak personnel of more than 3,000. A similar growth took place at the Aircraft Radio laboratory at Wright field, Dayton, Ohio.

Design staffs of some size were also maintained by the principal industrial concerns involved in the manufacture of radar equipment. The radar art advanced so rapidly during the early years of the war that manufacturers were often required to make major changes during the production of a given equipment in order to take account of new lessons either from the laboratory or from the battlefield.

Although the radar industry in the U.S. scarcely existed before 1940, it grew tremendously during World War II. At the end of June 1945, approximately $2,700,000,000 worth of radar equipment had been delivered to the army and navy, new equipment was being built at a rate exceeding $100,000,000 per month; and more than $1,500,000,000 worth of equipment was on order and not yet delivered.

Use of Radar in World War II.—The original use for which radar was developed was the detection of aircraft at ranges and under conditions of visibility which precluded locating planes in any other known way. The great success of the early British chain of stations in meeting the threat of the luftwaffe in the fall of 1940 showed the usefulness of radar in this role. As the war continued, many other uses for radar were developed, and special equipment was designed to fit these uses. The most important types of wartime radar sets are catalogued below.

Aircraft Warning.—The earliest sets used were those of the British home chain, shown in figs. 3 and 4, Plate I. These large installations used radio waves about ten metres in length, and gave their display on an A-scope. Target bearing was found by comparing the intensity of the target signal received on one fixed receiving array with the intensity of the echo from the same target received on another fixed array aimed in a different direction; the elevation angle of a target, and thus its altitude, was measured in a similar way. These CH radar stations, as they were called, remained the principal reliance of the British radar defense throughout the war, and were used in 1944 and 1945 for the detection of German V-2 rockets aimed at England.

Later aircraft warning sets used shorter radio wave lengths, usually about 1.5 to 3 metres. At this wave length, a relatively narrow beam can be produced by an antenna array small enough for installation on shipboard, or for use in a transportable ground equipment. At the same time, the use of a radar beam requires continuous scanning in azimuth in order to cover all directions from the station. Fig. 2, Plate I, shows the SCR-270, which is typical of sets of this type. Similar equipment was used aboard naval vessels for long-range aircraft warning.

In early 1944, there was introduced a microwave early-warning radar, operating on a wave length of 10 cm., which was highly successful. The radar beam produced by this set was only 1° wide in azimuth; in consequence, the ability of the set to resolve closely spaced targets on its PPI display was very much better than that of earlier equipments having broader beams. Fig. 1, Plate II, shows a photograph of the PPI of this set. The large R.A.F. raid shown on the scope comprises more than 500 individual aircraft, most of which can be seen separately. In situations of heavy air traffic, or under conditions where precise control of aircraft is important, such high radar resolution is extremely valuable.

Height Finding.—Sets like the microwave early-warning radar just described have no means for the measurement of target height. Often radar equipment was provided for this specific purpose. At the end of the war, microwave height-finders were the type most used. These sets had tall, narrow antennas which produced radar beams sharp in elevation angle but extending over several degrees in azimuth. This so-called "beavertail" beam was scanned up and down in the azimuth reported from the search set as being that of a target of interest. In the display, elevation angle of the beam and target range were shown on an intensity-modulated indicator in much the same way as azimuth and range are shown on a PPI. Target height could be read directly from the indicator. A British height-finder of this type is shown in fig. 2, Plate II.

Identification Equipment.—When a radar indicator shows echoes from dozens, or even hundreds, of aircraft, it becomes important to know which of these aircraft are friendly and which hostile.

This requirement was recognized by the British early in their work on radar, and they devised an identification system, called IFF (for identification as friend or foe), which was adopted by the Allied forces during World War II.

All friendly aircraft were equipped with a transponder—a radar beacon (*see* below) which gave a coded response when the aircraft carrying it was in the beam of a radar set. Arrangements were made to display this response on a scope which was either that used by the challenging radar set, or a special scope associated with the radar. Aircraft showing an IFF response were taken to be definitely friendly; aircraft not showing such a response were doubtful. Either they were hostile, or they were friendly planes whose transponders were out of order or not turned on.

While IFF was extremely useful in the early days of the war when aircraft density was still low, it failed operationally in the enormously high aircraft densities of the latter years of the war. Its development had not kept pace with that of radar itself, largely because IFF was regarded as so secret a device (despite the fact that dozens of IFF transponders descended on hostile territory each day in shot-down aircraft) that a full-scale development effort was never brought to bear on it. Instead, an attempt was made to restrict the number of individuals with a full understanding of IFF problems and techniques. A means for rapid and secure identification was, therefore, one of the unsolved operational problems of radar at the end of World War II. The British IFF equipment which had become standard was not generally used by Allied aircraft in Europe after June 1944 because of its inadequacy in high traffic densities.

IFF equipment of the standard type was also used by Allied naval vessels in order to identify friendly ships both to aircraft and to other surface vessels. In this use, of course, the problem of high density seldom arose, and maintenance of transponders was easier than it was in aircraft. IFF in ships was, therefore, considerably more reliable than it was in aircraft.

Control of Aircraft Interception.—The observation was early made by the British that, since both a hostile plane and a friendly fighter can be seen on the indicator of a single radar, it might be possible for a ground controller, viewing the radar scope, to coach the fighter into position to make an interception. The development of the plan position indicator greatly facilitated such ground control of interception. Special radar equipment, called GCI, was designed for this purpose in the earliest days of the war, and proved to be quite successful.

When the Germans abandoned daytime attacks on England at the end of 1940, the technique of ground control became much more exacting. It was no longer sufficient to bring the defensive fighters into the general vicinity of the enemy aircraft and then to rely on the pilot's vision to complete the interception. A skilful ground controller could, under favourable circumstances, bring a fighter close enough to his target to enable a visual contact to be made even at night; but this was so difficult that further radar aids to the interception were clearly needed.

AI Radar.—It was this reasoning which led to the development of radar for aircraft interception. Nightfighters were provided with air-borne radar sets with a range of a few miles against other aircraft. The ground controller coached the nightfighter into a position a mile or two behind the hostile plane, a little below, and on the same course. He then instructed the radar observer in the nightfighter to turn on his AI equipment. If the early phases of the interception had been successfully carried out, the hostile aircraft gave a signal on the AI radar, and the combat was joined on the basis of homing information made available by the nightfighter's own radar.

By the time reliable microwave AI equipment had been developed by the Allies in World War II, they enjoyed such thorough air superiority that it did not play a major tactical role. The early British 1.5 metre AI equipment used in 1940

and 1941 had many drawbacks, but it was sufficiently effective to enable the R.A.F. to master the night-bombing campaign of the luftwaffe.

Anti-aircraft Position Finders.—The earliest radar equipment developed for service use by the U.S. army signal corps was a set designed for giving accurate azimuth, elevation and range information on aircraft targets. It was intended for the control of anti-aircraft fire under conditions preventing visual tracking—at night or in overcast. Throughout World War II this was an important application of radar. The earliest equipments, working at "long" radio wave lengths of a metre or more, did not have sufficient accuracy to permit effective blind anti-aircraft fire.

The introduction of microwaves, however, enabled the design of radar position finders whose accuracy was good enough to permit blind fire that was as effective as visually controlled fire. The most successful of all Allied types of such equipment, the SCR-584, is shown in fig. 3, Plate II. This U.S. radar measured the azimuth and elevation angles of a target with an error of less than one-twentieth degree, and range with an error less than 25 yards. It was the first radar equipment which incorporated automatic tracking; when the SCR-584 was pointed at a target, it could be "locked on" in such a way that servo mechanisms actuated by the radar kept its antenna pointing continuously at that target. Under war conditions, the best U.S. anti-aircraft batteries made records in blind fire of only 40 rounds fired for each aircraft brought down.

Naval anti-aircraft fire was controlled by radar of a similar sort, although no navy, Allied or enemy, had an equipment for the purpose which was as effective or as satisfactory as the U.S. army's SCR-584.

Close Control of Aircraft.—The GCI techniques which were referred to above had as their aim the location of a friendly fighter in such a position that he could attack a hostile bomber, usually with the help of an AI radar carried by the nightfighter. Minor errors in positioning the friendly plane were usually relatively unimportant, and the target with respect to which the friendly plane was being positioned was an aircraft moving with a speed comparable with that of the plane under radar control. Both these facts simplified the GCI problem.

As the position-finding precision of radar grew, it began to be clear that a ground controller could direct aircraft accurately into a desired position with relation to ground targets. Two principal problems presented themselves during the war, of which one is important in peacetime air operations.

First, the tactical air commands which accompanied the U.S. armies on the continent of Europe were composed, for the most part, of fighter bombers. These single-seat aircraft were much too small to carry radar equipment, and the pilot of such a plane was much too busy to interpret its readings even if he had had radar. Nevertheless, the TAC aircraft had to operate often in conditions of greatly restricted visibility. Controllers located at ground radar sets had considerable success in guiding fighter-bombers of the TAC's to their targets by radiotelephone instructions. Even entirely blind bombing was done by such aircraft, altogether on the basis of course and release-time instructions received from a controller at a ground radar. The SCR-584, suitably modified, was used for this work.

The second application of close aircraft control from the ground is that of coaching a plane in to a landing under poor visibility conditions. A special high-precision radar set, called GCA (for ground controlled approach), was designed at the Radiation laboratory for this purpose. Though it emerged from production rather late in World War II, it was used quite successfully both in Europe and in the Pacific. Its use in peacetime air operations had commenced by 1946.

Surface Search and Fire Control.—In addition to locating aircraft and directing fire against them, radar was used during the war to locate and direct fire against surface vessels, both from other ships and from coastal defense stations. As will be seen in the next section, microwaves enjoy a great superiority in search for targets near the surface of the sea, so that it often happened that the same radar was used for search and for fire control against surface vessels.

Such radar could also locate precisely the splashes caused by the fall of shot, thus permitting the spot correction of unseen fire. In naval engagements in the Pacific, on several occasions, ships of the U.S. fleet engaged and sank Japanese vessels without ever seeing them visually.

ASV Radar.—Of the several types of air-borne radar equipment used in the war, that employed by patrol aircraft for searching out and attacking surface vessels was one of the most common. A ship on the open sea is an ideal radar target, and even quite primitive equipment suffices to home on such an object. As the art of radar design advanced, ASV equipment developed from a heavy, bulky installation to a compact and effective unit. Fig. 4, Plate II, shows one of the lightest and most compact ASV radars designed during World War II. This set was mounted in a streamlined housing shaped like a bomb, which could be hung from the bomb shackles of any standard naval aircraft. Its total weight installed was only about 150 lb.

ASV radar was most effective in the antisubmarine campaign. During much of 1943, German submarines were sunk at a rate not far from one per day, two-thirds of them by aircraft attack. Almost all of the aircraft attacks developed from radar sightings.

Means were also developed for bombing ship targets accurately on the basis of the radar display. In a single month, a single squadron of the U.S. 14th air force sank 110,000 tons of Japanese shipping in the China sea, entirely at night and entirely by radar.

Air-borne Radar for Navigation and Bombing.—During trials of AI and ASV radar, it was found that microwave equipment, with its narrow beams, could give a sufficiently good picture of the terrain beneath an aircraft to enable navigation by pilotage. Cities and built-up areas returned much stronger signals than open country, and hills, rivers, and coast lines were especially well defined. Examples of the indication offered by such air-borne radar are shown in Plate III.

The British R.A.F. bomber command pioneered in using such radar to guide its pathfinder aircraft. These planes, manned by specially chosen personnel, dropped on the target flares at which the main force aimed by ordinary optical means. The U.S. strategic air forces, committed to daytime bombing, found by experience that target visibility was often so poor that in order to maintain full operation they also needed such radar aids.

Because of an initial shortage of radar equipment, the U.S. 8th air force commenced radar operations on a pathfinder basis. However, the value of this equipment to a strategic air force became so clear in European operations that every B-29 sent to the Pacific had a radar of this sort installed in it.

Even on occasions when target visibility was good, the radar was useful in permitting the bombers to line up correctly on their approach to the bombing run. A medium-sized city is visible for about 50 miles on radar of wartime performance; it can rarely be seen as far as this with the eye. Of the 400,000 tons of bombs dropped by the 8th air force after Nov. 1943, when this equipment (called "Mickey, or H_2X) was introduced, more than half was aimed entirely by radar.

Beacon Bombing Systems.—Mention has already been made of the use of radar beacons for identification. Since these beacons give an immediate response to a radar challenge, they provide an excellent means for measuring the range to a point whose nature is known. Two such measurements based on a single point enable the exact position of such a point to be found by triangulation. Since range can be measured so conveniently and so accurately by pulse-timing methods, very precise position can be determined.

Two different bombing systems were based on this principle during World War II. In one of them, called "Oboe," the aircraft carried a radar beacon. The beacon was challenged by two ground stations, and the range of the aircraft from each station measured. Signals were sent to the plane by radio to keep it on a circular course of constant range from one station, called the

"cat." The other station, called the "mouse," sent to the aircraft signals indicating the exact moment of bomb release necessary to hit the previously chosen target.

The Oboe system was highly accurate; with good ground and air crews the operational errors were less than 250 yd. from an altitude of 30,000 ft. Its limitations were that, since it depended on the ability of ground stations to see the signals from a beacon in the bombing aircraft, it would not work over the optical horizon (about 250 mi. for an altitude of 30,000 ft.); and that it demanded a high degree of co-ordination between two widely-separated ground stations. Even with this co-ordination, it could handle only one aircraft at a time.

Despite the limitations of the Oboe system, the British used it quite successfully to guide the pathfinder aircraft of R.A.F. bomber command. The devastation of the Ruhr, which was just within Oboe range from the United Kingdom, was carried out almost entirely with the help of Oboe.

In the other type of beacon bombing system, called "H" by the British, beacons were placed on the ground at accurately located spots, and the interrogation and display equipment was carried in the bombing aircraft. A U.S. system based on this principle, called Shoran (for short range navigation), was highly successful during World War II. Though Shoran was subject to the same horizon limitation as that affecting Oboe, it did not suffer from as severe a limitation in traffic-handling capacity. Each aircraft could challenge the ground beacons independently of all other planes that might be doing so at the same time. It was with Shoran that the error in the map position of Corsica, already mentioned, was discovered.

Electronic Navigation Systems.—The beacon bombing systems and the air-borne radar for navigation that have just been described will be recognized as navigational equipment. They were rather specialized in nature, being designed for the exacting use of leading a bomber to its target. No such accuracy is needed to facilitate the ordinary en route navigation of aircraft from base to base. Radio-beam navigational aids to such en route navigation have been in use for years; but the development of pulse-timing methods for radar led to the development of navigational aids based on the pulse-ranging principle. Among the more important systems of this sort are the British Gee and the U.S. Loran.

Radar for Bomber Defense.—The vigorous opposition of German fighters to Allied bombing in the early days of World War II led to the U.S. development of light, compact radar to aid in air-to-air gunnery, intended principally to contribute to bomber defense. One type was an automatic radar range-finder for optically-aimed fire by daylight. Another provided complete position-finding to protect bombers against nightfighters under conditions precluding optical sighting. Both these equipments became available for service use at such a late date that fighter opposition had all but vanished, so that their operational usefulness was small.

Radar Countermeasures.—Use of radar by the Germans and the Japanese led to a considerable Allied effort in the field of countermeasures designed to mislead enemy radar or to render it ineffective. A similar effort was mounted by the Germans and the Japanese. These countermeasures took two forms; they consisted either of electronic "jamming" or "spoofing" of enemy radar by the transmission of suitably timed signals on the appropriate frequency; or, alternatively, they involved the dispersal of material which gave confusing radar reflections and thus hid attacking aircraft.

The second type of radar countermeasure was the most important single means of confusing enemy radar. Aluminum foil, cut into strips about a half wave length long at the enemy radar frequency, was the most commonly used form of material dispersed from aircraft to give false echoes. Such material was called "window" by the British, "chaff" by the U.S. AAF, and *Dueppel* by the Germans. Long-wave radar, with its broad beams, was the most readily confused by this means. Fig. 1, Plate II, shows the appearance on the scope of a 10-cm. radar of "window" cut to confuse the German 60-cm. radar. The false echoes are prominent, but not hopelessly confusing in this picture. German radar, however, could see the aircraft targets under these conditions only with the greatest difficulty.

For about 18 months, both the Germans and the British refrained from using this deceptive trick, on the theory that the other side was ignorant of the possibility of doing it. Once it was introduced, however, the R.A.F. bomber command dispensed in the form of window, on each full-scale raid, a weight of aluminum sufficient to construct three heavy bombers. Loss figures showed that the protection afforded by this amount of window saved, on the average, seven bombers per raid.

FACTORS AFFECTING RADAR PERFORMANCE

The Free-space Radar Equation.—A radar set must detect the weak signal returned from a distant reflecting object. The radar equation is important because it connects the various quantities that govern the strength of the signal so received. This relation will not serve to determine the maximum range at which the radar can detect a target unless the minimum power which gives a detectable radar signal, S_{min}, is known. The value of this latter important quantity will be found to depend on many factors, not all of which are accessible to measurement.

In discussing the radar equation, we first assume the very simple case of free-space propagation of the radio waves used in radar. This corresponds to a situation in which (1) no large obstacles intervene between the radar antenna and the target, along the optical line of sight; (2) no alternate transmission path, via a reflecting surface, exists for the radio energy; (3) the intervening atmosphere which must be traversed by the radio energy is homogeneous with respect to index of refraction at the frequency used; and (4) no appreciable absorption occurs in the atmosphere. These conditions restrict our attention to radar targets within the optical horizon, and in fact to targets high enough above the horizon to avoid important effects (*see* below) which arise from the reflection of an appreciable amount of energy from the surface of the land or sea. If the conditions of free-space propagation apply, the transmitted radio wave has spherical wave fronts (limited in extent by the directional properties of the antenna) which spread out in such a way that the intensity of the radio wave falls off with the inverse square of the distance from the radar antenna.

If the transmitting antenna radiated energy uniformly in all directions, the power flow through unit area at a distance R from the antenna would be the transmitted power, P, divided by $4\pi R^2$. Most radar antennas are directive, however, and concentrate the energy in certain directions, so that the power flow observed at some distant point will differ by a factor G from that which would be produced by an antenna radiating uniformly the same total power. The quantity G is called the gain of the antenna in the direction in question. Its average taken over a complete sphere surrounding the antenna must clearly be unity. As radar antennas are ordinarily highly directive, we shall usually be interested in the maximum value of G, which we call G_o. When the radiating system, or antenna, can be regarded as an aperture of large area (measured in square wave lengths), over which a substantially plane wave is excited, we can write a useful expression for the maximum antenna gain, G_o. The maximum antenna gain is related to the antenna area A and the wave length λ by the following relation:

$$G_o = \frac{4\pi A f}{\lambda^2} \qquad (2)$$

For actual antennas, the dimensionless factor f is usually about 0.6.

A second important property of an antenna is its effective receiving cross section. This quantity, whose dimensions are those of area, yields the total signal power available at the terminals of an antenna when an incident plane wave of unit power per unit area falls upon it. Effective receiving cross section is related to antenna gain as follows:

$$A_r = \frac{G\lambda^2}{4\pi}. \qquad (3)$$

In this equation, G has been written instead of G_o to emphasize that the applicability of Eq. (3) is not limited to the direction of maximum gain or to beams of special shape. Once the gain of an antenna in a particular direction has been specified, its effective receiving cross section for plane waves incident from that direction is fixed.

To obtain a measure of the amount of power reflected by the target, we define the radar cross section of the target, σ, as follows: σ is to be 4π times the ratio of the power per unit solid angle scattered back toward the transmitter, to the power per unit area in the wave falling on the target. In other words, if the power falling on an area σ located at the target position were to be scattered uniformly in all directions, the power received at the radar would be just the same as it is in the case of the actual target. Ordinarily, σ must be inferred by measurements on actual targets, since it depends in a complicated way on the wave length and on the angle at which a target is viewed.

We are now ready to formulate the radar equation. If S is the signal power received, P the transmitted power, G the antenna gain, λ the wave length, σ the radar cross section of the target, and R the range, or distance between radar and target,

$$S=\left(\frac{PG}{4\pi R^2}\right)\left(\frac{\sigma}{4\pi R^2}\right)\left(\frac{G\lambda^2}{4\pi}\right). \tag{4}$$

The quantity in the first parenthesis gives the power density at the target; when we multiply by the second parenthesis we obtain the power which returns to the radar antenna; the last factor is the receiving cross section of the antenna.
Rearranging,

$$S=P\frac{G^2\lambda^2\sigma}{(4\pi)^3R^4}. \tag{5}$$

This equation contains G, not G_o, and is thus valid for any direction. Usually we are interested in the return signal when the target lies somewhere along the direction the radar beam is pointing; G should then be replaced by G_o. If we then write G_o in terms of A, according to Eq. (2), we obtain

$$S=\frac{P\sigma A^2f^2}{4\pi R^4\lambda^2}. \tag{6}$$

The received signal power is proportional to the power of the transmitted signals, to the radar cross section of the target, and to the square of the antenna area. It is inversely proportional to the wave length squared, and to the fourth power of the range. If the minimum signal power required for detection, $S_{\min}$, is known, we can rearrange Eq. (6) to give the maximum range of detection, $R_{\max}$, for a target of given cross section, σ:

$$R_{\max}=\sqrt[4]{\frac{P\sigma A^2f^2}{4\pi S_{\min}\lambda^2}}. \tag{7}$$

To help fix ideas, it will be useful to give a numerical example of the use of this equation, with values for the quantities involved which were not unusual in wartime pulse radar practice. Let $\lambda=0.10$ ft. (=3.0 cm.), $P=10^5$ watts, $A=10$ ft.^{2}, $f=0.6$, $\sigma=100$ ft.^{2} (the radar cross section of a small aircraft), and $S_{\min}=5\times10^{-12}$ watts. We then obtain $R_{\max}=155{,}000$ ft. or 29 statute miles.

A sixteenfold increase in transmitted power is required to double the maximum range. It would appear that $R_{\max}$ could be doubled by doubling the linear dimensions of the antenna. However, this change cannot be discussed so simply, as the decrease in radar beam width resulting from making the antenna larger indirectly affects $S_{\min}$. A change in wave length is also difficult to discuss, since it produces changes in $S_{\min}$, P and possibly σ as well.

The Minimum Detectable Signal.—The reason that $S_{\min}$ has a finite value, and cannot be made indefinitely small, is that an amplifier intended to increase the power of a feeble electrical signal always produces random electrical fluctuations, called "noise." As the true signal entering any receiver is made weaker and weaker, it subsides eventually into the fluctuating background of noise and is no longer discernible.

The limit of sensitivity of an ordinary low-frequency radio receiver is set, not by internal noise, but by similar random disturbances which originate outside the receiver. These disturbances enter the receiver by means of the antenna, so that the effectiveness of a desired signal in competition with such interference is the ratio of signal to the interference power at the antenna terminals. The absolute level of interference power throughout the conventional radio bands (down to a few metres wave length) is so high that internal noise in a reasonably well-designed radio receiver is negligible by comparison.

The situation is different in the microwave region, where external noise interference is almost wholly negligible. Great effort has, therefore, been put on reducing the inherent noise of microwave receivers.

Quite general theoretical considerations give the result that the mean square noise voltage unavoidably generated in a receiver is proportional to the width of the band of frequencies amplified by the receiver. This band width will be denoted by B. The excellence of a receiver in respect of its noise output is usually specified in terms of an over-all noise figure, N. This quantity is more or less arbitrarily defined as the ratio to the quantity kTB of the signal power at the antenna necessary to make the output signal power equal to the mean noise power. In this definition, k is Boltzmann's constant (1.38×10^{-23} joules/degree), and the temperature T is taken as 291° absolute. Over-all noise figures of 10 were not uncommon in 1946 for the best microwave receivers. A noise figure of 10, at a bandwidth of 3 Mc./sec., means that an input signal of 1.2×10^{-13} watts is sufficient to increase the receiver output by an amount equal to the average noise output.

When a receiver is designed to detect pulses of duration τ seconds, there will be a best choice for the band width B. As already remarked, the average noise power increases in proportio. to B. However, this does not mean that B should be made as small as possible, for when B becomes much less than $1/\tau$, the output signal power resulting from each pulse will be proportional to B^2. Experiment has shown that the best value of B is about $B=1.2/\tau$, but it can be changed by small amounts from this best value without serious effect on performance. In 1946, a value of B near $2/\tau$ was typical of pulse radar practice.

What has just been said does not yet constitute a specification for $S_{\min}$, the minimum detectable signal. The noise with which a signal must compete for recognition is statistical in character; that is, while the likelihood of large noise peaks is small, such large peaks do occur. For example, in the output of a receiver whose band width is 2 Mc./sec., there is better than an even chance that one noise peak having more than 20 times the power of the average will be seen in an hour's observation. About 100 noise peaks greater than 10 times the average will be observed each second. This random character of the magnitude of noise peaks makes signal detection largely a game of chance. It is a game of chance in which several factors favour an actual signal, however. A true radar echo is repeated at the same point on the indicator for each successive sweep, while noise peaks occur at random locations. This important difference between a signal and noise can either be used by the indicator directly—if the indicator screen shows a stronger signal for repeated excitation in the same place—or by the eye and mind of the observer. The latter means is astonishingly effective, as has been shown by experiment. The practical effect of this phenomenon of integration, whether it occurs in the indicator or in the mind of the observer, is to make $S_{\min}$ depend upon the pulse repetition frequency, n, of a radar approximately in proportion to $1/\sqrt{n}$.

The problem of actual signal detectability is much more complicated than has been indicated here, and the interested reader is referred to J. L. Lawson and G. E. Uhlenbeck's book cited in the bibliography. It should be noted, however, that the very strong dependence of signal power on range shown by Eq. (6) illustrates the fact that most signals which are at all detectable will be very strong.

Propagation of Short Radio Waves.—We shall now examine the principal ways in which propagation conditions near the surface of the earth and through the atmosphere introduce effects which are not included in the free-space radar equation, Eq. (6). This is a vast subject, and only a few of the basic considerations can be mentioned here.

Effect of a Reflecting Surface.—If the transmission path between radar and target lies near a reflecting surface, energy may be able to reach the target (and scattered energy to return to the radar) by way of reflection from the surface, as well as directly (fig. 3). In the case of a flat, perfectly reflecting surface, the ratio, W, between the actual power at the point B of fig. 3 and the power which would have been observed at B for free-space conditions, can be readily computed. It depends on (among other things) the phase change produced in the reflected wave by the process of reflection. This phase change depends on the angle of incidence, θ, on the state of polarization of the incident wave, and on the electrical properties of the reflecting surface. In radar, only grazing angles of incidence are practically important, and only the surface of the sea is sufficiently smooth to be an adequate reflector for microwaves. Under these circumstances, the ratio of the power actually reaching B to that which would reach it under free-space conditions is given by

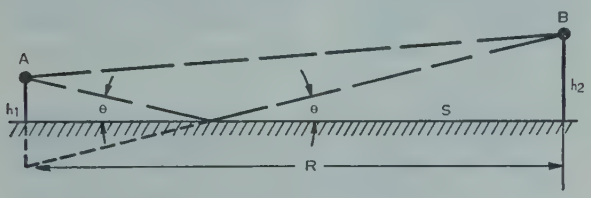

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FIG. 3.—RADAR PROPAGATION OVER A FLAT REFLECTING SURFACE. RADAR ANTENNA AT A, TARGET AT B

$$W = 4\sin^2\left(\frac{2\pi h_1 h_2}{\lambda R}\right). \tag{8}$$

This ratio, as shown by Eq. (8), varies between 0 and 4, the latter value being attained when the direct and reflected waves arrive at the target exactly in phase, as they will do when $4h_1h_2/\lambda R$ is equal to an odd integer. As the geometry of the problem is not affected by interchanging source and target, the reflection must affect the return of the radar echo to the same degree as it affects the pulse transmission. Therefore the required modification of the radar equation is obtained by multiplying the radar equation for free-space propagation by W^2, giving

$$S = P\frac{G^2\lambda^2\sigma}{(4\pi)^3R^4}\cdot 16\sin^4\left(\frac{2\pi h_1 h_2}{\lambda R}\right). \tag{9}$$

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FIG. 4.—LOBES OF SIGNAL-STRENGTH PATTERN RESULTING FROM INTERFERENCE OF DIRECT AND REFLECTED WAVES

The effect of this modification is to introduce a strong dependence upon target height into the expression for the signal returned by a target to a radar which looks out over the surface of the sea. This is important for ship-based and coastal radar sets. Radar coverage under such circumstances shows a strong "lobe" pattern like that of fig. 4. At the maxima of the lobes, the received signal shows an increase by a factor of 16, leading to a doubling of the maximum radar range against a given target. An aircraft flying high enough to be well above the lowest lobe shown in fig. 4 will give a signal which flashes up and disappears repeatedly as the plane flies in toward the radar at constant altitude. Under favourable conditions, target height can be estimated by noting the ranges at which signal "fades" occur.

For targets at low angles (*i.e.*, in the region where $\frac{2h_1h_2}{R\lambda} < 1$, we can replace the sine in Eq. (9) by its argument, obtaining

$$S = 4\pi P\frac{G^2\sigma(h_1h_2)^4}{\lambda^2R^8}. \tag{10}$$

In this region of angles, the signal strength falls off as the inverse eighth power of the range, rather than as the inverse fourth power, if all other factors are held constant. Since the range at which this eighth-power dependence begins varies as the reciprocal of the radar wave length for fixed heights of radar antenna and target, the shortest radar wave lengths have a very considerable practical advantage when the primary task of a radar is to search the sea for low-lying targets, the radar antenna itself being mounted at no great height. Experiments have borne out this conclusion, and microwaves were commonly used for ship-based sea-search radar sets during World War II.

The Round Earth.—Since beams of microwave radio energy travel substantially in straight lines, the distance at which a radar whose antenna is at height h_1 can see a target at height h_2 will be limited by the optical horizon. Actually, the diminishing density of the air with increasing height above the surface of the earth gives rise to a vertical gradient of atmospheric index of refraction, with the result that a slight downward curvature is introduced into all rays. The effect of this curvature is to extend slightly the practical horizon for microwaves. Due to a chance numerical relation between units, the following easily remembered formula gives R_h, the range to the horizon under "standard" conditions, for a height h above the surface of the earth:

$$R_h(\text{statute miles}) = \sqrt{2h(\text{feet})}. \tag{11}$$

If we desire to find the greatest range at which a radar whose antenna is at height h_1 can see a target at height h_2, we must add the corresponding horizon distances, obtaining

$$R = R_{h1} + R_{h2} = \sqrt{2h_1} + \sqrt{2h_2}. \tag{12}$$

Radio waves in the ordinary communication bands (down to a few metres wave length) are propagated over the horizon by either of two effects. At the very longest wave lengths, the energy is bent over the horizon by the phenomenon of diffraction. Energy can also travel around the curve of the earth, far beyond the horizon, because of the reflection of radio waves from the ionosphere, the ionized layer in the upper atmosphere. At radio

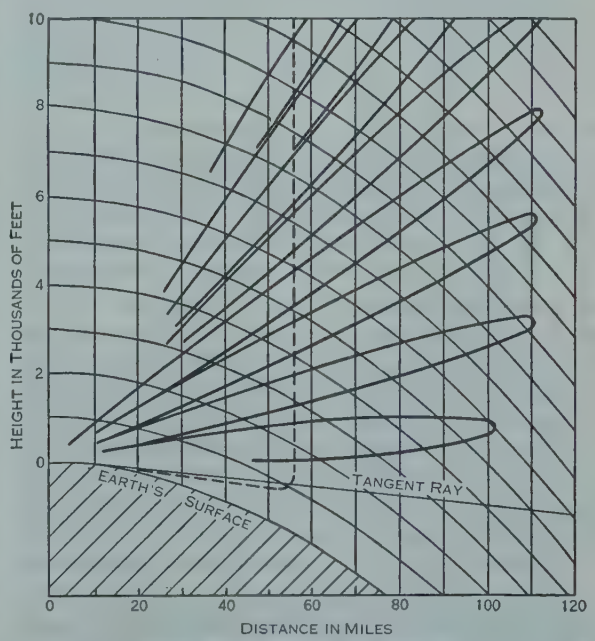

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FIG. 5.—COVERAGE DIAGRAM FOR 2,600 MC/SEC. RADAR WITH OMNIDIRECTIONAL ANTENNA AT HEIGHT OF 120 FT. SOLID CURVE FOR TOTALLY-REFLECTING EARTH, DOTTED CURVE FOR NONREFLECTING EARTH

frequencies around 100 Mc./sec., reflection from the ionosphere becomes spotty and does not always occur; in the microwave region, from about 1,000 Mc./sec. up to higher frequencies, the ionosphere is transparent to radio waves. Thus neither diffraction effects nor ionospheric reflection can enable microwave radar to detect targets over the horizon.

Within the horizon, the curvature of the earth complicates somewhat the geometry of the interference problem involving reflection. Eq. (9) and (10) are not strictly applicable, for they were derived on the assumption of a flat reflecting surface. The result of taking the earth's curvature into account can be shown by means of a coverage diagram (fig. 5). The curves of fig. 5 are contours of constant field strength, which means that the signal received from a given target will be the same no matter where it is located along a given contour.

Superrefraction.—It has already been mentioned that the atmosphere normally shows a vertical gradient of refractive index that results in a slight downward bending of rays of light or microwaves. Were this curvature only a few times greater, it would equal the curvature of the earth; under such conditions the "horizon" would vanish and a ray would bend around the earth without leaving the surface. Refractive index gradients of the magnitude necessary to produce such curvature amount to about five parts in 10^8 per ft. Under some conditions such gradients can be produced by temperature gradients alone, or, more commonly, by a vertical gradient in the concentration of water vapour in the atmosphere. Over the surface of the sea, the effects of evaporation of water into the air immediately above the surface and the diffusion of water vapour into still higher layers of air lead sometimes to the creation of a relatively shallow layer just above the water within which the vertical gradient of refractive index is negative and exceeds the critical value of five parts in 10^8 per ft. Under such circumstances, superrefraction takes place, and it is possible for microwaves to be propagated to distances many times the usual horizon distance. This phenomenon is specially common in certain parts of the world where climatic conditions favour its occurrence.

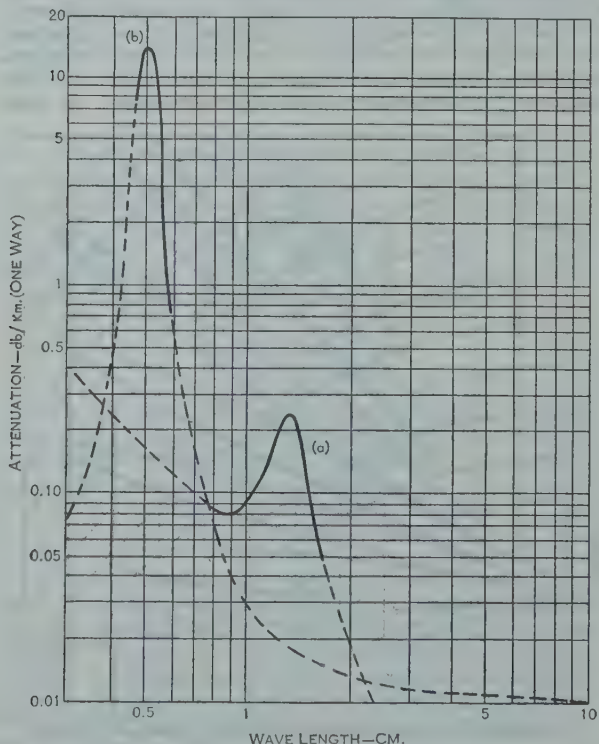

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FIG. 6.—ATTENUATION CAUSED BY WATER VAPOUR (CURVE a) AND BY OXYGEN (CURVE b) AS A FUNCTION OF WAVE LENGTH. CURVE a APPLIES TO AN ATMOSPHERE CONTAINING 10 GRAMS OF WATER VAPOUR PER CUBIC METRE. CURVE b APPLIES TO AN ATMOSPHERE WHICH IS 20% OXYGEN AND HAS A TOTAL PRESSURE OF 76 CM. OF MERCURY

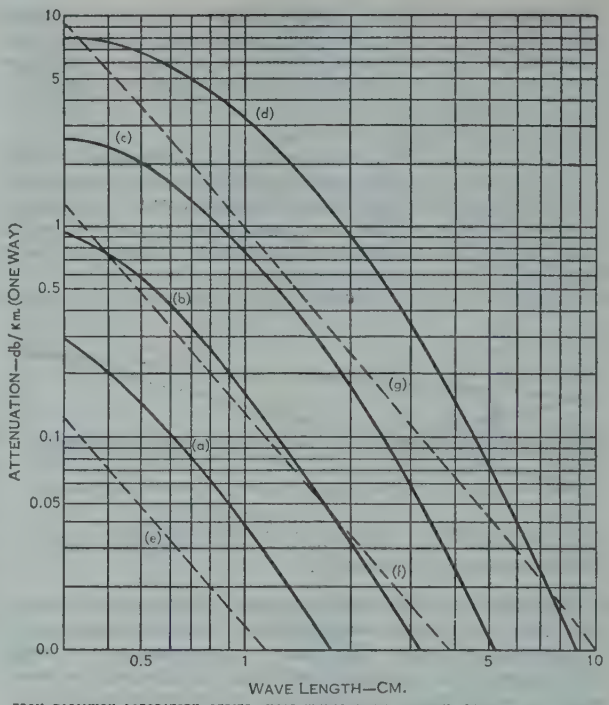

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FIG. 7.—ATTENUATION OF SHORT RADIO WAVES IN RAIN (SOLID CURVES) AND FOG OR CLOUD (DOTTED CURVES). CURVE a, DRIZZLE (0.25 MM./HR.). CURVE b, LIGHT RAIN (1.0 MM./HR.). CURVE c, MODERATE RAIN (4 MM./HR.). CURVE d, HEAVY RAIN (16 MM./HR.). CURVE e, FOR VISIBILITY ABOUT 2,000 FT. (0.032 GRAMS WATER PER CU. METRE). CURVE f FOR VISIBILITY ABOUT 400 FT. (0.32 GRAMS WATER PER CU. METRE). CURVE g FOR VISIBILITY ABOUT 100 FT. (2.3 GRAMS WATER PER CU. METRE)

Atmospheric Attenuation.—At the shortest microwave lengths, the earth's atmosphere is not entirely transparent, as it is for all practical purposes to waves of frequency lower than about 1,000 Mc./sec. The loss of energy, or attenuation, of a radar beam travelling through the atmosphere may be due to either of two causes: (1) direct absorption of energy in the gases of the atmosphere; or (2) absorption and scattering of energy by condensed matter such as raindrops. All such processes lead to an exponential decrease of energy in the beam with increasing distance from the source. This exponential decrease is superimposed on the inverse-square decrease in energy with increasing range that was used in formulating the radar equation. Of the atmospheric gases, oxygen and water vapour absorb microwave energy in the frequency range experimentally accessible in 1946. This absorption is due to the production thereby of a transition of the molecule of water vapour or of oxygen between two definite energy states. The observed absorption is thus characterized by "lines" like those found in more familiar regions of the electromagnetic spectrum. Experimental results (solid lines) and their theoretical extension (dotted lines) are shown in fig. 6.

Energy is also absorbed and scattered by particles of solid and liquid in the atmosphere. Droplets of water, present as fog, cloud or rain, are practically the most important particles of this sort. The attenuation by water droplets is of little practical consequence at wave lengths of 10 cm. or more, although sufficient energy is scattered from storm areas to give radar echoes at all microwave lengths (*see* fig. 1, Plate IV). At wave lengths shorter than 10 cm., increasing attenuation is observed. Experimental results are given in fig. 7.

Target Properties.—A few useful things can be said about the radar cross section, σ, of various targets. In the case of the simplest single targets, σ can be calculated by electromagnetic theory; for other simple cases an approximate calculation will

yield good results. A few values of radar cross section of such simple targets are collected below:

(1) Dielectric sphere of radius small compared with wave length. Sphere radius a, dielectric constant ϵ, wage length λ.

$$\sigma = 4\pi\left(\frac{2\pi}{\lambda}\right)^4\left|\frac{\epsilon-1}{\epsilon+2}\right|^2 a^6. \qquad (13)$$

(2) Metal sphere of radius small compared with wave length.

$$\sigma = 9\left(\frac{2\pi a}{\lambda}\right)^4 a^2. \qquad (14)$$

(3) Flat metal sheet of area A placed perpendicular to radar beam. Dimensions of plate large compared with wave length.

$$\sigma = \frac{4\pi A^2}{\lambda^2}. \qquad (15)$$

(4) Cylinder of radius R and length l, both large compared with wave length. Cylinder is viewed perpendicular to axis.

$$\sigma = 2\pi\frac{Rl^2}{\lambda}. \qquad (16)$$

(5) Segment of spherical surface of radius R, viewed either on concave or convex side. Diameter of segment, perpendicular to the incident beam, must be greater than λ.

$$\sigma = \pi R^2. \qquad (17)$$

Eq. (17) is also valid for a nonspherical curved surface, if for R is used the geometric mean of the two principal radii of curvature.

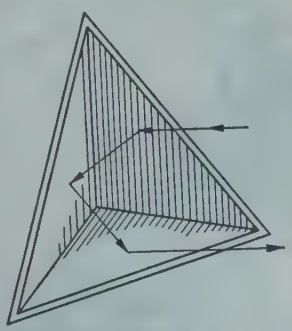

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FIG. 8.—PRINCIPLE OF THE CORNER REFLECTOR

An important type of simple target is the corner reflector. This is used when a compact radar target with a large cross section in any direction of observation is desired. It consists of an arrangement of three planes intersecting at right angles. The law of optical reflection yields the result that a ray directed into the corner formed by three such planes will undergo triple reflection and be sent back in the direction from which it came (*see* fig. 8). The maximum radar scattering cross section of such a corner, which it exhibits when viewed along the axis of symmetry of a single corner, is

$$\sigma_{max} = \frac{4\pi a^4}{3\lambda^2}, \qquad (18)$$

where a is the length of an edge of the corner and λ the radar wave length. The cross section remains large over most of the octant for which a single corner is effective; all directions can be covered by making a cluster of eight such corners (fig. 9).

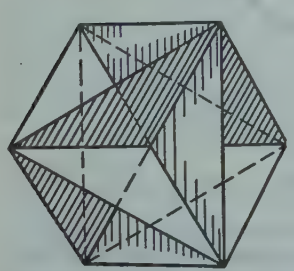

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FIG. 9.—CLUSTER OF CORNER REFLECTORS

Radar cross section can be reduced by the use of materials absorbent at radar frequencies. Such materials are of two principal types. In the first kind, reflections occurring at the front surface of the absorber are cancelled by destructive interference with the wave that enters the layer and subsequently reemerges. Such absorbers are similar to the anti-reflection coatings applied to glass. Absorbers of the second kind are designed so that no reflection takes place at the front surface and high attenuation in the material extinguishes the entering wave. A continuous gradation from one kind of absorber to the other exists.

During World War II, the Germans produced a material of the first kind which was used for the camouflage of U-boats, to lessen the likelihood of radar detection of a surfaced submarine. An absorber of the second kind, which was never actually used, was also produced by the Germans. Its absorption was excellent over the wave length range from 4 to 13 cm.

Complex Targets.—Most radar targets are much more complicated than the simple ones so far mentioned in this section. For such complex targets, the effect of interference of waves reflected from various parts of the target is extremely important in determining the strength of the received signal. A very simple case of such interference is shown in fig. 3, Plate IV. This is a series of recordings of an A-scope trace taken at intervals of one-sixteenth second. The signal at the right is received from the two antenna towers of radio station WBZ, in Boston, Mass. Signals from the two towers overlap in the centre, because of the pulse duration, and there show the effects of interference. In the last frame, No. 0311, the parts of the signal where there is no overlapping are separated by a gap of zero power due to destructive interference in the overlapping region. In frame No. 0303, the region of overlap shows the effect of full constructive interference. Had the A-scope used been linear in power, the signal height for constructive interference would have been four times that of the individual signals. The change in received signal is due to the change in the distance between the towers as they sway in the wind.

A relative motion of only one inch was required to pass from constructive to destructive interference at the radar wave length used.

The actual targets of radar, such as aircraft, ships and buildings, are far more complex than the simple model just considered. The measured relative cross section of a medium bomber viewed from various angles in its horizontal plane is shown in fig. 10. In many positions, the power returned changes by as much as a factor of 30 (15 db [decibel]) for an aspect change of only one-third degree. To a smaller but still very noticeable extent, the radar cross section is a function of propeller position, so that modulation of the received power occurs when the propellers are rotating.

Because of these irregularities in the cross section, a practical definition of the radar cross section of an aircraft has been adopted. The cross sections given in Table I are stated on the basis that the actual cross section attains the tabulated value during one half of a series of five-second intervals of observation. The signal is considered as seen in a given time interval if at least once during this interval it is distinguishable in the noise.

TABLE I.—*Radar Cross Section of Aircraft*

Aircraft type	Cross section in ft.²
OS2U (Kingfisher)	170
Taylorcraft	170
AT-11 (twin-engine Beechcraft)	200
PBY-5 (Catalina)	500
B-17 (Fortress)	800

A more serious modification of the idea of target cross section is made necessary by the reflection of radio waves when a low-lying target is viewed over the surface of the sea. Because of the effects of interference of direct and reflected rays, it is no longer possible to define a single cross section characterizing the target in such a way that the received power depends only upon the properties of the radar set (P, G and A_r), upon the range, and upon the cross section.

Ground "Painting" by Radar.—Air-borne radar equipment was extensively used in military aircraft during World War II for navigation by pilotage under conditions of restricted visibility. Point-to-point variations in the radar reflection properties of the earth's surface enable the radar indicator to display a picture which, at best, shows a good relation with a map. Radar displays marked contrast between land and water surfaces because of the greater diffuse scattering of the radio waves by the earth's surface. Cities and groups of structures on the ground return a bigger signal than open country, possibly in part because of the retrodirectivity of the corner reflectors formed by building walls and the ground. Mountains and ridges can be distinguished by increased intensity on the near side and shadows cast beyond. The higher definition available with narrow-beam equipment using the shortest micro wave lengths is important in giving a display which is easy to interpret. In all cases, however, experience and skill of the operator are important in making a good correlation between the radar picture and the ground beneath,

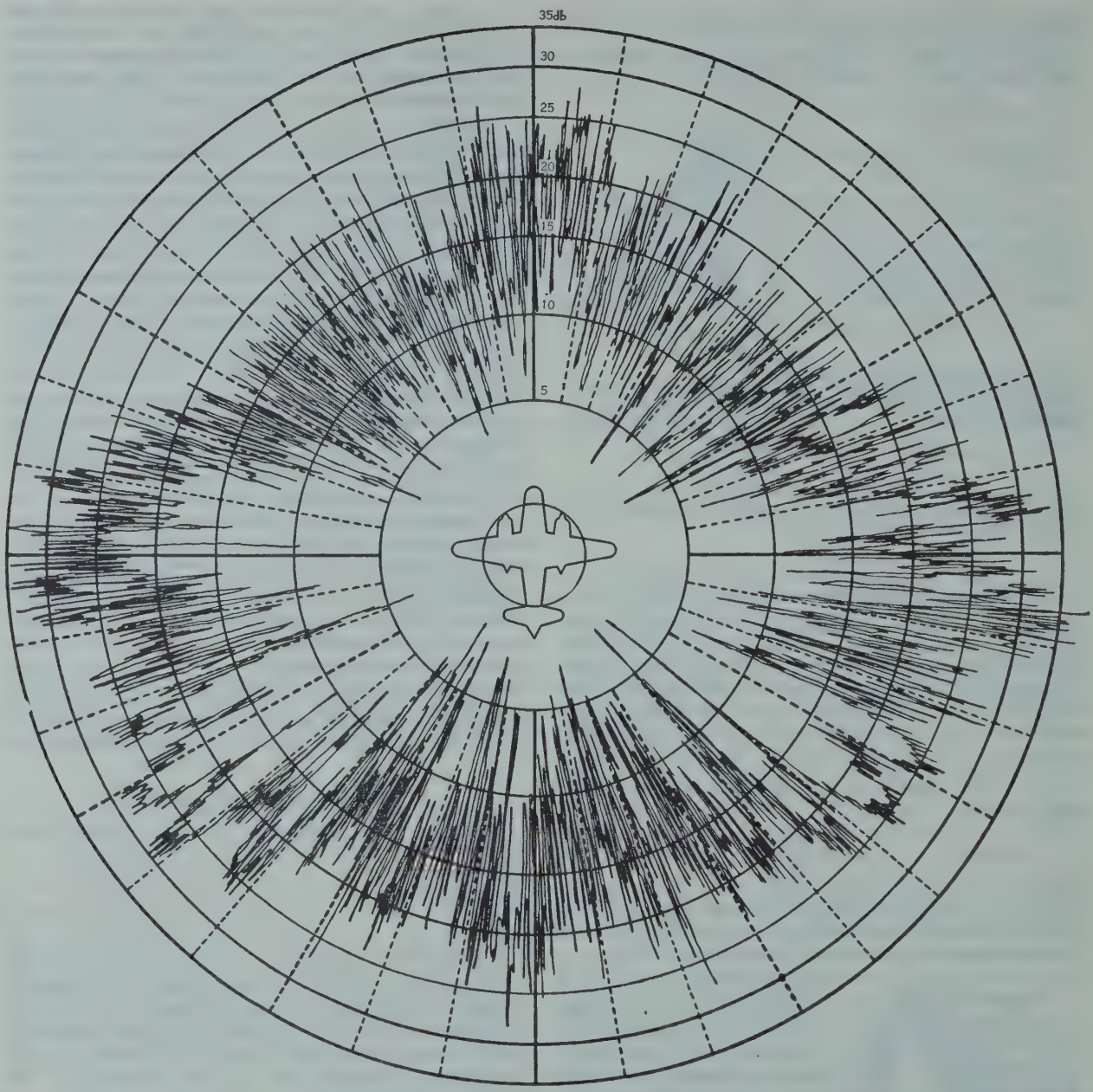

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FIG. 10.—RETURN POWER (ON A LOGARITHMIC SCALE) FROM B-26 AIRCRAFT AT 10-CM. WAVE LENGTH AS A FUNCTION OF AZIMUTH ANGLE

especially inland in rather featureless country. Misidentification is so easy under these and other circumstances that air-borne radar must be regarded as an aid to dead reckoning, rather than a complete means of navigation in itself. When the aircraft position is known to an accuracy of 20 or 30 miles, the radar display can hardly be interpreted incorrectly, even by an inexperienced operator. Examples of radar scope pictures taken with air-borne equipment are shown on Plate III.

C-W RADAR SYSTEMS

Since radar echo signals are so very feeble in comparison with the transmitted energy, they must be detected by some property which differentiates them from the transmitted signal in a readily measurable way. In pulse radar, this is done by turning off the transmitter for most of the time, so that signals received during the "off" time of the transmitter can be identified as echoes. It is possible to recognize echoes, however, even while the transmitter is working, on any of several schemes. Radio detection devices that involve a transmitter duty ratio of as much as 10% (in pulse radar this duty ratio is typically 0.1%) will be lumped here under the name "c-w" (for continuous-wave) radar. Some devices of this sort have found important practical application.

If the targets of principal interest all have a radial motion relative to the radar, their echo signals can be distinguished by the frequency shift which is a consequence of the reflection of waves from a moving mirror. This frequency shift, f_d, is given by $(2v_r/c)f$, where v_r is the radial velocity, c the velocity of light, and f the unmodified radar frequency. Numerically, with v_r in statute miles per hour and f defined by a wave length λ in cm. (equal to c/f), the frequency shift, which is called the "doppler

frequency," is given by

$$f_d = 89.4\frac{v_r}{\lambda}. \qquad (19)$$

Thus at 10-cm. wave length, v_r amounts to about 9 cps/m.p.h.

The doppler-shifted return signal, when added to the transmitter voltage and rectified, gives rise to a voltage with small pulsations recurring at the doppler frequency. The steady component can be removed by a high-pass filter (which may be simply a transformer or a series condenser) and the fluctuations then amplified and used to actuate an indicator. If the output signal is fed to ordinary telephone receivers, the ear can detect signals denoting the presence of a moving target over the range of World War II aircraft speeds, if the radar works at 10-cm. wave length.

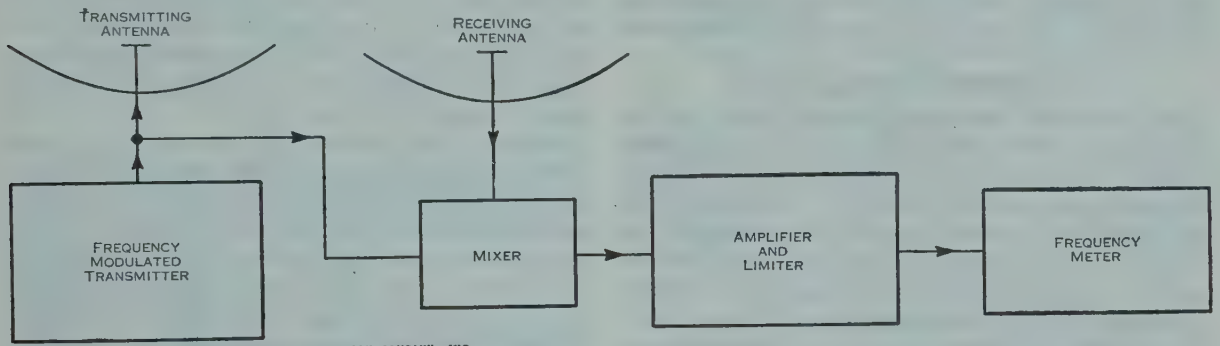

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FIG. 11.—SIMPLIFIED BLOCK DIAGRAM OF FREQUENCY-MODULATED C-W RADAR SYSTEM FOR MEASURING RANGE

C-w radar systems of the type just described, with suitable technical modifications which do not affect the principle of operation, were built during World War II. Although they were not used in actual combat, they proved most useful in making precise measurements of the velocities of projectiles.

The system just described, though measuring the radial velocity of a target in a simple and accurate way, affords no information regarding target range. To measure range, the outgoing wave must be marked or modulated in some way, and the time required for the marks on the wave train to return as an echo must be measured. Either amplitude modulation (AM), or frequency modulation (FM), of the outgoing wave can be used.

The most familiar way of employing AM is that of pulse radar to determine the time delay between the transmission and reception of a pulse. However, we can also measure range by the use of two separate c-w radar systems like the one described above, the transmitter frequencies of the two differing by an amount f_r. Let f_o be the frequency of one transmitter and f_o+f_r that of the other. The doppler frequencies developed by the two systems when they look at a single target moving radially will differ, since these doppler frequencies involve the transmitter frequency, as Eq. (19) shows.

If the target is very close to the system, the number of wave lengths in the distance from transmitter to target and back is very nearly the same for the two systems, since their frequencies differ only slightly. Thus the transmitter signal and the target signal will be in phase or out of phase with one another at the two receivers simultaneously, and the two doppler outputs will be in phase for very short range. As the target gets farther away, one doppler signal shifts phase more rapidly than the other, so that a phase difference between the doppler outputs of the two systems is developed. When the target is far enough away so that the number of wave lengths to the target and back is one greater for f_o+f_r than it is for f_o, the phase difference in the outputs is 2π. This phase difference, which is given by

$$\phi = \frac{4\pi f_r}{c} r, \qquad (20)$$

where ϕ is the phase shift, r the range, and c the velocity of light is a linear function of range and can be used as a measure of range. It becomes ambiguous for targets so far away that the phase shift is greater than 2π.

This is a perfectly feasible way of measuring range with c-w radar, and has been used in the laboratory. No practical application of it was made during World War II, largely because of the lack of a phase-measuring device which worked satisfactorily over large ranges in frequency and amplitude.

Range Measurement by FM.—One of the most important applications of c-w radar systems during World War II was their use for the measurement of the altitude of aircraft with reference to the earth or sea below. A system employing frequency modulation of the transmitted signal was developed for this purpose in the U.S., and independently a very similar system was worked out in Germany.

A schematic diagram of the system components is shown in fig. 11; the operating principle of the system is illustrated by the curves of fig. 12. The transmitter frequency varies linearly with time in the fashion shown. Energy arrives at the receiver both directly from the transmitter and by reflection from the target. Since the trip to the target and back takes time, the received frequency (indicated by the dotted line) is displaced along the time axis relative to the transmitter frequency. The two frequencies combine in the mixer to give a beat of constant frequency (except during the short crossover intervals when the sign of the FM is changing). The greater the target distance, the greater this beat frequency; its magnitude is a direct measure of the range. The beat signal between transmitter signal and echo is therefore amplified, and its frequency measured by a direct-reading frequency meter which can be calibrated in terms of range.

A practical radar altimeter which works on the principle just described, with some detailed modifications which do not affect that principle, is shown in fig. 2, Plate IV. It was very widely used in Allied military aircraft during World War II.

If it is desired to use this same principle for radar search, several targets may give return signals simultaneously. The receiver output will then contain several signals at different frequencies. These can be individually detected either by a frequency meter which will respond to and indicate several signals simultaneously, or by scanning a single-frequency meter over the frequency range corresponding to the target distances which must be covered. The vibrating-reed frequency meter will serve as an example of the first technique. In the second method, for example, a variable frequency can be added to the output signal and

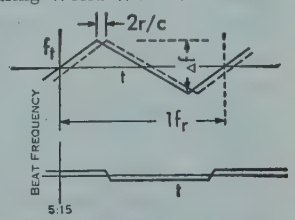

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FIG. 12.—PRINCIPLE OF FM RADAR ALTIMETER. THE UPPER FIGURE SHOWS, IN THE FULL CURVE, THE INSTANTANEOUS TRANSMITTER FREQUENCY AS A FUNCTION OF TIME. THE DOTTED CURVE IS THE RECEIVED FREQUENCY. THE LOWER FIGURE SHOWS THE DIFFERENCE, OR BEAT, BETWEEN TRANSMITTED AND RECEIVED FREQUENCIES AS A FUNCTION OF TIME

observations made when the beat frequency between the two signals falls in the pass band of a resonant circuit. Scanning devices are usually objectionable because they increase the time necessary to make an observation.

In addition to the c-w radar systems whose operating principles have been sketched, there are many other types that involve different schemes of modulation of the transmitted signal and different techniques for handling the received echo. Though the amount of wartime development work which went into such c-w systems was only a tiny fraction of that expended on pulse radar, there are applications for which c-w radar is markedly superior.

For example, for measuring accurately ranges as small as 10 ft., a c-w system is simpler than a pulse system. A system making use of the doppler shift in frequency will measure the speed of a bullet in an easy and direct way, and to any desired degree of accuracy. Or, again, simplicity may be desired; this can be provided by a c-w system which, carried to the ultimate in this direction, becomes the proximity fuze.

RADAR COMPONENTS

The Multicavity Magnetron.—Beginning about 1938, the British made strenuous efforts to develop sources of high-power pulses at microwave frequencies, because of the importance of narrow radar beams in the air-borne equipment they were then attempting to develop. The modification of conventional tube types offered little promise; since to a first approximation, the electronic characteristics of a low-frequency tube are maintained at high frequency only if all tube dimensions are scaled in proportion to the wave length, λ. Near 1,000 Mc./sec., the practical consequences of this reduction in tube dimensions become serious. Electrode clearances become so small that they are hard to maintain, while the reduction in cathode and plate areas (proportional to λ^2) rapidly reduces peak emission and plate power dissipation.

An entirely new type of tube, the multicavity magnetron, was invented to serve the new requirement. In 1946, magnetrons had produced pulse powers as high as 10,000,000 watts at frequencies near 3,000 Mc./sec., and hundreds of kilowatts even at 24,000 Mc./sec. Klystrons are useful sources of continuous r-f power at frequencies as high as 24,000 Mc./sec.; but they cannot give high pulse power.

The magnetron is a self-excited oscillator capable of converting D.C. power into r-f power with high efficiency. The main features of the design of a typical magnetron are shown in fig. 13. Between the indirectly-heated cylindrical cathode *C* and the anode block *A* is an interaction space *I* in which the conversion takes place. A constant, uniform, magnetic field is maintained in this interaction space in a direction parallel to the axis of the cathode. The anode block is pierced in a direction parallel to the field by a number of resonating cavities *R*, which open into the interaction space so that the inner anode surface consists of alternate segments and gaps. At the ends of the cavities are open "end spaces" which permit lines of magnetic flux to link one resonator to the next. Coupling between the resonators is increased by conducting bars called straps, *S*, which connect together alternate anode segments. An output coupling loop, *L*, extracts r-f power from one resonator and feeds it to the output circuit.

Each of the eight resonant cavities shown in fig. 13 can be thought of as a simple oscillating circuit consisting of lumped inductance L_o and capacity C_o. When the magnetron is oscillating in the desired way, the capacities of the individual cavities are connected in parallel, and so are their individual inductances. The frequency of the magnetron as a whole is then about the same as that of an individual cavity, since the frequency is proportional in either case to the product of inductance and capacity. The impedance of the oscillators, however, depends on L_o/C_o, and magnetrons of the same frequency but different impedance can be constructed by changing the shape of the individual resonators to keep L_oC_o constant while altering L_o/C_o.

Like all systems of coupled individual oscillators, the resonant system of a magnetron can oscillate in different modes; in general these modes will have different frequencies. One of these modes has been found to be by far the most desirable from the standpoint of reliable operation, and much attention has been paid to the problem of making the frequency of the desired mode sufficiently different from that of any other to encourage the magnetron to oscillate in the desired mode. The straps shown in fig. 13 are primarily for this purpose of accomplishing mode separation in frequency; another way of achieving such separation is to make the alternate individual resonators of different natural frequencies. Fig. 4, Plate IV, is a photograph of a tube of the latter sort.

This figure also shows an alternative way of constructing the magnetron. Instead of a tube like that of fig. 13, intended to be put between the poles of an electromagnet or a permanent magnet, a tube can be built in which the magnet pole tips are actually part of the construction of the magnetron proper. In this way, the air gap over which the magnetic field must be maintained is cut down, and thus the required magnetomotive force (and the physical size of the magnet) can be greatly reduced. Permanent magnets are usually employed with magnetrons, as shown in fig. 4, Plate IV.

An electron in the interaction space is acted on by a constant magnetic field parallel to the cathode axis, a constant radial electric field resulting from the D.C. voltage applied between anode and cathode, and the rapidly-varying electric field extending into the interaction space from charges momentarily concentrated near the ends of anode segments. Such an electron is also part of a space charge subject to extreme variations in density. The very complex problem of the resulting electron motion has not been solved in detail, but a qualitative idea of the major processes responsible for magnetron behaviour can be given.

A simplified picture of the motion of individual electrons is offered in fig. 14. The distribution of charges shown on the anode segments is that appropriate to the desired mode of magnetron operation. The dotted lines with arrows show the resultant electric field. An electron located at point *A* at the instant shown will be speeded up by the r-f field. The result of an increase in the tangential velocity of an electron is, under the field conditions obtaining in the magnetron, to increase the curvature of the electron's path. The electron thus moves along the path shown, strikes the cathode, and plays no further role in the operation of the magnetron.

An electron at point *B*, however, is in a decelerating r-f field; the curvature of its path will thus be decreased. If the frequency of oscillation is appropriate to the motion of the electron, this electron will always be in a decelerating field as it passes before successive anode segments. It will then follow a path of the sort shown, and eventually strike the anode. Since the electron is always retarded by the r-f field, it gives up to the r-f field practically all of the energy gained in its fall through the D.C. field between cathode and anode. While this simple picture is qualitatively correct, the detailed operation of a magnetron is doubtless much more complicated. One experimental fact difficult to explain, for example, is that the anode efficiency of some magnetrons can be as high as 85%.

The behaviour of the space charge in the interaction space can be inferred from what has been said about the motion of an individual electron. The result is shown in fig. 15. Four spokes of high electron density contain those electrons which are in the proper position to be decelerated by the r-f field. This configuration rotates about the cathode with an angular velocity which keeps it in step with the alternating r-f charges on the anode segments. The r-f current flowing in the oscillators is principally a displacement current produced by this rotating space charge. Fig. 15 shows the space charge at an instant when the r-f electric field is zero; the lines of magnetic field in the resonators are shown.

The behaviour of a magnetron with changes of anode current and of pulse voltage is displayed on a performance chart, which shows how these parameters affect frequency, power, magnetic field and efficiency under conditions of constant r-f load. The performance chart of a typical magnetron is shown in fig. 16.

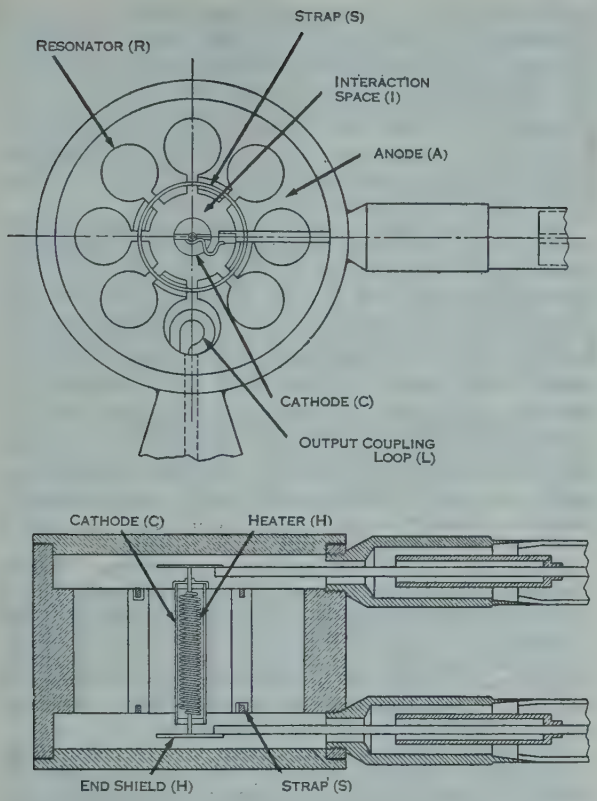

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FIG. 13—CROSS SECTIONS OF A TYPICAL CAVITY MAGNETRON. MAGNETIC FIELD PERPENDICULAR TO UPPER FIGURE; VERTICAL IN LOWER FIGURE

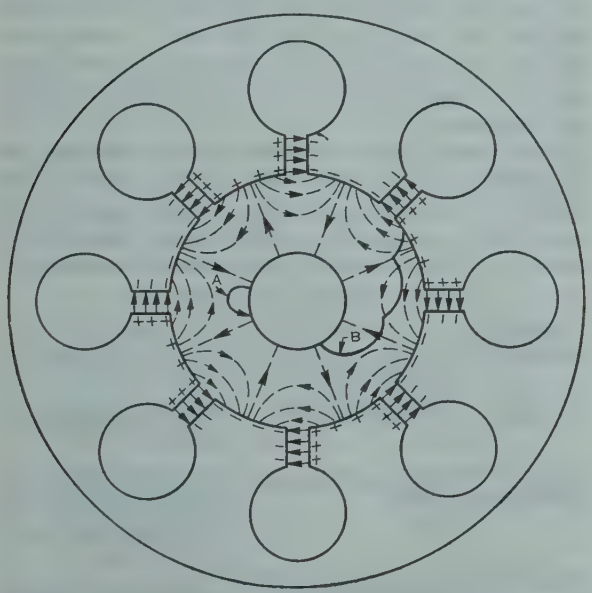

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FIG. 14.—PATHS OF ELECTRONS IN THE INTERACTION SPACE WHEN MAGNETRON IS OSCILLATING. ELECTRON AT A WOULD TAKE ENERGY FROM R-F FIELD, BUT HITS CATHODE AS A RESULT OF SPEEDING UP, AND IS THUS REMOVED FROM SPACE CHARGE. ELECTRON AT B CONTRIBUTES ENERGY TO R-F FIELD, THUS SUSTAINING OSCILLATIONS

The magnetron as it has so far been described is a fixed-frequency device. However, several different schemes have been worked out for tuning cavity magnetrons. In one way or another, each of these schemes involves loading the resonators so as to change their natural frequency of oscillation.

While most multicavity magnetrons made during World War II were designed for pulsed operation, it is possible to modify the design slightly to fit a magnetron for continuous oscillation. It is also possible, by loading one or more of the resonators by means of an electron beam travelling along the direction of the magnetic field, to modulate the magnetron frequency at a very rapid rate. The magnetron thus appeared in 1946 to hold considerable promise as an oscillator for FM communication purposes.

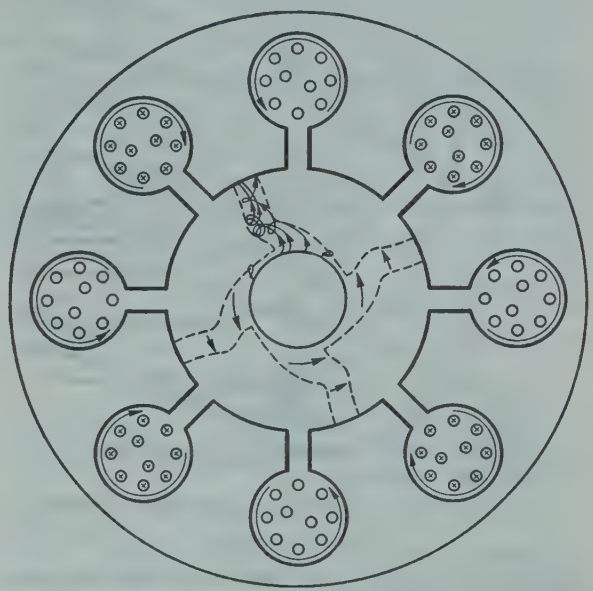

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FIG. 15.—SPACE-CHARGE DISTRIBUTION IN AN OSCILLATING MAGNETRON. INSTANT SHOWN IS THAT OF ZERO R-F ELECTRIC FIELD. LINES OF R-F MAGNETIC FIELD ARE INDICATED WITHIN CAVITY RESONATORS

Pulse Modulators.—The modulator, or pulser, of a radar set is a somewhat unusual electrical device. It must supply, in the form of electrical pulses whose duration is in the range from 1/10 to 5 μ sec., currents of some tens of amperes at voltages as high as 50 or 60 kilovolts. These pulses must be generated with a recurrence frequency of a few hundred to a few thousand per second, usually must be accurately spaced relative to one another, and, since the magnetron is such a highly nonlinear load, they must be "flat" on top to better than 5% of the rated pulse voltage. In a typical case, a variation in pulse voltage of only 3 kv., will produce, in a magnetron operating at 25 kv. and 13.5 amp., a drop in anode current of 7 amp., which practically stops the oscillation of the magnetron.

In all pulsers, electrical energy stored in some circuit element is released rapidly during the pulse, and replenished during the interval between pulses. Energy can be stored either in the electrostatic field of a condenser or in the magnetic field of an inductance carrying a current. Pulsers employing electrostatic energy storage are far more common than those using an inductance as the storage element, largely because power losses in the latter type of pulser are ordinarily much greater for the same useful pulse output. The following discussion refers to pulsers using electrostatic energy storage.

The basic circuit of a pulser is shown in fig. 17. If the energy-storage element is a condenser of capacity C, charged to a voltage V, the stored energy is $\frac{1}{2}CV^2$. At $t=0$ the switch S is closed, and the condenser begins to discharge exponentially through the load resistance. If S is now opened suddenly at a time τ small compared with the time constant R_LC of the circuit, the voltage appearing across the load while the current is

flowing is given by

$$V_L(t) = V(1 - \frac{t}{R_L C}), \qquad 0 \geqslant t \geqslant \tau \qquad (21)$$

which is constant within a few per cent if $\tau \ll R_L C$.

In practice, vacuum tubes are the only switches that can be used to open the load circuit suddenly while it is still carrying

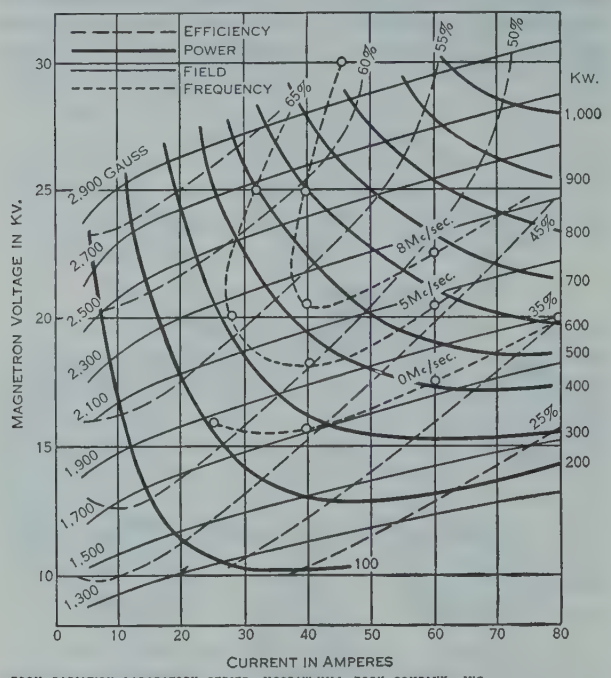

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FIG. 16.—TYPICAL PERFORMANCE CHART OF A MAGNETRON. CHART SHOWN IS FOR RMA TYPE 4J31

a large current. The plate resistance of such tubes is always rather large, resulting in a high voltage drop across the switch during the pulse, and a corresponding loss in pulser efficiency. It would be desirable to use a very low-resistance switch, such as a spark or gaseous discharge, to eliminate this difficulty. However, all such devices have the property that the current flow through them, once started, cannot be interrupted until the voltage across the switch has fallen to an extremely low value. Thus, if such a low-resistance switch were used with a pulser having a simple condenser for an energy-storage element, the condenser would have to be completely discharged at each pulse. This is unsatisfactory, since the wave shape of the output pulse would then be exponential, instead of being substantially rectangular, as desired.

If, however, a transmission line is used as an energy-storage element instead of a condenser, its discharge properties under the appropriate load conditions are such that it will supply energy at constant current until it is completely discharged. This is exactly what is wanted for the generation of rectangular

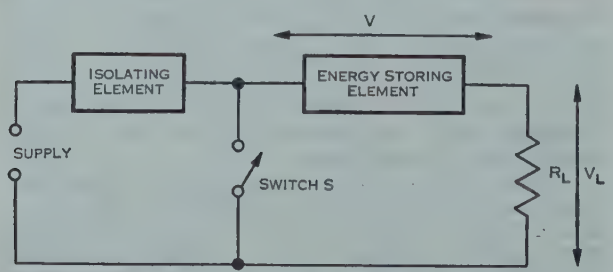

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FIG. 17.—BASIC CIRCUIT OF A PULSER EMPLOYING ELECTROSTATIC ENERGY STORAGE

pulses. Elementary transmission-line theory shows that if a line of inductance L and capacity C per unit length is charged to a voltage V and then suddenly connected across a resistance R_L, a discontinuous current of magnitude $V/(Z_0+R_L)$ will flow for a time $2t$, where Z_0 is the characteristic impedance of the line $(=\sqrt{L/C})$, and t is its one-way transmission time. If $R_L = Z_0$, no current flows after a time $2t$, and a genuinely rectangular pulse has been generated. The time t is given by $l\sqrt{LC}$, where l is the physical length of the line.

Since the pulse durations desired in radar are usually a microsecond or more, it is ordinarily impracticable to use actual transmission lines or cables in pulsers; a cable to supply a 1-μ sec. pulse would be about 500 ft. long. Instead, an "artificial line" (fig. 18) made up of properly chosen inductances and condensers is used. Such an artificial line is sometimes called a "pulse-forming network." A pulser employing a network as storage element is less flexible than one which uses a condenser and hard-tube switch, since the properties of the network itself fix the pulse duration and the load impedance. Components available for network construction make it desirable to give the network a low impedance; 50 ohms is typical. The magnetron load usually has a much higher impedance, in the neighbourhood of 500 ohms. Specially designed "pulse transformers" are used to match the load impedance to that of the network.

Devices used as the low-impedance gas-discharge switch in a network pulser include rotary spark gaps, fixed spark gaps in series, fixed gaps with an auxiliary electrode for triggering (called "trigatrons"), and thyratrons using either mercury or hydrogen as the filling gas. Hydrogen thyratrons were developed specifically for radar pulsers, and have the advantage over heavy-gas thyratrons in that they can pulse at much higher frequencies, because of the higher ion mobility in hydrogen.

The charging circuit used with either type of pulser so far considered—the "hard-tube" pulser which uses a single condenser as storage element, or the "network" pulser which uses a low-voltage switch—is an important part of the circuit. In the hard-tube pulser, the energy source must clearly supply direct current for recharging. The isolating element prevents excessive power from being drawn out of the energy source when the switch is closed (fig. 17), and must also permit sufficient energy to flow in the interpulse interval to replace that used during the pulse. In the hard-tube pulser, it can be either a high resistance, an inductance, or a series combination of resistance and inductance.

In the case of the network pulser, on the other hand, the full energy of the charged network must be supplied by the recharging circuit after each pulse. This means that a resistance is a very inefficient isolating element, for as much energy will be dissipated in it, each time the network is recharged, as is usefully stored in the network. Accordingly, an

TABLE II.—*Comparison of the Two Pulser Types*

Characteristics	Hard-tube pulser	Network pulser
Efficiency	Lower; more power required for auxiliary circuits and for dissipation in switch tube	High, particularly when pulse-power output is high
Pulse shape	Better rectangular pulses	Poorer rectangular pulse, particularly through pulse transformer
Impedance matching to load	Wide range of mismatch permissible	Smaller range of mismatch permissible (± 20–30%). Pulse transformer will match any load, but power input to nonlinear load cannot be varied over a wide range
Interpulse interval	May be very short; as for coding beacons. (*i.e.*, 1 μ sec.)	Must be several times the deionization time of discharge tube (*i.e.*, 100 μ sec.)
Voltage supply	High-voltage supply usually necessary	Low-voltage supply, particularly with inductance as isolating element
Change of pulse duration	Easy; switching in low voltage circuit	Requires high-voltage switching to new network
Circuit complexity	Greater, leading to greater difficulty in servicing	Less, permitting smaller size and weight

inductance is almost always used as an isolating element. Further, the network can be recharged from an alternating-current source, provided the pulse repetition frequency is a multiple of one-half the A.C. supply frequency. An extremely simple high-power pulser can be made by mounting a rotary spark gap switch directly on the shaft of the A.C. machine supplying the recharging current for the network.

The hard-tube and the network types of pulser have different fields of usefulness. A comparison of their properties is shown in Table II.

Radio-frequency Components.—A considerable body of new theory and technique grew up during the development of microwave radar because of the necessity of handling power at frequencies so high that the wave length of the r-f energy is of the same order as the physical size of the circuit elements. The length of a microwave transmission line may be, and usually is, several wave lengths. For a fuller description of r-f

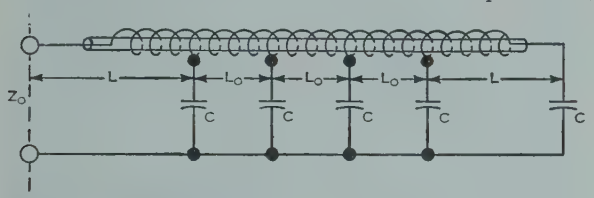

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FIG. 18.—SCHEMATIC DIAGRAM OF A PULSE-FORMING NETWORK. NUMBER OF MESHES REQUIRED DEPENDS ON DURATION OF PULSE

techniques at microwave frequencies, reference should be made to the works quoted in the bibliography. Some of the outstanding problems will be briefly discussed there.

Coaxial Line.—A transmission line is characterized, as already remarked, by a characteristic impedance which depends upon the inductance and capacity per unit length of line, and is thus a function of the geometry of the insulators and conductors of which the line is made. In a coaxial line, a type frequently used for the transmission of high-frequency energy (fig. 19), the characteristic impedance, Z_o, is given by

$$Z_o = \frac{138}{k} \log_{10}(r_2/r_1) \text{ ohms}, \qquad (22)$$

where k is the dielectric constant of the material in the annular space between the conductors, r_2 is the inner radius of the outer conductor, and r_1, is the outer radius of the inner conductor.

A uniform line terminated at any point in a load duplicating its characteristic impedance behaves as if it were infinitely long; there is no reflection of energy from the termination. However, any impedance changes along the line (such as those introduced by dents, bends, or obstacles in the line), or any departure of the load from the characteristic impedance of the line, will cause the reflection of energy. The reflected wave, which travels back toward the power source, interferes with the outgoing wave to produce standing waves in the line. These can be detected and measured by exploring the voltage along the line with a small movable probe, such as that shown in fig. 19. There will be voltage maxima spaced at half-wave length intervals with minima halfway between them. A line which is properly terminated and uniform, so that it exhibits no standing waves, is said to be "matched."

When a lossless transmission line a quarter wave length long and of characteristic impedance Z_o is terminated in an impedance Z_t, the input impedance of the line is

$$Z_i = Z^2_o/Z_t. \qquad (23)$$

This property enables two transmission lines of different impedance to be matched to each other by joining them through a quarter-wave line whose characteristic impedance is the geometric mean of the impedances of the two lines. Such a quarter-wave section is called a "matching transformer." If a quarter-wave line is terminated by a short circuit, its input impedance is infinite; conversely, an open-circuited quarter-wave line appears at the input terminal to be a short circuit.

For a lossless line a half wave length long,

$$Z_i = Z_t, \qquad (24)$$

irrespective of the characteristic impedance of the line. This property is also very useful.

At microwave frequencies, the losses in the solid dielectrics used to insulate the inner from the outer conductor in a coaxial line are prohibitive at the power levels usually encountered. "Stub-supported" lines have therefore been developed (fig. 20), in which the "insulators" are short-circuited quarter-wave lines. Since the input impedance of such a quarter-wave line is infinite, it has no effect when placed in parallel with the main line. The stub is exactly a quarter wave long only at one frequency, however, and it is often desired to make r-f fittings which can work over a frequency band several per cent wide. In the stub support shown in fig. 20, this frequency sensitivity is compensated, over a band of ±15% of the base frequency, by the quarter-wave transformers formed by the fat sections of the centre conductor near the stub support.

Rotary joints which permit mechanical motion while transmitting r-f power without reflection or mismatch are often required. These devices also make use of the property of a quarter-wave line. Fig. 21 shows two designs of coaxial rotary joint.

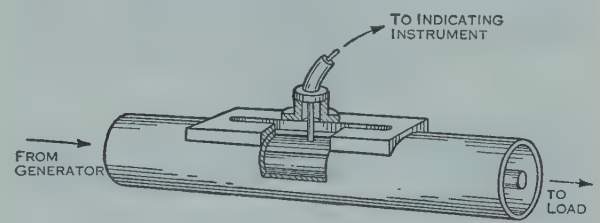

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FIG. 19.—SLOTTED SECTION OF COAXIAL LINE WITH PROBE FOR MEASURING STANDING WAVES

Quarter-wave line sections used to prevent loss of r-f power in the way shown in fig. 21 are called "chokes."

Standard coaxial line usually has a characteristic impedance of 50 ohms, this corresponding to a ratio of 2.30 for the radii of the inner and outer conductors. This is a compromise between a ratio of 3.60 (77 ohms) which, for a given outer diameter, gives the lowest attenuation due to conductor losses, and a ratio of 1.65 (30 ohms) which enables the maximum power to be carried at a given breakdown voltage gradient across the dielectric.

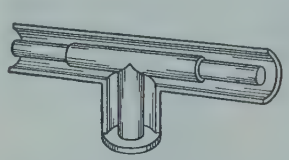

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FIG. 20.—BROAD-BAND STUB SUPPORT FOR CENTRE CONDUCTOR OF COAXIAL LINE

The size of a coaxial line is limited by the wave length of the radiation transmitted. The electric fields within a coaxial line have axial symmetry if the line is small enough. If, however, the mean circumference of the annular dielectric space between the conductors exceeds one wave length, a second "mode" of propagation of the r-f energy can be excited. In this second mode, the field distribution has diametral symmetry. Since serious design complications arise if it is possible for two modes of propagation to be excited simultaneously in an r-f line, the over-all size of coaxial line is always kept so small that only the axially symmetric mode of propagation can exist. The resulting limitation on power-handling capacity has restricted the use of coaxial lines to wave lengths of 8 cm. and more.

Wave Guide.—At shorter wave length, and for handling the highest powers even in the 10-cm. band, wave guide is used. Though a metallic pipe of almost any shape will transmit or guide electromagnetic waves whose wave length is short enough, rectangular tubing whose internal dimensions have a ratio between 2.0 and 2.5 is ordinarily used to transfer microwave energy. Though a detailed understanding of the propagation of r-f energy in wave guide demands the solution of Maxwell's

equations with the appropriate boundary conditions, we can get a picture of the mechanism of this propagation by considering the resemblance between a rectangular wave guide and a two-wire transmission line.

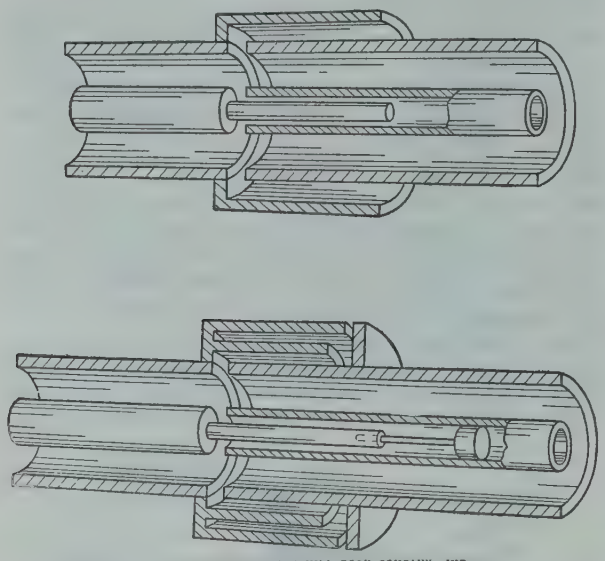

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FIG. 21.—DESIGN OF COAXIAL ROTARY JOINTS. OPEN-CIRCUITED QUARTER-WAVE SECTIONS APPEAR AS SHORT CIRCUITS AT LINE END; SHORT-CIRCUITED QUARTER-WAVE SECTIONS PRESENT HIGH IMPEDANCE AND PREVENT RADIATION

Fig. 22a shows a two-wire line with a single short-circuited stub support, analogous to the coaxial quarter-wave stub support already described. At the proper frequency, the input impedance of the stub is very high and the stub has no effect on the propagation of the wave on the line. In fig. 22b a great many stubs, extending both ways from the two-wire line, have been added, still without affecting the propagation of the frequency in question. In fig. 22c the stubs have been coalesced into a rectangular tube which looks like a wave guide. For a single stub, a slight correction to the length must be made to compensate for the inductance of the crosspiece, but when the stubs become a solid tube, no lines of force can link the narrow side, and the quarter-wave distance becomes exact. This also shows why the length of the narrow side of the rectangular tube is not critical.

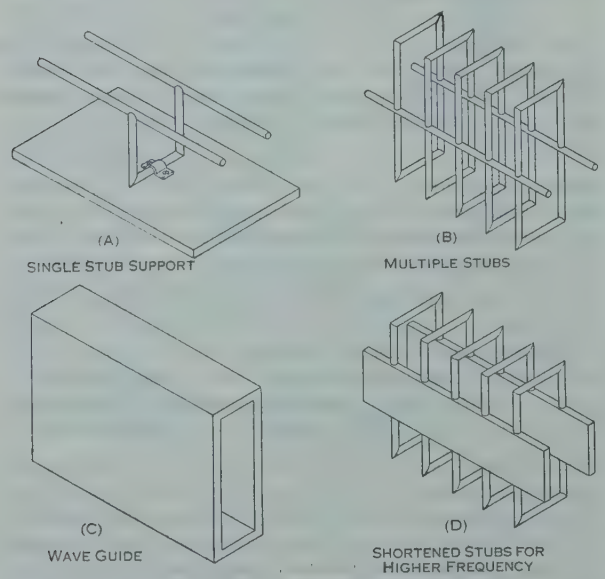

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FIG. 22.—TRANSITION FROM STUB-SUPPORTED TWO-WIRE TRANSMISSION LINE TO WAVE GUIDE. (A) SINGLE STUB SUPPORT. (B) MULTIPLE STUBS. (C) WAVE GUIDE. (D) SHORTENED STUBS FOR HIGHER FREQUENCY

All frequencies higher (wave lengths shorter) than that for which the quarter-wave stubs of our model were designed can be transmitted by wave guide. In such a case (fig. 22d) the two wires become broad bus bars with only as much of the wide side given over to stubs as is required by the now shorter wave length. Wave lengths greater than twice the broad dimension of the guide cannot be propagated because then the stubs become less than a quarter-wave long and shunt the line with a rather low inductive impedance which would extinguish the wave.

Fig. 23 shows an instantaneous picture of the electric and magnetic fields in a rectangular wave guide whose wide dimension is slightly more than half the free-space wave length of the radiation being transmitted. Lines of current-flow in the walls are also shown. As the dimensions of the wave guide increase relative to the wave length of the radiation being transmitted, modes of propagation different from that illustrated (*i.e.*, having different space distributions of electric and magnetic field) can be excited. As in the case of coaxial line, this is almost always objectionable, and the maximum size of the broad dimension of a rectangular guide is usually chosen to be less than 0.95 of the free-space wave length of the radiation to be transmitted.

Each type of wave guide has a cutoff frequency for propagation in the lowest mode. Waves of higher frequency are transmitted; those of lower frequency are rapidly attenuated. The wave length of the radiation inside the guide is longer than the free-space wave length and is given by

$$\text{Guide wave length} = \lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}} \qquad (25)$$

where λ is the free-space wave length and λ_c is the cutoff wave length. For the lowest mode in rectangular guide, as we have seen, the wave length corresponding to the cutoff frequency is twice the broad dimension. This sets a lower limit to the practical size of wave guide. Its broad dimension is usually chosen to be greater than 0.6 times the free-space wave length, because of design complications that ensue if the cutoff value of $0.5\,\lambda$ is approached too closely.

The narrow dimension of rectangular guide is chosen as large as possible to raise the breakdown field strength (the electric field being across this narrow dimension); but it must be less than half a free-space wave length of the radiation to be transmitted, so that there is no possibility of transmitting a wave polarized at right angles to that shown in fig. 23.

Transitions between wave guide and coaxial lines usually take the form of a quarter-wave stub antenna on the coaxial line projecting into the wave guide at the proper distance from a reflecting end plate, as shown in fig. 24. Rotary joints make use of quarter-wave choke sections, like those employed in the coaxial rotary joints of fig. 21. The power-handling capacity of wave guide is more than double that which can be realized by the largest coaxial line it is practical to use; the attenuation in a given length of wave guide is about half that encountered in coaxial line. Mechanically, wave guide is superior, being easier to fabricate and more difficult to damage in use. Nothing but its size, weight and clumsiness at long wave lengths restricts the practical use of wave guide to the region below 12-cm. wave length.

Resonant Cavities.—If both ends of a wave guide are closed by short-circuiting plates, and energy is introduced by a probe or through a hole so small that the properties of the enclosure are not affected, the resulting box is called a resonant cavity. When its length is an integral number of half-wave lengths of the radiation in the guide, the reflections from the end plates will reinforce one another and cause a resonant build-up of the energy in the cavity. Because the wave length in the guide differs from that in free space, as shown by Eq. (25), the shortest resonant piece of a wave guide whose broad dimension is $1/\sqrt{2}$ free-space wave lengths is also $1/\sqrt{2}$ free-space wave lengths long. The narrow dimension of the cavity does not affect the resonant wave length, though it should be less than

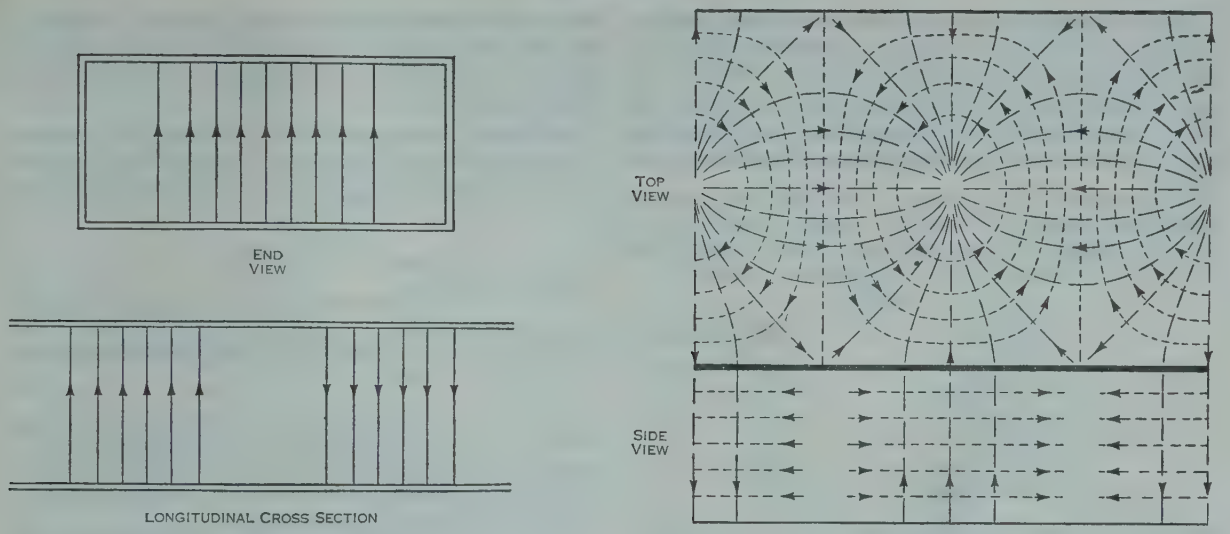

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FIG. 23.—FUNDAMENTAL MODE OF WAVE PROPAGATION IN A RECTANGULAR GUIDE. SOLID LINES ARE THOSE OF ELECTRIC FIELD; DASHED LINES SHOW CURRENT FLOW IN WALLS; DOTTED LINES SHOW MAGNETIC FIELD

$\lambda/2$ to avoid the possibility of exciting the cavity in a mode polarized at right angles to the one desired.

The sharpness of resonance exhibited by a resonant cavity at microwave frequencies is very great. It is usually measured by a number called the Q of the cavity. If f_0 is the resonant frequency and f_1 and f_2 are the two frequencies, one above resonance and one below, at which the voltage in the cavity is 0.707 that at resonance, then

$$Q=\frac{f_0}{f_1-f_2}. \qquad (26)$$

The Q of a 10-cm. cavity made of copper is typically as great as 15,000. This is much higher than the Q of resonant circuits made of coil-and-condenser combinations, for use at lower frequencies, because of the great effectiveness of a resonant cavity as a device for the storage of energy.

TR and ATR Switches.—Resonant cavities are used in the construction of the TR and ATR switches needed to permit duplex operation of a radar transmitter and receiver on a single antenna. Fig. 25 shows schematically how gas-discharge switches, fired by the high-power r-f pulse from the magnetron, can be mounted to perform the TR and ATR switching functions. Breakdown of the TR tube puts a low-resistance short circuit across the receiver line, thus protecting it; but since this short-circuit is a quarter wave length away from the junction with the antenna line, there is no attenuation of the wave travelling toward the antenna. Breakdown of the ATR closes the circuit from magnetron to antenna; when the pulse is over and the ATR discharge goes out, the impedance at the T junction looking toward the magnetron is infinite because there is an open circuit half a wave length away. Looking toward the receiver, there is a matched line, so that all the echo power goes into the receiver.

To reduce the voltage necessary to break down the discharge gaps of the TR and ATR switches, they are filled with gas at a pressure of about 1/200 atmosphere. Further reduction is accomplished by mounting the discharge gap across a resonant cavity, to make use of the build-up in voltage accompanying resonance. Fig. 26 is a cutaway view of a TR tube used in the 3-cm. band. The resonant cavity is part of the tube envelope, and is made to be bolted between standard wave guide coupling flanges. Energy is coupled into and out of the cavity by means of round holes (filled with glass to retain the gas) in each side of the cavity. The discharge takes place between the two conical electrodes in the centre of the cavity; tuning is accomplished by moving one of them, mounted on a flexible diaphragm, toward or away from the other. To ensure rapid breakdown of the gap at the beginning of a pulse (within 0.01 μ sec.), a supply of ions is maintained in the gap by an auxiliary discharge which takes place constantly inside one of the cones.

ATR tubes are similar, except that they need have no output window, being mounted on the side of (*i.e.*, in series with) the r-f line. Ordinarily they are made with lower Q, to reduce the chance of accidental maladjustment of tuning.

Antennas and Scanners.—The antenna of a radar set must radiate into space the energy fed to it as r-f pulses, and must gather in the echo signals and send them down the r-f line to the receiver. A good transmitting antenna is also a good receiving antenna; thus only the former function need be considered. Sharp beams are needed to make radar direction-finding possible, and a great deal of attention has been paid to the design of highly directional antennas that are capable of producing beams of the desired shape and dimensions. The nature of the beam wanted depends, of course, on the radar application.

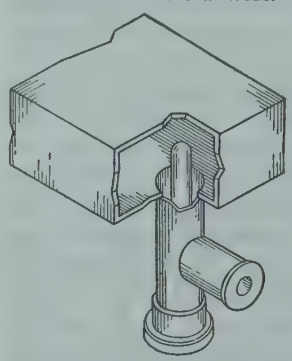

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FIG. 24.—TRANSITION FROM COAXIAL LINE TO WAVE GUIDE

Antenna Design.—The beam width, Θ, produced by an antenna is directly proportional to the wave length of the radiation used, and inversely proportional to the width of the antenna. Beam width as usually defined is the full angular interval between the points at which the power radiated from the antenna has fallen to half its maximum value (fig. 27). Fig. 27 shows also the "side lobes," small subsidiary maxima unavoidably produced by a directional antenna. Their effects are usually objectionable, and attention is paid in antenna design to reducing the power in the side lobes. The beam width in degrees is given approximately by

$$\Theta=70\lambda/D, \qquad (27)$$

where λ is the wave length and D the width of the antenna in the same dimension as that for which Θ is measured. D and λ should be given in the same units.

Among the simplest microwave antennas is a reflecting paraboloid of revolution illuminated by a source of radiation, or "antenna feed," placed at its focus. Since the diameter of the reflector is several wave lengths, this antenna can be regarded from the standpoint of ray optics (fig. 28). Fig. 28 does not explain the side lobes or the beam width, but it does emphasize that the feed for such an antenna must itself be directive.

In accordance with Eq. (27), a paraboloid whose top and bottom have been cut off to leave a reflector wider than it is high will produce a fan-shaped beam whose vertical beam width is larger than its beam width measured horizontally. A

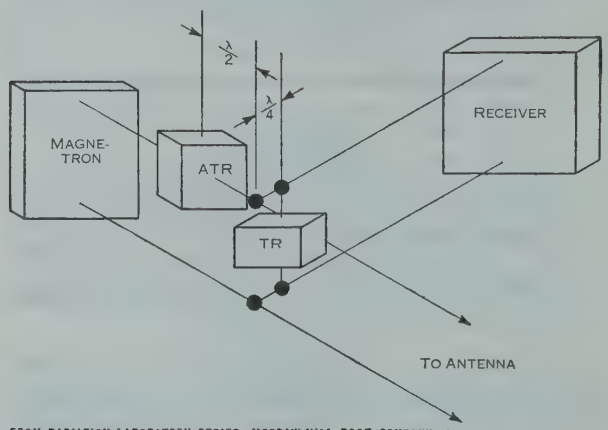

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FIG. 25.—PRINCIPLE OF A DUPLEXING SYSTEM SHOWN IN TERMS OF TWO-WIRE R-F TRANSMISSION LINE

"beaver-tail" beam wider in the horizontal than in the vertical direction can be produced by cutting off the sides of a paraboloid to leave a tall, narrow reflector. Further adjustment of the energy in the beam can be accomplished by altering the shape of the reflector without changing its over-all dimensions (fig. 29).

Instead of a paraboloidal reflector with a feed at its point focus, a parabolic cylinder with a linear feed located along its line focus can be used as an antenna.

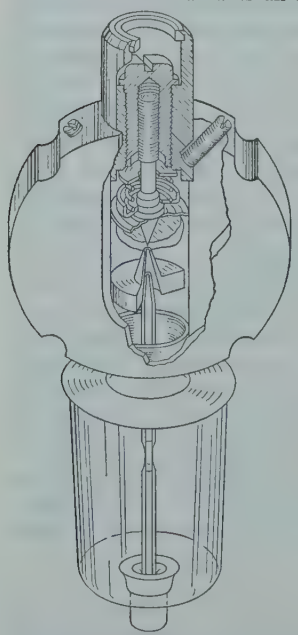

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FIG. 26.—CUT-AWAY VIEW OF 1B24 3-CM. TR SWITCH

Long-wave radar sets frequently employ "bedspring" antennas which are plane arrays of individual dipole antennas (fig. 2, Plate I). If the dipoles are excited in the proper phase with respect to one another, the radiation from each will combine with that of all the others to form a beam normal to the plane of the array. Since a similar beam is formed in the backward direction, a plane reflector is used behind the array. As the relative phasing of the dipoles is altered in a uniform way (for example, as it would be if the transmitter frequency were changed), the direction in which the beam leaves the array is changed. This scheme has sometimes been used to scan the beam over a range of angles by frequency modulation of the transmitter; usually, however, it simply constitutes a requirement for frequency stability in the transmitter. Arrays of dipoles are so difficult to construct and to phase properly at microwave frequencies that they are seldom used. Feed-and-reflector combinations are usually far simpler to construct, more rugged, and more flexible in design. Much ingenuity has gone into microwave antenna design, and the interested reader is referred to the bibliography for sources of further information.

Mechanical Scanning.—In order to cover the necessary volume of space with the narrow beam produced by a directional antenna, the beam must be swung around, or scanned. In most cases, the permissible rates of beam motion, fixed as

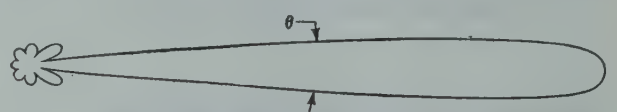

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FIG. 27.—A TYPICAL ANTENNA PATTERN. MAIN LOBE HAS BEAM WIDTH θ. SIDE LOBES ARE SHOWN

they are by the desirability of receiving several echo pulses from each target per scan, are so low that scanning can be accomplished by mechanical motion of the antenna array. The assembly of an antenna on its supporting structure, or pedestal, is called an antenna mount, or scanner.

Radar scanners are of many different sorts, the detailed design being dictated principally by the size of the antenna (this being determined by the wave length used and the beam width desired), and by the scanning pattern used to cover the volume being searched. A few simple scanning patterns are:

(1) *Azimuth scan.*—The beam is swung around the horizon at a uniform rate. The desired vertical coverage is obtained by fanning the beam in the vertical direction.

(2) *Helical scan.*—If information on the elevation angle of targets is wanted, a pencil beam can be used, uniform azimuth rotation employed, and the elevation angle of the beam altered constantly at a slow uniform rate (fig. 30). When the full elevation-angle range of interest has been covered, the motion in elevation angle is reversed.

(3) *Conical scan.*—For accurate direction-finding on a single target, a pencil beam can be rotated rapidly in a cone whose angular opening is smaller than the beam width. Only when the axis of the cone is directly pointed at the target will the signals received in various phases of the rotation of the beam have constant intensity. A change in signal strength will accompany conical scan when the axis of the cone is not quite on the target. The magnitude and phase of this change in signal strength as the beam rotates indicates the direction and the magnitude of the pointing error. The direction of the cone axis is changed to make the "error signal" zero. By the use of this scheme, radar direction-finding can be given a precision of about one-fiftieth of a beam width; this is far greater precision than can be obtained by noting the direction of maximum signal return when a beam is swept over a target.

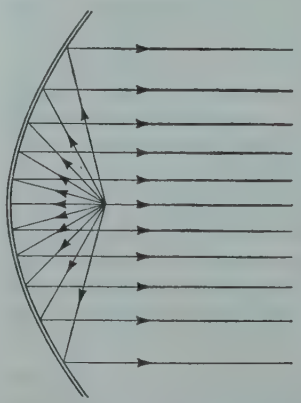

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FIG. 28.—RAY DIAGRAM OF A PARABOLOID ANTENNA

(4) *Spiral scan.*—If a rapid axial rotation of a pencil beam, like that used in conical scanning, is combined with a slow change in the cone opening, a spiral scan (fig. 31) results. This permits rapid coverage of a fairly large area, with facilities for determining roughly both the azimuth and the elevation of targets.

Data Transmission.—In order to make use at the radar indicator of the directional information afforded by scanning, means must be provided for transmitting to the indicator a knowledge of the scanner position in all important co-ordinates. Only azimuth must be transmitted for an azimuth scan, azimuth and elevation for a helical scan, and azimuth, elevation and phase of rotation for a conical or a spiral scan.

This "data transmission," as it is called, is almost always accomplished electrically. The flexibility of mechanical means of data transmission is not sufficient to meet radar requirements. Self-synchronous generators and motors of the type used in other

applications for transmitting position information are frequently employed. So are precision adjustable resistors. The latter have the advantage that they can be wound in such a way that the output voltage is any desired function of angle of rotation. Further, the applied voltage, to which the output voltage is proportional, can be varied in any fashion desired. Thus computation can be performed directly by the data transmission device.

For example, suppose it is desired to find target height, h, from a measurement of range, R, and elevation angle, ϕ; it will be given by

$$h = R \sin \phi. \qquad (28)$$

If the resistance card of the adjustable resistor used to measure elevation angle is so wound that its output voltage for an elevation angle ϕ is proportional to $\sin \phi$, and the voltage applied to this resistor is developed from another adjustable resistor used to measure range and having an output linear with R, then the voltage at the output terminals of the elevation-angle resistor will be a direct measure of the height of the target. A highly successful anti-aircraft computer was built during World War II on this principle. When it was used with radar, the data-transmission units of the radar actually formed part of the computing mechanism.

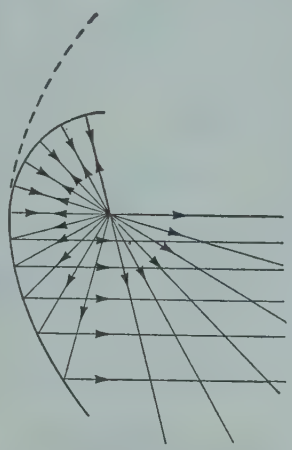

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FIG. 29.—DISTORTION OF A PARABOLOID REFLECTOR TO PRODUCE A FAN BEAM WITH DESIRED DISTRIBUTION OF ENERGY

Rapid Scanning.—In some radar applications, such rapid scanning is desired that mechanical motion of a large antenna mount is not feasible. A number of devices have been developed to permit rapid scanning in one dimension by relatively subtle mechanical motions of parts of the antenna. These devices are sometimes referred to as "electrical" scanners, although rapid mechanical motion is almost always fundamental to the scanning.

The scanning of the beam of a dipole array by variation of the frequency fed to the antenna, as already mentioned, can be done very rapidly and can be done entirely electrically. Since means for frequency modulation of magnetrons were developed only late in the war, this scheme was never used with microwaves.

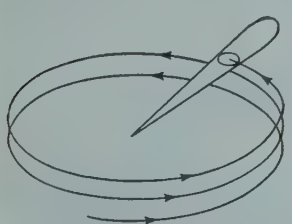

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FIG. 30.—HELICAL SCANNING PATTERN

Scanning arrays were built that made use of mechanical phase shifters built into the feed lines going to the various units of the array. These phase shifters had low inertia and were driven in continuous rotation; the scanning could thus be very rapid.

Similarly, a linear array of dipole radiators all fed from a single wave guide was used to produce a fan beam. The angle which this beam made with the wave guide could be varied by altering the phase difference between neighbouring elementary dipoles. This was accomplished by changing the guide wave length of the radiation (which was fed in at a fixed free-space wave length) by altering the width of the guide in its broad dimension. *See* Eq. (25).

Other schemes for rapid scanning involved antenna feeds which transformed the continuous and rapid rotation of a feed horn into a linear motion of the radiation source used to illuminate a reflector. Great care must be taken, in such a scanner, that the "optical" system formed by reflector and feed has low aberration when the feed is displaced considerably from the focus of the reflector.

Stabilization.—When a radar scanner is mounted on an unstable platform, such as a ship or an aircraft, readings of azimuth and elevation relative to the platform must be converted into readings of these angles with respect to a stable set of reference axes. Compasses, directional gyros, and gyro stable verticals are commonly used as reference devices, and the stabilization of the radar data, as this conversion process is called, can be performed in a variety of ways.

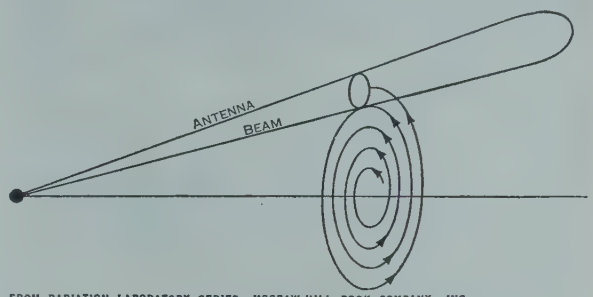

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FIG. 31.—SPIRAL SCAN

Radar Receivers.—Under the term "receiver" is classed that part of the radar equipment which accepts the feeble echo pulses from the r-f line, amplifies them, rectifies them, and delivers to the terminals of the indicator or display equipment unipolar pulse signals at a level usually of several volts.

Without important exception, radar receivers are of the superheterodyne type shown in fig. 32. In a superheterodyne, a local oscillator supplies c-w signals at a low level to a mixer, where the echo signal and the local oscillator signal beat to give a signal at a frequency (called the intermediate frequency) equal to the difference between the frequencies of the signals mixed. This beat signal is modulated with the same intelligence as that conveyed by the r-f echoes, and its frequency is chosen to permit fairly standard techniques to be used in the i-f amplifier.

The i-f amplifier is normally tuned to a fixed frequency, and the receiver tuning is changed by altering the frequency of the local oscillator. Arrangements, called AFC (for automatic frequency control), are incorporated in most radar receivers for keeping the local oscillator properly tuned with respect to the radar transmitter. Demodulation of the amplified i-f signal is accomplished by a second detector followed by a filter for the intermediate-frequency signal. The resulting signals, called "video signals" because their frequency range is about that of television video signals, are further amplified and sent to the indicator.

Microwave Mixers.—No satisfactory amplifier for microwaves was developed during the wartime work on radar, so that conversion to intermediate frequency in the mixer had to be done at the low level of received signal power. This requires that the nonlinear element used in the mixer be as efficient as possible, and introduce a minimum amount of random noise. The most satisfactory element found was the rectifying contact between a metallic point and a silicon crystal. The whole assembly was sealed up in a cartridge, referred to as a "crystal," for protection and stability. The standard form for this cartridge is shown in fig. 33.

The D.C. characteristic of a crystal is shown in fig. 34. It was possible in 1946 to make crystals with nearly as good a conversion efficiency as could be obtained from a thermionic diode at much lower frequencies—and much better efficiencies than were available from tube converters in the microwave region.

The contact area between the metal and the silicon is only about 10^{-6} cm^2. High current densities are therefore produced even by low currents, and a crystal can readily be burned out, especially by a pulse so rapid that heat cannot be conducted

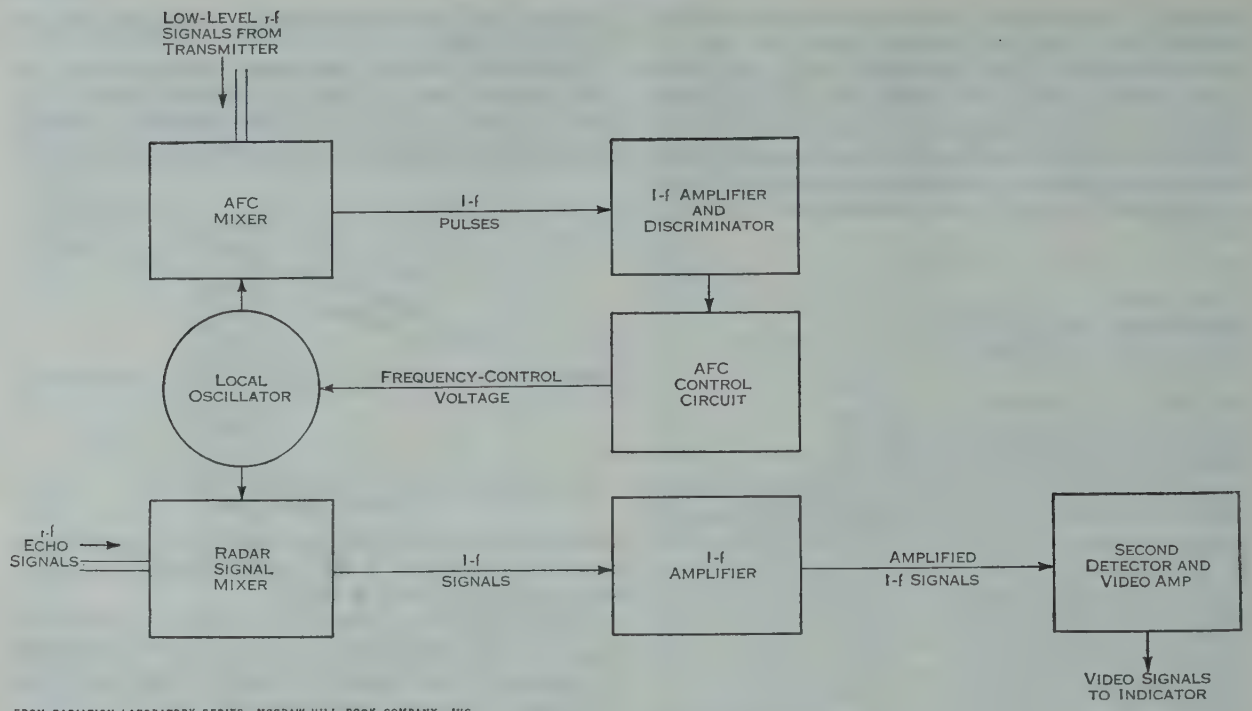

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FIG. 32.—BLOCK DIAGRAM OF A SUPERHETERODYNE RECEIVER

away from the contact.

The r-f circuit in which the crystal is installed is called the "mixer." It has input terminals for the signal and for the power from the local oscillator. Its output terminals are connected to the first stage of the i-f amplifier. Care is taken in mixer design to make the crystal appear as a matched load to the incoming signal; to prevent, as far as possible, loss of echo-signal power into the local-oscillator input line; and to provide a reasonably good match looking into the mixer from the local oscillator.

Local Oscillators.—The magnetron, although a very efficient source of high pulse powers, was not employed in wartime radar as a source of the low-level c-w signal required from the local oscillator of a superheterodyne receiver. Quite satisfactory tubes of other types were developed for this purpose.

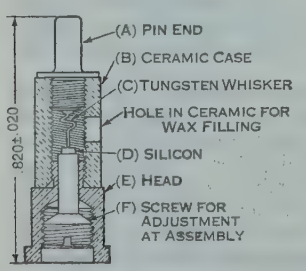

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FIG. 33.—STANDARD MICROWAVE MIXER CRYSTAL

Some wartime radar sets used a special triode, called a "lighthouse" tube because of its construction, as a local oscillator. The lighthouse tube is designed with planar electrodes and extremely small interelectrode spacing to reduce electron transit time. External connections to its electrodes are provided in the form of disks and cylinders (fig. 35), so that a cylindrical r-f circuit can be built directly around the tube. An average power output of a few watts can be obtained from a lighthouse tube, and the tube can also be pulsed to give peak power of about 1 kw. It has been used as a transmitter in some low-power radar sets.

Most radar sets used a reflex klystron as a local oscillator. Fig. 36 is a schematic diagram of such a tube. Integral with the tube structure is a doughnut-shaped resonant cavity with grids across its central portion. An "electron gun" focuses a stream of electrons through the grids. Upon arrival at the first grid, the electrons have a velocity corresponding to the 300 volts applied to accelerate them. If oscillations exist in the cavity, electrons will either be accelerated or decelerated by the r-f field which they encounter as they pass through the space between the cavity grids.

An electron which goes through just as the r-f field is passing through zero will not have its velocity changed, and will be described as a reference electron. In the space just beyond the second grid there is a strong retarding field produced by a reflector electrode maintained about 100 volts negative with respect to the cathode. The path of the reference electron in this retarding field is similar to that of a ball thrown into the air. It will return to the grids after a time proportional to the retarding field. An electron that leaves the second grid earlier than the reference electron will have been accelerated by the r-f voltage which then existed across the cavity, and, because of its higher velocity, it will spend a longer time in the reflection space than will the reference electron. By proper adjustment of the retarding field, the delay can be made to compensate for its earlier departure, so that it arrives back at the grids at the same time as the reference electron.

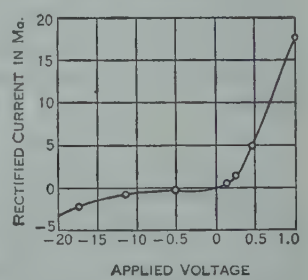

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FIG. 34.—TYPICAL CHARACTERISTIC CURVE OF A SILICON RECTIFIER

Similarly, an electron leaving later than the reference electron has been decelerated by the r-f field, has a lower velocity, and thus catches up with the reference electron because it spends less time in the reflection space. The net effect is that the electrons gather in a bunch which is formed about the reference electron. At certain reflector voltages, the bunch will return through the cavity grids in such a phase that the r-f field retards the electrons, and thus receives from them energy to sustain the oscillations in the cavity. Oscillation is observed for more than one reflector voltage, since drift times differing by a whole r-f period still produce satisfactory bunching.

The net energy given to the electrons during their first passage through the cavity is negligible when averaged over a whole r-f cycle, being balanced between acceleration and deceleration.

On the return passage, most of the electrons go through in a bunch at the most favourable phase to aid the oscillation. Very few electrons pass through on the return trip half a cycle later, when they would absorb energy from the r-f field. Power is coupled out of the cavity through a loop feeding into a coaxial line. Power outputs in the range from 20 to 50 milliwatts and efficiencies of about 1% were typical of such tubes in 1946.

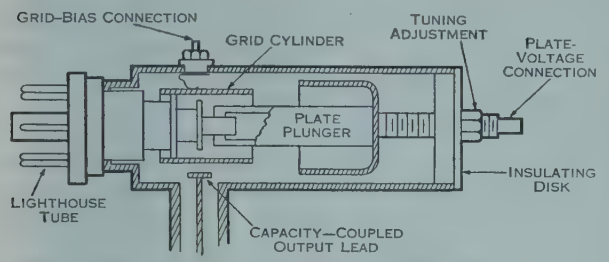

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FIG. 35.—LIGHTHOUSE TUBE MOUNTED IN A COAXIAL CIRCUIT

Tuning over a wide range is accomplished by changing the size of the cavity mechanically; a small amount of tuning can be done by varying the reflector voltage. Fig. 37 shows the frequency and power output of a 10-cm. reflex klystron as a function of reflector voltage. Reflector tuning is used in automatic frequency control.

Automatic Frequency Control.—The problem of keeping a radar set properly in tune consists in maintaining the difference

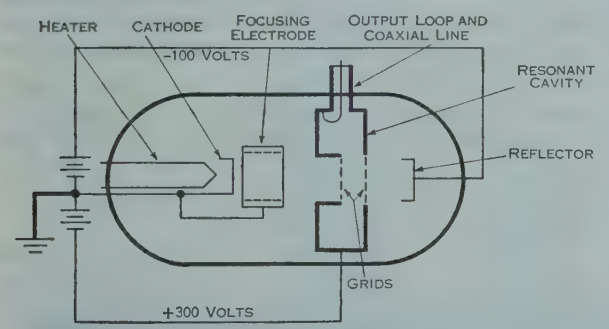

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FIG. 36.—SCHEMATIC DIAGRAM OF REFLEX KLYSTRON OSCILLATOR

between the local-oscillator frequency and the magnetron frequency constant at the value appropriate to the i-f amplifier, with an accuracy of perhaps 0.5 Mc./sec. AFC is a practical necessity in scanning radar, for the magnetron frequency can be altered several Mc./sec. by changes in standing-wave ratio occurring in the r-f system either in consequence of unsymmetrical rotary joints or because of strong reflections from nearby objects such as the masts of a ship or the engine nacelles of an aircraft carrying the radar. Further, variations in voltage, temperature, and pressure all produce changes in frequency. Manual tuning is quite unsatisfactory, and AFC has come to be a standard part of all radar.

In the AFC system, part of the local-oscillator power is mixed, in a crystal, with a small fraction of the magnetron power drawn out during transmission of the pulse. The resulting signal at the difference frequency is applied to a discriminator circuit similar to those used in a frequency-modulation receiver. The crossover or no-output frequency of the discriminator is set at the intermediate frequency of the radar. The pulses which come from the discriminator are integrated to produce a voltage that is applied to the reflector of the local oscillator in the proper sense to change the frequency toward that value which will bring the discriminator output to zero. It is desirable to use an AFC mixer which is separate from the signal mixer, but it is possible to make an AFC system which obtains its information from the leakage power which inevitably reaches the signal mixer during the transmission of an r-f pulse from the magnetron.

The I-f Amplifier.—Because of the low power level of the input signal to a radar i-f amplifier, the greatest attention must be paid to minimizing the inherent noise of the amplifier itself. Further, since strong pulses several hundreds of μ sec. in length may be followed immediately by weak signals which must not be missed, the transient response of the i-f amplifier must be excellent. The amplifiers which resulted during World War II from attention to these requirements were rather different from anything which had previously existed.

The intermediate frequency is usually chosen in the range from 15 to 60 Mc./sec. The over-all gain of the i-f amplifier is usually around 120 db. or 1,000,000 times in voltage. The desired over-all band width of the amplifier is ordinarily about 2 Mc./sec. Since the cascading of amplifier stages results in an over-all band width much less than the band width of an individual stage, it is very important to attain the highest possible product of gain and band width in the individual stages.

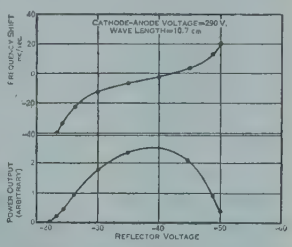

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FIG. 37.—FREQUENCY AND POWER OUTPUT OF A 10-CM. REFLEX KLYSTRON AS A FUNCTION OF REFLECTOR VOLTAGE

The design of the interstage coupling circuit used in an i-f amplifier has an important effect on the gain band width product that can be achieved with given tubes. The characteristics of the tubes themselves are also of the greatest importance, the leading property being the ratio of trans-conductance to input and output capacity.

It is important that regenerative feedback of signals does not take place from later stages to earlier stages of the i-f amplifier, or from plate to grid circuit in a single stage. Circuit layout and shielding must be carefully planned to avoid regeneration.

Second Detector.—The second detector produces a rectified voltage proportional to the amplitude of the i-f waves. In most radio receivers it is important that this proportionality be exact; in a radar receiver the response of the second detector may be proportional to a higher power of the i-f amplitude, so long as reasonable efficiency is maintained. Either a thermionic diode or a rectifying metal semiconductor contact ("crystal") is used as the nonlinear rectifying element. Second-detector crystals usually employ germanium, instead of silicon, as the semiconductor, since germanium crystals can be made to stand a somewhat higher reverse voltage.

Video Amplifier.—The unipolar signals from the second detector, usually at a level of a few volts, are further amplified by a wide band resistance-capacitance-coupled amplifier called the video amplifier, because of its similarity to the video amplifiers used in television.

When the line from the radar proper to the indicator must be long, it is economical to drive the line at a low video-signal level and provide video amplification at each indicator. Since the standard dielectric-filled coaxial cable ordinarily used for the transmission of video signals has a low impedance—in the neighbourhood of 75 to 100 ohms—a "cathode follower" stage is frequently used to drive the line.

Radar Indicators.—The device which presents radar data in observable form is called the indicator. It is almost always a cathode-ray tube (CRT). The CRT presents a representation of electrical phenomena in terms of a picture painted on a phosphorescent screen by a sharply-focused beam of electrons controlled in position and intensity by electrical signals. The CRT is capable of using and displaying many millions of separate data per second, and the geometrical expression which it gives to radar data is particularly appropriate, since a geometrical situation involving the various radar targets is usually precisely what must be represented.

CRT Screens.—Both magnetic and electrostatic CRT types are used, the term referring to the means of deflecting the stream of electrons (fig. 1). The properties of the materials (phosphors) making up the luminous screen are of particular importance to the performance of the tube. If, as is usually the case, the scanning of the radar antenna interrupts the display in a given sector of the screen for longer than the retentivity time of the eye, it is desirable to introduce persistence into the screen—that is, to use a phosphor which will glow for some time after having been excited.

If little or no persistence is needed, the green willemite phosphor used in ordinary oscilloscope tubes and known as type P-1 is satisfactory. This material is extremely efficient in converting the energy of the electrons which strike it into luminous energy; it has an exponential decay with a time constant of a few milliseconds. If a rather short persistence is needed, a zinc-magnesium fluoride phosphor designated as P-12 is used. Its decay properties are shown in fig. 38.

Most radar applications demand even a longer persistence. This can be achieved by a "cascade" screen consisting of two layers of different phosphors. The electrons strike and excite an inner layer of silver-activated zinc sulphide, which glows with a blue light. This blue light excites a layer of persistent phosphor, usually copper-activated zinc-cadmium sulphide. The zinc-to-cadmium ratio determines the decay characteristics. The two screen types most used in radar, P-14 and P-7, have decay characteristics shown in fig. 38. Since the long-persistence phosphor emits a predominantly yellow or orange light, an orange filter is used to remove the blue "flash" of the inner phosphor, which is annoying to the observer.

Radar Displays.—Because of the many special purposes that radar can serve, a considerable variety of different forms of display have been developed and used. The A-scope (fig. 1, Plate I) and the PPI (Plate III) have already been mentioned. These are typical of two general classes in which the radar echo signals are used either (1) to deflect the CRT electron beam, or (2) to alter its intensity. Displays of the first type (deflection-modulated displays) are useful for giving precise information on the strength and character of the signals delivered by the receiver, but leave only one dimension of the tube face free to represent a geometrical quantity. Displays of the second type (intensity-modulated displays) permit the presentation of a two-dimensional figure on which the signals appear as bright spots or patches, but the intensity response of CRT electron guns is so nonlinear that the brightness of each patch offers only qualitative information about signal intensity.

When a three-dimensional picture must be presented on the two-dimensional face of a CRT indicator, either more than one display must be used, or a formalized way of presenting the third dimension in an understandable, though unnatural, fashion must be devised.

The vast majority of radar displays use as one co-ordinate the value of slant range to the target. Range is displayed by causing the electron beam of the CRT to sweep across the tube at a uniform rate starting from a given point or line at a definite time in each pulse cycle. Distances on the tube face from the starting point are then proportional to increments of range.

The angle at which the scanner is pointing, either in azimuth or elevation, may enter the display (1) directly as a polar angle, (2) directly as a cartesian co-ordinate, or (3) as the basis for resolving a range sweep in a particular direction.

Usually markers are employed to assist in making measurements of range or angle on a radar indicator. These may be "electronic" markers introduced into the signal channel as artificial video signals generated by a precision timing circuit (for range markers) or an angle-measuring circuit (for angle markers). Alternatively, they may be mechanical grids or markers placed over the face of the CRT.

A few of the most important radar display geometries are catalogued below, according to the spatial geometry represented.

One-dimensional Deflection-modulated Displays.—The simplest display of this type is the A-scope (fig. 1, Plate I). Range is invariably the spatial co-ordinate presented on a display in this class. If it is desired to do accurate range-finding with the help of an indicator in this category, arrangements are made to delay the start of the range sweep by any desired amount, so that the interval displayed will include the target of interest. The sweep speed is then greatly increased, to give higher resolution in range. Usually a movable electronic marker is provided for the precise measurement of range. Such a display is called an R- (for range) scope. Fig. 39 shows R-scope displays with various types of movable range markers.

Greater sweep length can be obtained by bending the range sweep into a circle on the face of the tube, and using the radar echo signals to deflect the beam radially from the centre of the CRT. Fig. 40 shows such a display called a J-scope.

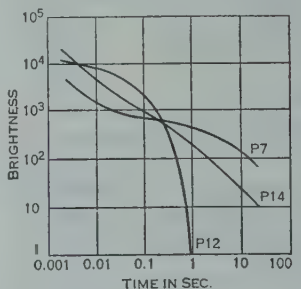

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FIG. 38.—DECAY CHARACTERISTICS OF VARIOUS TYPES OF CRT SCREENS

Simple deflection-modulated range displays can be used for comparing the signal strength from two antennas whose patterns make a small angle with one another, or from a conically scanning antenna in two positions 180° apart. The K-scope is so arranged that the range sweeps to be compared start from different origins, so that the echoes to be compared are side by side. In the L-scope, signals from the two antennas produce deflections of opposite sign, the range origin being common (fig. 41).

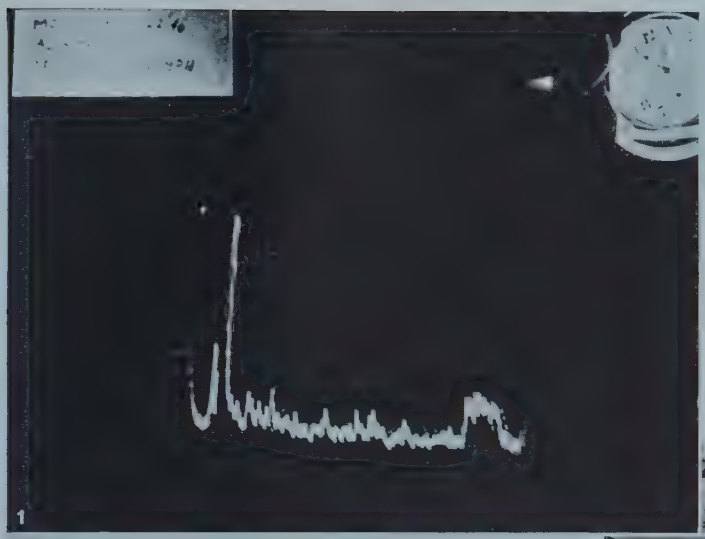
Two-dimensional Intensity-modulated Displays.—The PPI is the most generally useful of the indicators in this category. For certain purposes, it is altered by moving the range origin (off-centre PPI; *see* fig. 1, Plate II), or by expanding the zero-range origin of the PPI into a circle (open-centre PPI), or by delaying the start of the sweep, so that a ring-shaped area is collapsed into a solid circle (delayed PPI).

A PPI can also be deformed by "stretching"; that is, by giving different scale factors to the two cartesian co-ordinates of the display. Straight lines remain straight but, except for those parallel to the cartesian axes, their directions are changed. If elevation, instead of azimuth, is the angular co-ordinate used on the scope, the resulting display is called a range-height indicator, or RHI. Lines of constant target height are horizontal and equally spaced. (*See* fig. 42 and fig. 1, Plate V.)

A plane surface can also be represented in a deformed manner useful for certain radar applications by presenting range and angle in cartesian rather than in polar co-ordinates. This is accomplished by moving a range sweep laterally across the tube face in synchronism with the scanner motion so that the range origin is stretched out into a line. The resulting deformation is shown in fig. 2, Plate V. If the angular field shown by such a display is small enough, it can be "normalized" to reduce the distortion to modest limits. Normalization is performed by keeping the angular dispersion proportional to the range to the centre of the display.

Occasionally, two-dimensional intensity-modulated radar displays consist of a rectangular plot of azimuth and elevation. From the standpoint of signal discernibility such an indicator, called a C-scope, is very bad. Noise from all ranges piles up in each spot on the indicator face, and the desired signal must compete with the combined effect of this noise for recognition. As a result, a C-scope is never used alone as the only indicator of a radar set, and it is used at all only under special circumstances.

Three-dimensional Displays.—As already remarked, no real three-dimensional display can be presented on the two-dimensional face of a CRT. However, certain formalized ways have been developed for indicating target elevation on a display



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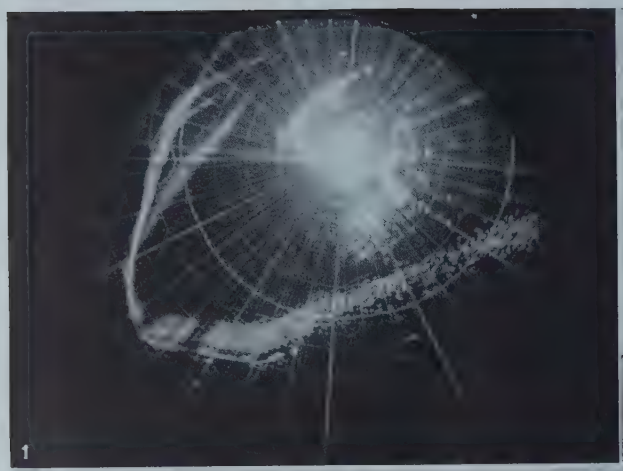
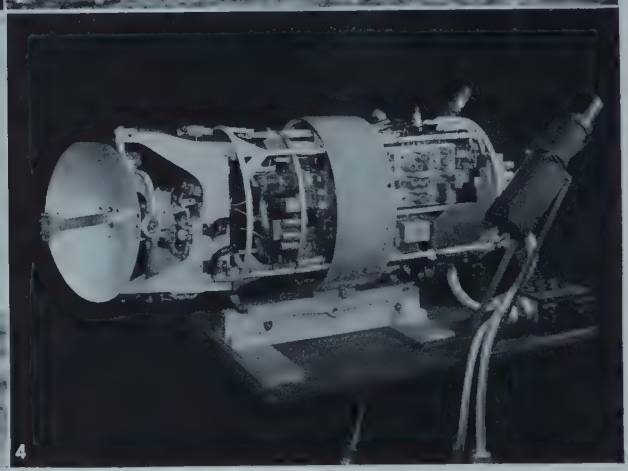
1. The simplest radar display, the A-scope. Range is measured horizontally from left to right; echo-signal intensity shown by upward deflection of trace. Signal at right is radar echo from the moon
2. One of the earliest army radars, the SCR-270. Sets of this type, used for long-range warning of aircraft attack, served throughout World War II. The Pearl Harbor radar warning came from one of these sets
3. Wooden receiving-antenna masts of the earliest British radar, the CH. These sets were used throughout World War II, being used in 1944–45 for plotting German V-2 rockets directed at London. Set shown is at Swingate, Dover, looking across the English channel toward France
4. Operations room of CH station, located near bottom of centre mast shown in fig. 3. Large signs with "S" indicate that equipment is "serviceable"; *i.e.*, in working order

RADAR





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1. Indicator of high-power ground radar sited near western German border in early 1945. Centre of "spiderweb" is location of station; concentric circles are range markers 10 mi. apart. Radial lines are angle markers 10° apart. Signals within 30 mi. are mostly permanent echoes returned by hills in view of radar. Stream of dots between 40 and 70 mi. range at right and below is a 500-plane R.A.F. bomber raid. Wispy trail at left of picture is signal returned by "window" —tinfoil strips cut to give confusing echoes on enemy radar—dropped by bombers during raid. "Window" trail shows that bombers have just made sharp left turn
2. British Type-13 radar height finder. Tall, narrow antenna shown produces a "beavertail" beam broad in azimuth and sharp in elevation. This is oscillated up and down in target azimuth to find elevation angle of target, and thus target altitude
3. "X-ray" view of SCR-584, the most successful anti-aircraft radar of World War II. Range, azimuth and elevation of a target were continuously supplied by this set to computer controlling gun battery. Accuracy was so great that good crews made combat records of only 40 shells fired per plane shot down. Versatility and good performance of set led to its use in many other wartime roles
4. One of the lightest and smallest of wartime radars. This sea-search (ASV) radar is shown complete except for streamlined housing that enables set to be hung under aeroplane like a bomb, which housing resembles in shape. Total installed weight of equipment is less than 200 lb.

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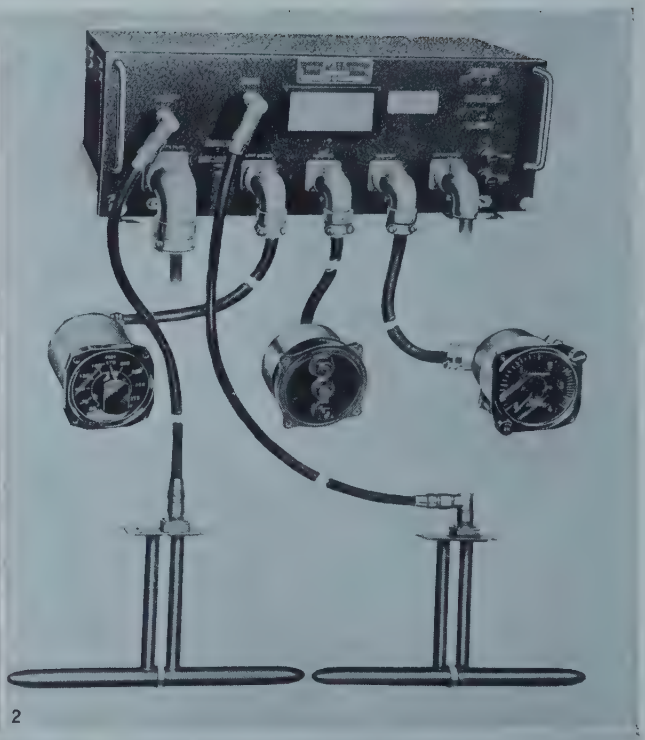
RADAR SCOPE PICTURES TAKEN WITH AIR-BORNE EQUIPMENT

ALL PICTURES PRINTED WITH NORTH AT TOP

1. Tip of Cape Cod, Mass., showing Provincetown harbour and jetties, ponds on Cape and other topographic features. Picture was taken from low altitude with air-borne PPI radar using 1.25-cm. wave length and having beam one degree wide. Bright spot over water just below largest pond marks position of aircraft
2. Connecticut coast between New Haven and New London. Relief of ground below as shown by radar is clearly seen. Note aid to recognition offered by river valley
3. Runways of airport at Bedford, Mass. Dark sectors at 5 and 7 o'clock on picture are regions obscured by aircraft wheels when lowered for a landing
4. Tokyo area on PPI of 3-cm. radar. Altitude 30,000 ft. This picture was taken with service radar equipment in actual combat mission. Tokyo is bright spot on edge of bay at 3 o'clock. Triangular shadow thrown by Mt. Fuji appears at 9 o'clock. Mt. Echizen, less than half the altitude of Fuji, throws a semicircular shadow at 8 o'clock
5. Lower Manhattan and neighbouring part of New Jersey on high-definition 1.25-cm. radar. Note Central park, bridges across East river, shipping in Hudson river and docks along its banks, Passaic river with its bridges, railroad lines and elevated highways over New Jersey meadows, and indications of Manhattan street pattern
6. Chicago, Ill., on 20-mile sweep. Note strong indication of predominantly rectangular street pattern

RADAR

1



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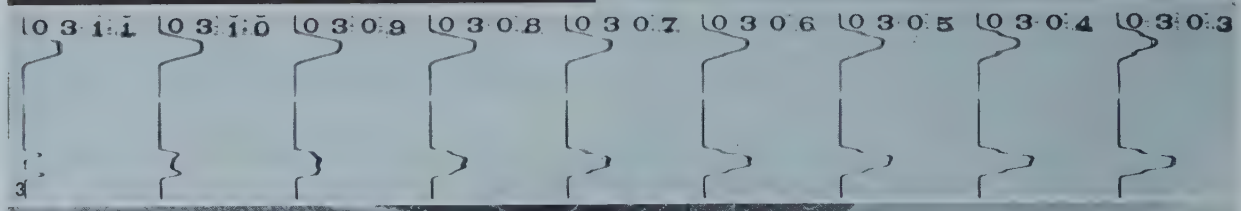

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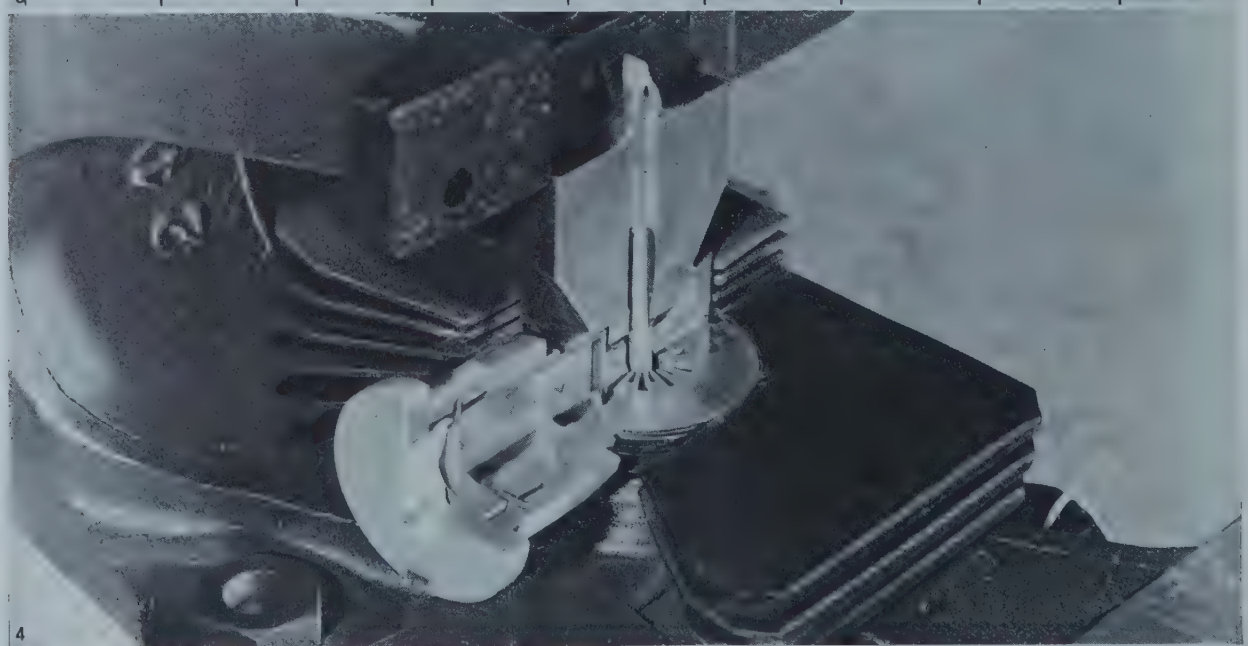
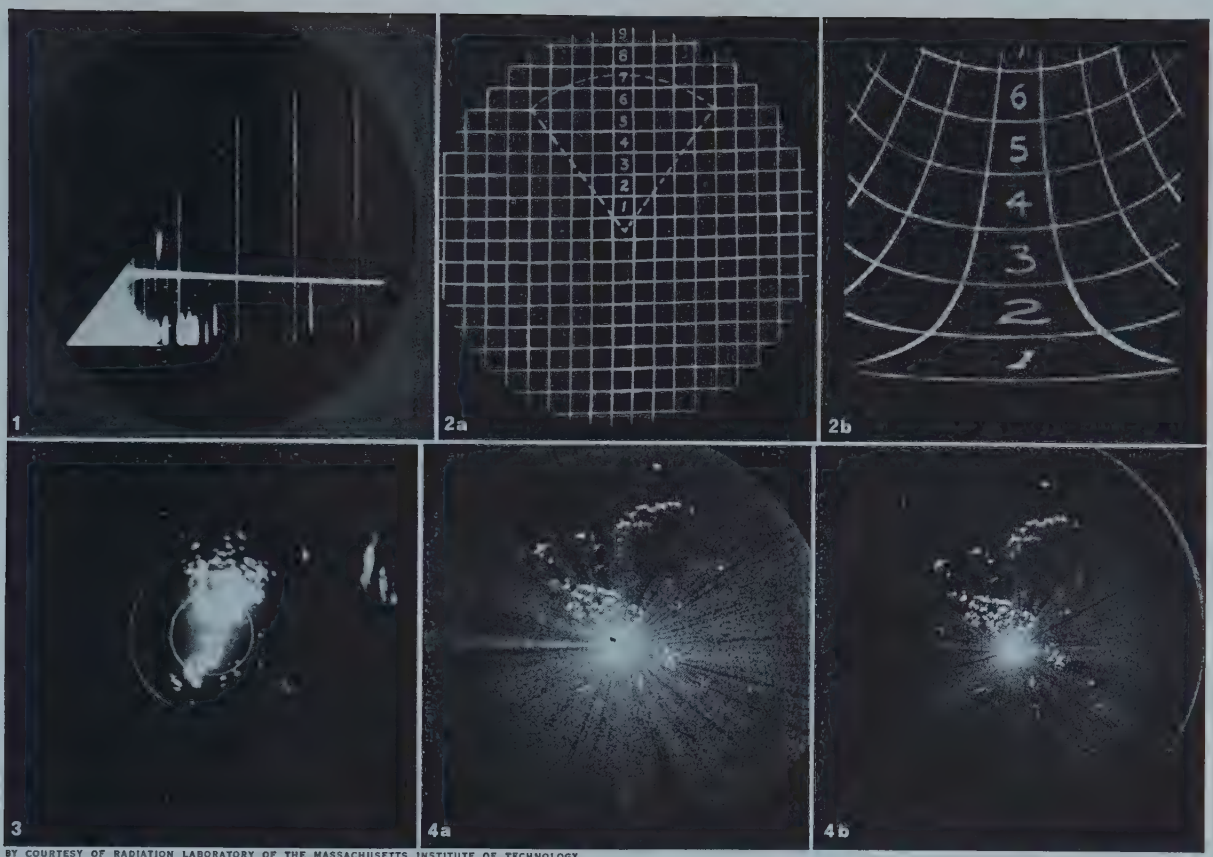


4

BY COURTESY OF (1) U.S. ARMY AIR FORCE, (2, 3) RADIATION LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, (4) BELL SYSTEM TECHNICAL JOURNAL

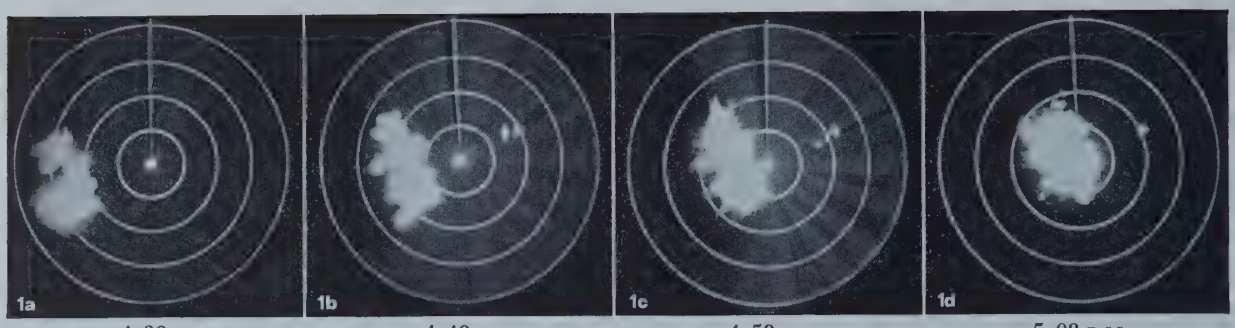
1. Echoes from a typhoon on the PPI of a 10-cm. radar system. Eye of the storm is clearly visible above centre of scope
2. The AVQ-6 FM radar altimeter. Antennas, controls and indicators are shown attached to the main unit
3. Successive frames of a photographic recording of an A-scope trace taken at one-sixteenth second intervals. Target at right consists of two radio towers and shows effect of signal interference in region where two echoes overlap
4. Cut-away view of 1.25-cm. magnetron in which mode separation is accomplished by making alternate cavities at different resonant frequency. Pole tips of permanent magnet are integral parts of magnetron construction



BY COURTESY OF RADIATION LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

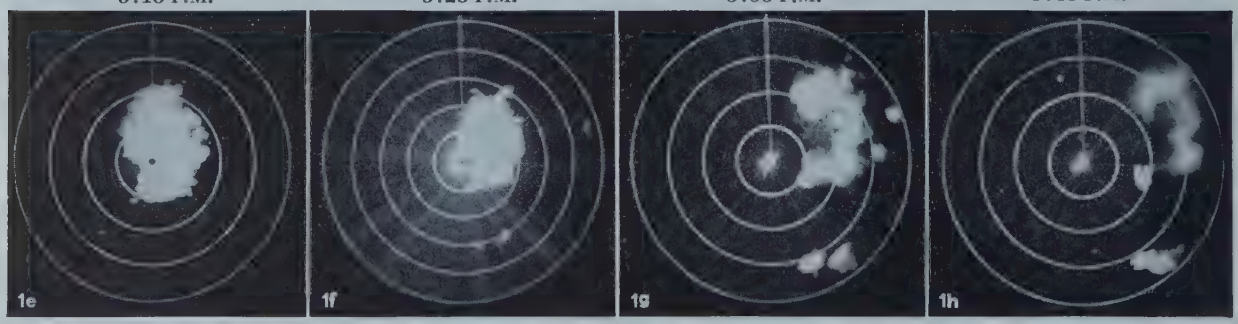
1. Photograph of an RHI scope. Vertical lines of constant range are 1 mi. apart, fifth lines being heavy. Strong return at short range is permanent-echo clutter. Heavy horizontal line is movable height index which is set to bisect target signal when height reading is taken. Three aircraft at various altitudes shown at ranges of 8, 13 and 21 mi.
2. Distortion produced in a type-B display which plots range and azimuth as cartesian co-ordinates. Sector outlined on PPI (a) is displayed as a rectangle on B-scope (b) with consequent distortion of grid
3. Radar echoes and beacon returns shown simultaneously on the PPI of a ground radar set. Range circles are 20 mi. apart. Beacon response at 4 o'clock, 43 miles. Range code is 1-1-1
4. PPI of a ground radar seen simultaneously at the radar (a) and at a radar relay receiving station more than 10 mi. away (b)

RADAR

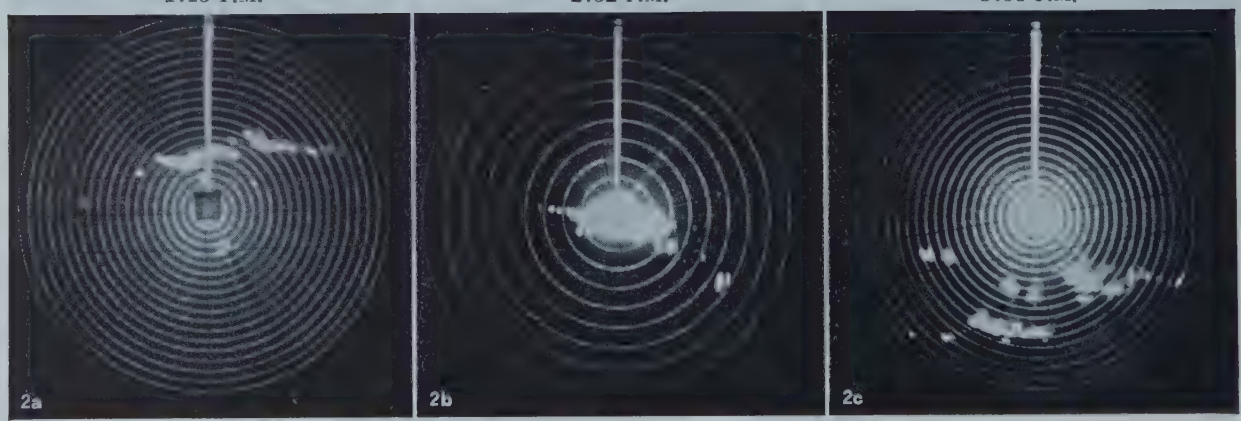


4:38 P.M. 4:48 P.M. 4:58 P.M. 5:08 P.M.

5:18 P.M. 5:28 P.M. 5:38 P.M. 5:48 P.M.



1:15 P.M. 2:32 P.M. 3:58 P.M.

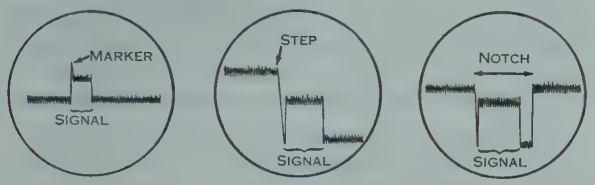


BY COURTESY OF U.S. SIGNAL CORPS ENGINEERING LABORATORIES

STORM DETECTION BY RADAR

1. Detection of a summer thunderstorm passage at Sea Girt, N.J. White line to top is true north, the right is east, etc. Circular markers are at intervals of 5 nautical miles. At 4:38 P.M. the storm was 9 to 18 mi. W.; at 5:08 P.M. the storm was over the station, at which time heavy rain was reported; the storm showed signs of dissipation on passage out to sea (5:38 to 5:48 P.M.)
2. Detection of a summer frontal storm by 3-cm. radar at Belmar, N.J. The line storm was 30 mi. to the north at 1:15 P.M., on the station at 2:32 P.M. and approximately 40 mi. to the south at 3:58 P.M. Note the change in shape of the storm during the 2½-hour period

which already shows target range and bearing. An example of this type is the "double-dot" display. On alternate range sweeps the origin of this modified Type-B indicator is moved to the right and left respectively by a fixed amount. On the sweeps occurring in the right-hand pattern the origin is simultaneously shifted vertically by an amount proportional to the sine of the elevation angle. Any single echo then appears in two neighbouring positions, and the slope of the line joining the two dots is a rough measure of elevation angle, accurate to two or three degrees under the usual circumstances of use. (*See* fig. 43.)



(a) R-SCOPE WITH MARKER PIP (b) R-SCOPE WITH STEP MARKER (M-SCOPE) (c) R-SCOPE WITH NOTCH

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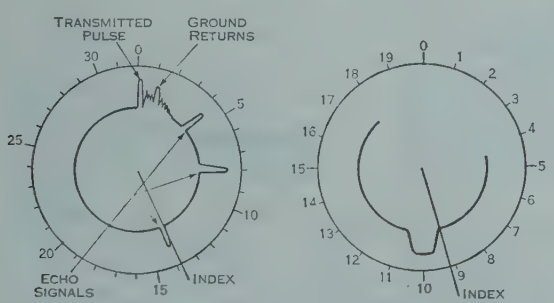
FIG. 39.—RANGE SCOPES. EACH DISPLAYS A DELAYED, EXPANDED INCREMENT OF RANGE. MOVABLE ELECTRONIC MARKERS USED IN MEASURING TARGET RANGE ARE (A) PIP MARKER, (B) STEP MARKER, (C) NOTCH MARKER

A Simple Indicator.—The electrical means of achieving the rapid and accurate sweeps necessary for radar indicators are beyond the scope of this article, and the interested reader is referred to the works quoted in the bibliography. However, it will be useful to outline the functions of the important parts of a simple display system.

The parts of the indicator circuit concerned with the pulse repetition cycle are called the "timer." The timer provides synchronization with the modulator, sweeps and markers for the display and measurement of range, blanking of the CRT during unused parts of the pulse cycle, and other related operations.

In some cases, the timer exerts control of the firing time of the modulator by sending it a trigger pulse; in others it responds to a trigger from the modulator. The latter type of system is shown in fig. 44. Waveform *b* is used to turn the CRT on



(a) READING IN THOUSANDS OF YARDS (b) READING IN HUNDREDS OF YARDS

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FIG. 40.—ANOTHER TYPE OF RANGE SCOPE, THE J-SCOPE. LEFT-HAND TUBE DISPLAYS 32,000 YD. OF RANGE AND HAS MOVABLE MECHANICAL INDEX WHICH CAN BE SET ON TARGET OF INTEREST. THIS TARGET IS THEN DISPLAYED ON EXPANDED 2,000-YD. CIRCULAR SWEEP OF RIGHT-HAND TUBE. INDEX OF RIGHT-HAND TUBE IS SET ON TARGET SIGNAL FOR ACCURATE DETERMINATION OF RANGE. THIS DISPLAY IS USED IN SCR-584

during the useful display cycle. The linearly-increasing (or sawtooth) waveform *c*, is used to provide the uniform range sweep for the indicator. Timing of this wave is controlled by waveform *b*. Electronic range markers (waveform *d*) are also generated by the timer and mixed with the radar video signals before they are sent to the CRT.

For illustrative purposes, fig. 44 shows provisions for either an A-scope or a B-scope display. For the former presentation, the range-sweep voltage is applied to one pair of deflecting plates and the mixed signal and range-mark voltages to the other pair. The square wave controlling the CRT intensity is applied to the cathode in the proper polarity to brighten the tube during the range sweep.

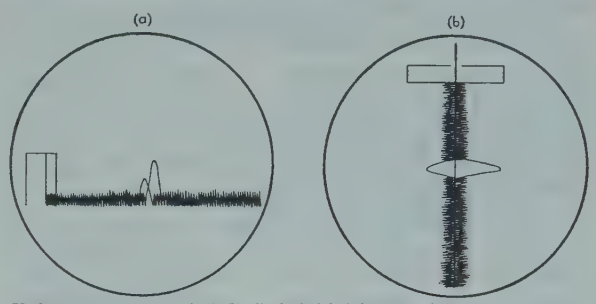

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FIG. 41.—DISPLAYS PERMITTING COMPARISON OF STRENGTH OF ECHO FROM A GIVEN TARGET ON TWO ANTENNAS, OR IN TWO POSITIONS OF A CONICAL SCAN. (a) SIDE-BY-SIDE PRESENTATION (K-SCOPE). (b) BACK-TO-BACK PRESENTATION (L-SCOPE)

In the Type-B display, the range sweep is applied to one pair of deflection plates, as before. Signal modulation is applied to the control grid, and the second set of deflection plates receives a voltage which produces the azimuthal deflection. This voltage may be furnished, for example, by a linear potentiometer geared to the axis of rotation of the scanner.

The arrangement shown is equally applicable to a magnetic CRT, the only changes being in the deflection amplifiers.

ACCESSORY DEVICES

Radar Beacons.—In nearly all cases where it would be advantageous if a particular radar echo could be made much stronger or more readily distinguishable from other confusing echoes, a radar beacon is indicated. By the use of a beacon, particular aircraft can be identified among heavy ground echo signals, or in the midst of a large formation of aircraft; the exact location of a specific point on the ground can be indicated, and so on.

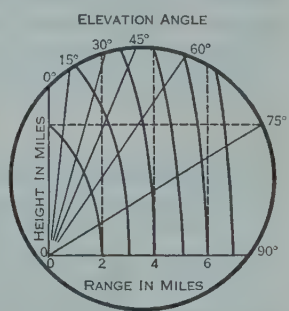

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FIG. 42.—THE RANGE-HEIGHT INDICATOR (RHI). THIS IS A POLAR DISPLAY WITH DIFFERENT SCALE FACTORS ALONG THE TWO CARTESIAN CO-ORDINATES. THE VERTICAL STRETCHING IS SHOWN BY THE TWO-MILE GRID SHOWN DOTTED IN THE DIAGRAM. LINES OF CONSTANT HEIGHT ARE STRAIGHT AND HORIZONTAL ON THIS DISPLAY

A beacon is a repeater of radar pulses (fig. 45). It has an antenna and receiver that convert pulses of energy received at high frequency from a radar set or a special beacon interrogator into triggering signals. Each such triggering signal fires the transmitter in the beacon and causes it to radiate one or more pulses of radio energy that may have almost any desired characteristics in regard to power, frequency, number, duration and spacing. A short time is required for the beacon to reply to an incoming pulse, so that the first reply pulse is slightly delayed beyond the radar echo which would be received from an object at the beacon location. This delay can be made as small as a few tenths of a μ sec. (a few tens of yards in range); if this small delay is still not negligible, it can be made very constant and allowed for in interpreting the beacon signals.

To permit the display of beacon signals alone, without radar echoes, the beacon transmitter frequency is ordinarily chosen to be different from the radar frequency. Beacon signals can be received at a radar set either by retuning the receiver to the beacon reply frequency, or by providing an extra independent receiver tuned to the beacon. Since the power of the beacon transmitter

can be made as great as desired, there is no limit to the strength of the beacon reply. The range at which a beacon can be seen will then be limited only by the power of the radar transmitter and the sensitivity of the beacon receiver, which together determine whether the beacon will be triggered or not.

Since the beacon interrogation and reply links are independent, instead of being two paths for the same energy (as in the case of radar echoes), the range at which beacons can be challenged and their replies received is usually very great, and ordinarily limited only by the optical horizon. The interrogation signal at the beacon falls off as the inverse square of the range to the challenging radar; the reply of the beacon has a power at the radar which is the same function of range.

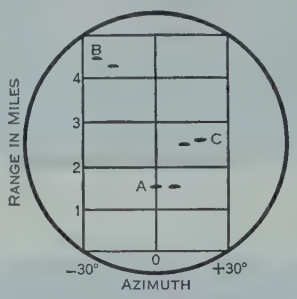

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FIG. 43.—THE DOUBLE-DOT INDICATOR. A B-SCOPE IN WHICH EACH TARGET ECHO APPEARS TWICE. ANGLE OF LINE JOINING TWO SIGNALS SHOWS ELEVATION ANGLE OF TARGET RELATIVE TO AXIS OF RADAR SCANNER. TARGET A IS LEVEL WITH SCANNER, 1.5 MI. AWAY, AND DEAD AHEAD. TARGET B IS 4.5 MI. AWAY, 25° LEFT AND SLIGHTLY BELOW. TARGET C IS 2.5 MI. AWAY, 12° RIGHT AND ABOVE

Beacons of the synchronous sort just described are variously called radar beacons, responder beacons, racons, or transponders, there being no important distinction among these terms. Free-running beacons that are not triggered by a pulse challenge are seldom used in conjunction with radar sets, since from them only the bearing of the beacon can be determined, and not its range. Range is so useful a part of the data supplied by radar that beacons which enable its measurement are far preferable to those that do not.

In order to avoid overloading a beacon located where there are many radar sets, it is usually desirable to provide an interrogation coding arrangement whose purpose is to limit the beacon responses to only those interrogation pulses specifically intended to elicit such a response. The decoder shown in fig. 45 is intended to serve this purpose. In the case of ground beacons serving as navigation check points for air-borne radar, it is customary to use pulse-width discrimination in the decoder. The usual radar pulses of an air-borne set are 1 μ sec. or less in duration; the beacon decoder is arranged to produce a trigger for the beacon transmitter only if it receives a pulse whose duration is 2 μ sec. or more. The air-borne radar is then fitted with a control which lengthens the transmitter pulses and simultaneously retunes the receiver to the beacon reply frequency when it is desired to look at beacon signals instead of at radar echoes.

Reply coding is intended to identify the particular beacon whose response is seen. In the case of microwave radar beacons, this reply coding is usually "range coding," involving the transmission of a closely-spaced series of short pulses from the beacon transmitter. Fig. 3, Plate V, shows the three-pulse reply of a beacon on a display in which radar echoes are simultaneously presented.

Other possibilities for coding both interrogation and reply are numerous. Distinct frequencies can be chosen. Simultaneous challenge on two or more frequencies may be necessary to unlock the beacon and elicit a reply. Combinations of properly timed multiple pulses can be used. The beacon reply may be keyed on-and-off to send letters in Morse code. The particular coding system chosen will depend on the application.

Sometimes it is desirable to use, as the device intended to trigger a beacon and to display its replies, not a radar set but a much lower-powered device intended only to work with beacons. Such an equipment is called an interrogator-responsor. It is a radar set in all respects except that its transmitter power is so low that radar echoes cannot be obtained at useful ranges. This reduction in power output enables the equipment to be made much lighter and simpler than a radar set at the same frequency would be. The interrogator-responsor can be especially small and light if only range information is wanted from the beacons, so that a scanner is not necessary and fixed antennas can be used. By providing two sets of fixed antennas aimed in slightly different directions, homing on a beacon can be done by turning the aircraft or ship carrying the interrogator-responsor until equal beacon responses are received on the two antennas.

By altering the interrogation and reply coding of a beacon to correspond with intelligence which it is desired to transmit, two-

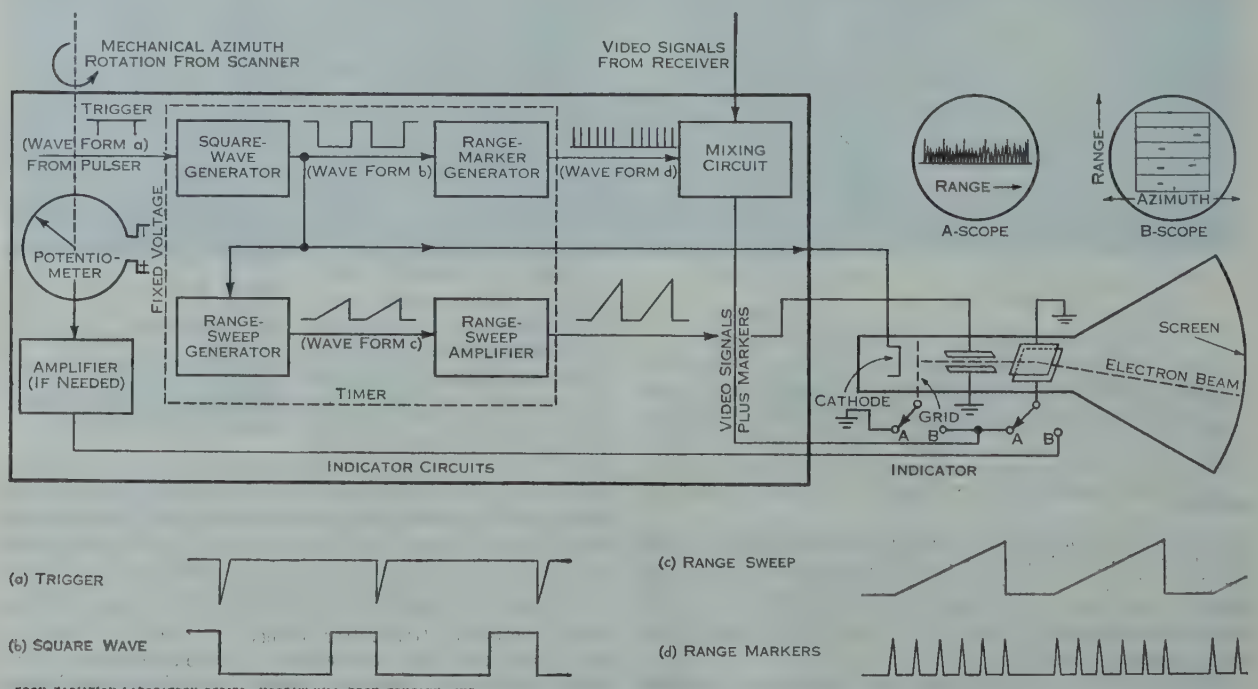

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FIG. 44.—BLOCK DIAGRAM OF A SIMPLE INDICATOR SYSTEM PROVIDING FOR EITHER A-SCOPE OR B-SCOPE DISPLAY. BELOW, WAVE FORMS IN CIRCUIT OF FIGURE

way communication using a radar-beacon link is feasible, and has been accomplished.

Radio Relay of Radar Displays.—It frequently happens that the best site for a radar equipment is not the best location for the organization which is to make use of the information provided by the radar. For example, in the World War II organization for fighter defense of the British Isles against hostile air attack, the operating centre was maintained at Stanmore, north of London; information was sent there from radar sets located all around the coasts.

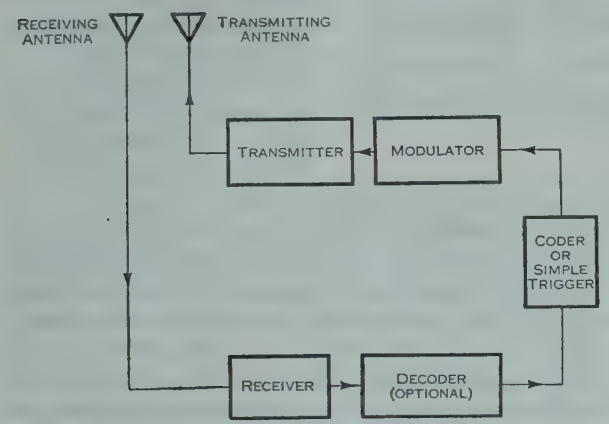

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FIG. 45.—FUNCTIONAL DIAGRAM OF A RADAR BEACON. TRANSMITTING AND RECEIVING ANTENNAS ARE USUALLY SEPARATE

During World War II it was customary to transmit radar information from one point to another by "plotting and telling." The radar echoes seen were entered at the proper range and bearing on a map with a superimposed rectangular grid; this was plotting.

The letters and numbers comprising the grid reference for the location of the plot were "told" vocally over telephone lines or radio circuits to the control centre, where the targets were replotted.

Such a system has several drawbacks. Not only are there many chances for the introduction of errors in target position, but also the speed and traffic-handling capacity of the system are severely limited. It has already been remarked that a radar indicator presents several millions of separate data per second. By no means all of these are significant, but in a situation involving hundreds of targets, which may not be at all uncommon (*see* fig. 1, Plate II), it is clearly impossible for even many tellers to give as useful a picture of the air situation as is available at the radar set.

For these reasons, methods were worked out during the war for transmitting, by a radio link, radar video information, synchronizing signals, and signals giving the direction in which the radar scanner was pointing at any instant. At the receiving station, these data could be used to construct a radar indication whose quality was just as good as that of the indicators located at the radar set itself.

The problems are mainly those of any wide-band radio link, complicated by the fact that both pulses and long blocks of video signals must be transmitted and received. The elements of a system for accomplishing radar relay are shown schematically in fig. 46. Radar data are delivered to a "synchronizer" which arranges them in proper form to modulate the transmitter. At the receiving station, the receiver amplifies and demodulates the incoming signals and delivers its output to an "analyzer." The latter sorts out separately video signals, trigger pulse and scanner data. The video signals and the trigger are delivered immediately to the display system.

The scanner data must usually be modified in a "scan converter" before being used in display synthesis, because a code is ordinarily used for the transmission of scanner angle.

The scan converter uses the coded data to construct a duplicate of the scanner motion that can be used to drive a position-data transmitter connected to the indicators. The over-all requirements of the system are quite similar to those of television, since the band of frequencies which must be transmitted is about the same.

Comparative PPI photographs taken simultaneously at a transmitter and receiver several miles apart are shown in fig. 4, Plate V.

The direct relay of radar video signals is preferable to televising an indicator at the radar station and transmitting the information by television means, for the following reasons: (1) Persistent indicators do not televise well; their light is too far toward the red end of the spectrum. This leads to a loss in signal-to-noise ratio and in definition; (2) the display available at the receiving end must be identical with that scanned by the television camera at the transmitting end. If video signals are transmitted directly, any desired type of indication can be synthesized at the receiver.

The first, but not the second, of these objections can be removed by storing the radar information on an orthicon or other television pick-up tube directly, instead of viewing a CRT with a television pick-up.

It appeared in 1946, however, that direct radio transmission of radar video signals and synchronizing information was superior to schemes involving television proper.

Moving Target Indication.—"Ground clutter," the system of strong permanent radar echoes returned by hills and buildings in the vicinity of a radar set, is often a limiting factor on the performance of radar, especially in mountainous terrain. Similarly, the echo signals returned by waves to a radar set carried on a ship or located on the shore ("sea clutter") can be most troublesome. C-w radar often makes use of the doppler shift in frequency of the signal returned from a target in radial motion relative to the radar, and thus responds only to moving targets. This same property can be conferred on pulse radar by special techniques, now to be sketched, called MTI (moving target indication).

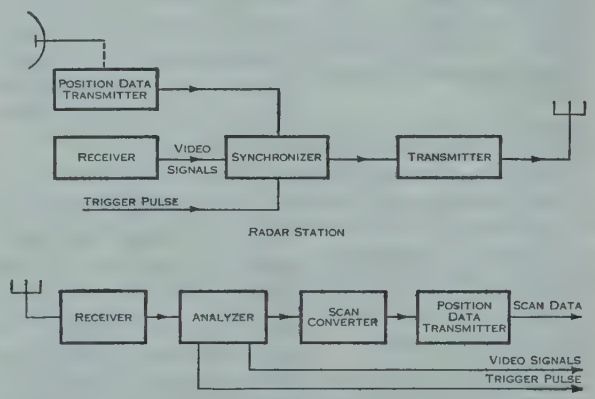

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FIG. 46.—ELEMENTS OF A SIMPLE RADAR RELAY SYSTEM FOR THE DIRECT TRANSMISSION OF RADAR INDICATIONS TO A REMOTE POINT BY RADIO MEANS

In pulse radar, the effect of the doppler shift is to cause a phase shift from pulse to pulse of the echo from a moving target. If the radial velocity of the target is v, and the repetition period, or time between successive pulses, is T, each pulse travels a distance $2vT$ different from that travelled by the preceding pulse. This difference is $2vT/\lambda$ wave lengths, so that the phase change between each pulse and the one which follows it is $2\pi \cdot 2vT/\lambda$ radians. The doppler frequency is $2v/\lambda$, in agreement with Eq. (19).

The basic idea of MTI is to compare the phase of each echo on successive pulses. If there is no phase change, the target is stationary, and its signal is not passed to the indicator. If the phase changes from pulse to pulse, the target is moving, and

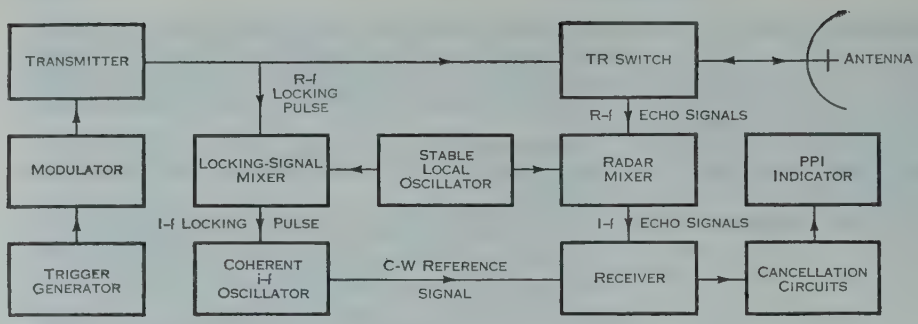

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FIG. 47.—SCHEMATIC DIAGRAM OF A PRACTICAL SYSTEM FOR ELIMINATING FROM THE INDICATOR OF A PULSE RADAR ALL SIGNALS EXCEPT THOSE FROM TARGETS IN RADIAL MOTION RELATIVE TO THE RADAR. THIS TECHNIQUE IS CALLED MOVING TARGET INDICATION (MTI)

its signal is displayed. The phase comparison is made in terms of a very stable oscillator which is adjusted at the instant each pulse is transmitted, to have a standard phase with respect to the outgoing pulse. Beating the echo signal with that of this "coherent oscillator" will give a signal whose amplitude depends on the relative phase of the echo and the output of the coherent oscillator. If the echo comes from a stationary target, the amplitude of the signal which results from beating the echo with the coherent oscillator output will not change from one pulse to another. If the echo comes from a moving target, the amplitude of the beat will change from pulse to pulse.

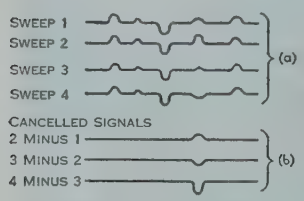

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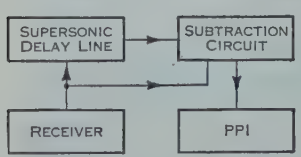
FIG. 48.—PULSE-TO-PULSE CANCELLATION OF ECHO SIGNALS HAVING CONSTANT PHASE. (a) FOUR SUCCESSIVE SWEEPS OF AN A-SCOPE. (b) THE RESULT OF SUBTRACTING EACH SIGNAL FROM THE CORRESPONDING ONE ON THE SUCCEEDING PULSE

It is not important in principle whether the coherent oscillator used as a phase reference runs at radio frequency or at the intermediate frequency of the superheterodyne receiver, provided that the local oscillator of the superheterodyne is stable. Since it is easier practically to have the coherent oscillator run at intermediate frequency, this scheme has been used. A schematic diagram of a practical MTI system is shown in fig. 47.

A stable local oscillator supplies a signal to two mixers, one of which provides a "locking signal" for adjusting the phase of the coherent oscillator to its standard value with reference to the outgoing r-f pulse. The other mixer is the signal mixer of the receiver. When the i-f echo signals and the i-f reference signal beat against one another, the phase of the receiver output signal depends on the number of cycles executed by the local oscillator and by the coherent oscillator during the out-and-back time of travel of the pulse. The result is shown in fig. 48a. Four successive sweeps of an A-scope are shown, corresponding to four successive pulses. It will be seen that four of the five echo signals seen on each trace are of constant amplitude from pulse to pulse, and thus correspond to stationary targets. The other echo signal shows a changing amplitude from pulse to pulse; this corresponds to a changing echo-signal phase, and indicates radial target motion.



FROM RADIATION LABORATORY SERIES, MCGRAW-HILL BOOK COMPANY, INC.

FIG. 49.—SCHEME FOR CANCELLATION OF SIGNALS HAVING CONSTANT PHASE FROM PULSE TO PULSE

The way in which stationary targets can be cancelled is shown in fig. 48b. If the signals from successive pulse cycles are subtracted from one another, echoes of constant amplitude vanish, while echoes of changing amplitude do not. The actual subtraction is performed by sending the receiver output to a "subtraction circuit" both directly and through a delay line which introduces an amount of delay exactly equal to the interpulse interval (fig. 49). Thus the subtraction circuit receives and compares echo signals from the immediately preceding pulse (direct from the receiver) and from the next earlier pulse (through the delay line). The length of the usual interpulse interval is so long—some hundreds of μ sec.—that electrical delay networks are impracticable for use in MTI. Instead, a supersonic delay device is often employed. Signals from the receiver output are turned into sound waves in a liquid or solid by a piezoelectric transducer, allowed to travel through the liquid or solid medium as supersonic waves for the distance necessary to introduce the required delay, and turned back into electrical signals by a transducer at the end of the medium. The velocity of sound waves in such a medium as mercury permits the necessary delays to be produced by sonic paths of reasonable length (17.6 μ sec./in.). Alternatively, an electronic "storage tube," which works in a manner related to that of a television iconoscope can be used as a delay element.

Great difficulties are presented by proper design of MTI components, such as the stable oscillators, the delay lines, and the amplifiers necessary in the cancellation circuits. Work on MTI was begun rather late in World War II, but proceeded to such a point that it was clear pulse radar systems could be made to display only targets having radial motion relative to the radar. (*See* also ELECTRIC WAVES; NAVIGATION; RADIO; WIRELESS TELEGRAPHY.) (L. N. R.)

RADAR STORM DETECTION

Radar storm detection is the detection by radar of precipitation in the form of rain, snow or hail.

At the Radiation laboratory of the Massachusetts Institute of Technology, Cambridge, it was realized in 1942 that precipitation was being detected by ten-centimetre radar. In 1943 microwave equipment was installed on the Isthmus of Panama for storm-detection purposes. Observational work comparing several different radars for weather use was made by the U.S. air force at Orlando, Fla., during 1945. From 1944 to 1948 the signal corps laboratories engaged in theoretical and experimental research on the optimum wave length for storm detection; three experimental storm-detection radar models at three centimetres were constructed for the signal corps in 1948. From 1946 to 1952 Weather Radar Research of the Massachusetts Institute of Technology under contract with the signal corps conducted theoretical and experimental research in storm detection by radar with the aid of aircraft flights.

In 1908 G. Mie solved the general problem of scattering and absorption of a plane electromagnetic wave by a dielectric sphere. J. A. Stratton in 1930 computed the attenuation to be expected from rainfall by centimetre waves. Echo intensities and attenuation of electromagnetic waves by precipitation were derived in detail by J. W. Ryde during 1941 to 1946.

Theory.—A pulse of electromagnetic energy, microseconds in duration, is emitted by the radar and is intercepted by the precipitation. Some of this energy is transmitted through the precipitation; some is absorbed and scattered by the individual particles. That small portion of the electromagnetic energy that is scattered back to the radar is detected, amplified and displayed on the indicators of the radar during the interval between pulses. On an A-scope presentation, displaying signal intensity *v.* distance, a skilled operator can easily recognize the characteristic fluctuating return signal of precipitation. On the PPI (plan position indicator), a plot of azimuth and distance, the distribution of precipitation in space is mapped. This enables the meteorologist to follow the movement and development of precipitation areas. A third type of presentation is the RHI (range height indicator), which enables one to see a vertical cross section of the storm in any direction from the station.

For complete interception of the radar beam by the precipitation, the radar equation (neglecting attenuation) may be put in the form

$$P_r = \frac{PAh\sigma}{8\pi R^2}$$

where P_r is the power received by the radar, P is the transmitted power, R is the distance of the detected precipitation, A is the effective area of the antenna (equal to about two-thirds the actual area) and h is the pulse length. The radar cross section σ of a unit volume of rain cloud is defined as the equivalent area of an isotropic scatterer which scatters energy in all directions equal to that scattered back by the precipitation.

For drops which are small compared to the wave length of radiation, the radar cross section of a unit volume of rain cloud is given by the familiar Rayleigh law:

$$\sigma = \pi^5 \left(\frac{\epsilon - 1}{\epsilon + 2}\right)^2 \frac{Z}{\lambda^4}$$

where Z is defined as the summation of the sixth power of the diameters of the drops in a unit volume, λ is the wave length of radiation and ϵ is the dielectric constant of the precipitation. The equation is valid for ten-centimetre radiation and is only approximate at three centimetres. For a raindrop diameter of six millimetres, σ is twice that of Rayleigh for three-centimetre radiation.

In general, precipitation particles of diameter greater than one-tenth millimetre are detectable by radar. Cloud particles ranging from 10 to 20 μ diameter are not detectable.

Using raindrop size data, an empirical equation has been derived relating Z to the rain intensity r:

$$Z = 180r^{1.55}$$

where Z is in $mm.^6 m.^{-3}$ and r is in millimetres per hour. The probable error is 20%. The utilization of such a formula and the measurement of the signal return to the radar permits computation of the approximate intensity of distant rainfalls observed on the radar. A technique for measuring rainfall intensity by radar can be of value in flood control as well as for meteorological purposes.

Attenuation and Refraction.—Atmospheric attenuation at centimetre wave lengths arises largely from absorption bands of water vapour centred at 1.33 cm. and of oxygen centred at 0.5 cm. J. H. Van Vleck in 1941 predicted from theoretical considerations the absorption caused by these gases, and his predictions were later substantiated by experimental work. Although the water vapour content of the air may vary considerably, an approximate value for the attenuation by these gases at three centimetres and ten centimetres may be given as 0.01 db./km. This value is in general small compared with rain attenuation and the effects of refraction.

The attenuation caused by rain was found both theoretically and experimentally to be 0.03 db./km. per millimetre per hour rainfall at three centimetres and only one one-hundredth that value at ten centimetres. For heavy rains of ten millimetres per hour or greater, the attenuation of three-centimetre waves is such as to block the detection of rain beyond 10 or 20 mi. For this reason the use of ten-centimetre radar through long distances of heavy tropical rains is advantageous. In addition, because of this attenuation at three centimetres, an erroneous impression concerning the shape of a storm and the relative intensities within a storm may be obtained. A wave length near six centimetres is estimated to be optimum for storm-detection with equipment bulk and rain attenuation values intermediate between those of three centimetres and ten centimetres.

In passing through the atmosphere radio waves are refracted and thereby travel a curved path. The curvature of the ray normally varies from 25% to 40% of the curvature of the earth. A ray leaving the earth at 0° elevation will be at a height of about 2 km. above the earth at a distance of 200 km. from the radar. A serious deterrent for storm detection beyond this distance is the fact that the upper portion of the beam is above most storms, and even the lower portion is intercepted by relatively weak portions of the storm.

Precipitation Structure.—Two extremes of precipitation types observed by radar are continuous precipitation, which is characterized by horizontal stratification, and showers which appear on an RHI as elongated bands. There is a continuous transition between the two types. Occasionally the two types are observed simultaneously on different sectors of the radar scope.

A striking characteristic of continuous rain is the "bright band," a region of intense signal return located near the freezing level. The signal return from the bright band is about five times that from immediately above and below. The thickness of the bright band is about 300 m. but is often less than half the pulse length, the minimum resolving distance of the radar; it has been observed to be as thin as 75 m. The increase in signal strength at the upper portion of the band is ascribed to the increase of the dielectric constant as a film of water develops on the exterior of the snowflake. The decrease in signal strength at the lower portion of the band is ascribed to a rapid increase in fall velocity as the snowflake approaches complete melting; this increase in fall velocity decreases the number of particles per unit volume, decreasing the signal return. In addition, shape factors are considered to play an important part in the formation of the bright band: a water-coated snow crystal in the shape of a circular disk may give as much as 18 times the signal return from a water sphere of equal mass. The bright band is not observed in showers and thunderstorms because the precipitation particles of wet ice (hail) and water droplets exist above and below the freezing level.

An upper radar band was observed by E. G. Bowen of Australia to form at about the −16° C. level and to descend at a rate of about two metres per second. This upper band is probably due to the formation of a layer of graupel (ice crystals with attached frozen water droplets). The subsequent descent of this layer depletes the liquid water content in its path to below the critical value necessary for the formation of the graupel.

The rate of increase of radar-signal strength from upper to lower levels is a measure of the growth of precipitation particles as they descend through the atmosphere. By analysis of such radar data it is possible to determine quantitatively the physics of precipitation growth in different types of storms.

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RADAUȚI, a town in Bukovina, Rumania, 35 mi. S. by W. of Czernowitz by rail. Pop. (1930) 16,808, of which about 70% were Germans and 28% Rumanians. It was formerly the seat of a Greek bishopric, removed to Czernowitz in 1786, and possesses a cathedral (1402) with the tombs of Moldavian princes.

RADCLIFFE, ANN (1764–1823), English novelist, only daughter of William and Ann Ward, was born in London on

July 9, 1764. She was the author of four famous novels: *The Sicilian Romance* (1790), *The Romance of the Forest* (1791), *The Mysteries of Udolpho* (1794) and *The Italian* (1797). When she was 23 years old she married William Radcliffe, an Oxford graduate and student of law. He gave up his profession for literature, and afterward became proprietor and editor of the *English Chronicle*. After *The Italian* she gave up writing for publication. She died on Feb. 7, 1823. *Gaston de Blondeville* (1826) was published after her death, as were her *Poems* (1834). In the history of the English novel, Mrs. Radcliffe deserves at least the credit of originating a school of which she was the most distinguished exponent. She had a genuine gift for scenic effect, and her vivid imagination provided every tragic situation in her stories with its appropriate setting. Sir Walter Scott wrote an appreciative essay for the edition of 1824, and Christina Rossetti was one of her admirers. She exercised a great influence on her contemporaries, and Schedoni in *The Italian* is one of the prototypes of the Byronic hero.

There are later editions of *The Italian* (1884); *Udolpho* (1903); and *The Romance of the Forest* (1904). *See* D. Scarborough, *The Supernatural in Modern English Fiction* (1917); C. F. MacIntyre, *Ann Radcliffe in Relation to her Time* (1920); E. Birkhead, *The Tale of Terror* (1921).

RADCLIFFE, JOHN (1650–1714), English physician, born at Wakefield, a well-known physician in the reigns of William III and Anne. He left property to University college for founding two medical travelling fellowships and for building the Radcliffe observatory, hospital and library at Oxford, and enlarging St. Bartholomew's hospital in London. Radcliffe was elected M.P. for Bramber in 1690 and for Buckingham in 1713. He died at Carshalton on Nov. 1, 1714.

See J. B. Nias, *Life of John Radcliffe* (1918); A. B. Luckhardt, *Surg., Gynec. and Obst.*, 72:674–677 (1941).

RADCLIFFE, a municipal borough in the Heywood and Radcliffe parliamentary division, Lancashire, Eng., on river Irwell, 8 mi. N.W. of Manchester on the London Midland Region railway. Pop. (1951), 27,551. Area, 7.7 sq.mi. In the church of St. Bartholomew the tower arch dates from the early 15th century. Radcliffe was incorporated in 1935. There are collieries, cotton and chemical manufactures, and the making of small wares.

RADEBERG, a German town in the *Land* of Saxony, on the Röder, 10 mi. N.E. of Dresden. Pop. (1939) 16,076.

RADEGUNDA, ST. (d. 587), Frankish queen, was the daughter of Berthaire, king of the Thuringians. Berthaire was killed by his brother Hermannfried, who took Radegunda and educated her, but was himself slain by the Frankish kings Theuderich and Clotaire (529), and Radegunda fell to Clotaire, who later married her. She left him when he unjustly killed her brother, and fled to Medardus, bishop of Poitiers, who consecrated her as a nun. Radegunda stayed in Poitiers, founded a monastery there, and lived for a while in peace. The queen died on Aug. 13, 587.

RADEK, KARL (1885–), Russian politician, was born in Lwów (Lemberg) and he was educated at the universities of Cracow and Berne. In 1904 he became a member of the Social Democratic party of Poland and Lithuania. During the revolution of 1905 he spent a year in prison, and subsequently became a member of the editorial staff of social democratic newspapers in Poland, Leipzig and Bremen which supported the left wing of the German Social Democrats. During World War I, after some months of illegal antimilitarist activity in Germany, he established himself in Switzerland where he wrote for the Berne *Tageblatt*. He took part in the Zimmerwald and Kienthal internationalist conferences in September 1915 and April 1916. After the Russian revolution of March 1917 he crossed Germany, together with V. I. U. Lenin, G. E. Zinoviev, Julius Martov and others, and remained in Stockholm as the representative of the central committee of the Bolshevik party, issuing a weekly bulletin on the Russian Revolution in French and German. After the second revolution, in Nov. 1917, he took part in the Brest-Litovsk peace negotiations. When the German revolution broke out in 1918 he made his way illegally to Germany, where as a representative of the central committee of the Soviet Communist party he took an active part in reorganizing the German Communist party, working in its central committee after the murders of Karl Liebkneckt and Rosa Luxemburg on Jan. 16, 1919. He was imprisoned in Germany from Feb. to Dec. 1919. On his release from prison Radek returned to the U.S.S.R., where he became one of the leading members of the presidium of the Communist International. He returned illegally to Germany, however, and took part in the organization of the joint congress of German Communists and Left Independents. He was made a scapegoat for the failure of the German Communists to seize power in the autumn of 1923, and, on account of his support of the "right" groups of the German Communists, he lost his authority in the Communist International, losing his place in its executive committee and in the central committee of the Soviet Communist party. He was a prolific writer in the Soviet press on questions of international politics. Expelled from the Communist party in 1927, he was readmitted in 1930. In Jan. 1937, he was tried with 16 others for plotting against the Soviet Union and was sentenced to 10 years' imprisonment. He was released after serving only four years of his term in order that he might serve as a propagandist.

RADETZKY, JOSEF, Count of Radetz (1766–1858), Austrian soldier, was born at Trzebnitz in Bohemia in 1766, of an old noble family, originally Hungarian. He joined the army as a cadet in 1785. Next year he became an officer, and in 1787 a first lieutenant in a cuirassier regiment. He served as a galloper on Count Franz Moritz Lacy's staff in the Turkish War, and in the Low Countries during the Revolutionary War. In 1795 he fought on the Rhine, and next year with Beaulieu against Napoleon in Italy. His personal courage was conspicuous; at Fleurus he had led a party of cavalry through the French lines to discover the fate of Charleroi, and at Valeggio, with a few hussars, rescued Beaulieu from the enemy. Promoted major, he took part in Dagobert S. Wurmser's Mantua campaign. As lieutenant colonel and colonel he displayed bravery and skill at Trebbia and Novi (1799), and at Marengo was hit by five bullets.

In 1801 Radetzky received the knighthood of the Maria Theresa order; in 1805 he was promoted to major general and given a command in Italy under the archduke Charles, and thus took part in the successful campaign of Caldiero. Peace again afforded him a short leisure, which he used in studying and teaching the art of war. In 1809, now a lieutenant field marshal, he fought at Wagram, and in 1810 received the commandership of the Maria Theresa order and the colonelcy of the 5th Radetzky hussars. From 1809 to 1812, as chief of the general staff, he was active in the reorganization of the army and its tactical system, but, unable to carry out the reforms he desired because of the opposition of the treasury, he resigned the post. In 1813 as chief of staff to the prince of Schwarzenberg, he had considerable influence on the councils of the allied sovereigns and generals. He had a considerable share in planning the Leipzig campaign and as a tactician won great praise at Brienne and Arcis sur Aube. He entered Paris with the allied sovereigns in March 1814, and returned with them to the Congress of Vienna.

He then resumed his functions as chief of the staff, but his ardent ideas for reforming the army came to nothing in the face of the general apathy. His zeal added to the number of his enemies, and in 1829, after he had been for twenty years a lieutenant field marshal, it was proposed to place him on the retired list. The emperor, unwilling to go so far as this, promoted him general of cavalry and shelved him by making him governor of a fortress. In 1834, however, his services were again required in Italy, first under Frimont, and then in chief command.

In 1836 Radetzky became a field marshal. Apathy and parsimony caused the authorities again to neglect his many suggestions, and the outbreak of the wars of 1848 found the Austrian army in an unprepared condition through no fault of Radetzky's. Nevertheless, recalled to command, he conducted his famous operations in the Quadrilateral, leading up to the triumph of Novara on March 23, 1849. (*See* Italian Wars.) To the soldiers of his army who idolized him, he was always simply "Vater Radetzky." He died, still in harness, though infirm, on Jan. 5,

greatly mourned by all whom he had commanded.

RADFORD, a city of Virginia, U.S., in Montgomery county, but administratively independent; 42 mi. W. of Roanoke, on federal highway 11 and the Norfolk and Western railway. Pop. (1950) 9,026. The city lies between the Blue Ridge and the Allegheny mountains. Radford college is there.

RADHANPUR, an Indian state, in the Western India States Agency, Kathiawar, Bombay. It is situated in the northwestern corner of Gujarat, close to the Runn of Cutch. The country is an open plain without hills and with few trees. It contains an area of 1,150 sq.mi. with a population in 1941 of 67,691.

RADIATION, RAYS. Modern physics has developed mainly as a result of an intensive study of radiations and rays, and their relation to matter. It is possible to make a distinction between the two terms, but they are generally used by men of science as more or less synonymous. We have on the one hand the vast field of electromagnetic radiations, all travelling through empty spaces with the same velocity, the velocity of ordinary light. According to the wave length of these radiations we speak of wireless waves, infra-red radiation, visible light, ultra-violet light, X-rays or γ-rays: the order given being that of decreasing wave length. On the other hand we have radiations which consist of streams of particles all moving in the same direction, either corpuscles of electricity, not associated with ordinary matter, as in cathode rays, or material particles which may be either charged or uncharged, such as positive rays or molecular rays. These particles may travel with any velocity, from zero, up to, in extreme cases, a velocity approaching that of light. We might distinguish between the two classes by agreeing to confine the term radiation to electromagnetic waves, and to restrict the term rays to streams of particles, but while a tendency in this direction is traceable it is by no means correct to represent this convention as one invariably used by experts. For instance, it is quite usual in dealing with β-rays, which are swift electrons, and thus corpuscular in nature, to speak of the scattered radiation and the transmitted radiation, and even to refer to the atoms of radioactive matter thrown back by the discharge of particles as a recoil radiation. (*See, e.g.,* Rutherford's *Radioactive Substances.*) On the other hand it is a commonplace to speak of rays of light. To indicate further the way in which, in actual practice, the terms are used indifferently it may be recalled that in a previous edition of the *Encyclopædia* electromagnetic radiation was dealt with, in different aspects, both under the heading RADIATION and under the heading RAY.

ELECTROMAGNETIC RADIATION

Considerations of electromagnetic radiations are involved in nearly every branch of modern physics, and various aspects of the subject are treated in separate articles, notably ELECTRICITY; LIGHT; QUANTUM MECHANICS; X-RAYS, NATURE OF; HEAT; SPECTROSCOPY; ELECTRIC WAVES; WIRELESS TELEGRAPHY. Various biological effects of radiation are dealt with under the heading RADIOLOGY. In this article a general survey is made of the whole range of radiations, with the object of showing how the different types merge into one another, and discussing certain characteristic differences which are associated with different ranges of wave length.

It may be well to give here the units used for measurement of the shorter wave lengths. These are:

The micron	= one-millionth of a metre	$= 10^{-4}$ cm.,	denoted by μ
The millimicron	= one-thousandth of a micron	$= 10^{-7}$ cm.,	" " $\mu\mu$
The Ångström unit	=	10^{-8} cm.,	" " Å.U.
The Siegbahn unit	=	10^{-11} cm.,	" " X

The millimicron is often used for giving visible and ultra-violet wave lengths, and the Siegbahn unit for giving X-ray and γ-ray wave lengths. These two units are not employed in this article, but are inserted for completeness.

Historical.—The fact that there are radiations outside the limits of the visible spectrum was demonstrated by Sir William Herschel in 1800. He found that a thermometer showed a higher temperature when placed in the red end of the spectrum than in the blue, and a still higher temperature beyond the red end, where nothing could be seen. Two years later Ritter and Wollaston independently proved the existence of rays beyond the violet end by establishing that the chemical action of light on silver chloride was even stronger there than in the visible violet. These ultra-violet rays were called at the time "dark chemical rays." The wave nature of the ultra-violet was proved by Young, who with the help of paper impregnated with silver chloride produced a record of Newton's rings formed by these invisible rays, the rings being smaller than those formed by the visible violet, which proved the smaller wave length. The interference properties of the infra-red were established by Fizeau and Foucault in 1847. By the use of a very small alcohol thermometer, read with a microscope, they were able to demonstrate small differences of temperature at different points, corresponding to the alternations of intensity in the interference pattern produced in the infra-red by a suitable arrangement of two mirrors, or by diffraction at a straight edge, as with visible light. (*See* LIGHT.) Fizeau made measurements of wave length in the infra-red about this time. In 1842 Becquerel photographed part of the ultra-violet spectrum. By 1850 it had already been definitely established that beyond the red end of the spectrum were invisible radiations of longer wave length, and beyond the violet invisible radiations of shorter wave length, and that those rays could be reflected, refracted, polarized and made to interfere in just the same way as the visible rays. In 1884 Langley made accurate measurements in the infra-red as far as 5.3μ by means of the diffraction grating, and virtually inaugurated a new branch of spectroscopy. Mascart, in 1864 and 1866, took the first photographs of the ultra-violet which were good enough for wave length determination.

The electromagnetic waves, first generated by H. Hertz in 1888, were soon proved to have all the properties of light waves, as was to be anticipated from Maxwell's theory. (*See* ELECTRIC WAVES; ELECTRICITY; LIGHT.) Hertz himself, using parabolic reflectors to obtain definite beams, established the reflection and refraction of the rays, using a large prism of pitch for the latter purpose. (*See* ELECTRIC WAVES.) Polarization was produced by means of screens of parallel wires, which take the place of the Nicol prisms used in experiments with ordinary light, and also by reflection. Interference, and later dispersion, were also demonstrated with Hertzian waves. The velocity of propagation along wires, measured by Blondlot and by Trowbridge and Duane, was found to be equal to that of light. There is, then, no doubt of the essential similarity in nature between Hertzian waves and light.

Hertzian waves are the longest of the electromagnetic waves. Their wave length depends upon the apparatus used to generate them. They cover a range of wave lengths from 0.1 mm. up to waves as long as one desires to generate. Waves less than a few centimetres have as yet found no practical application. Waves of the order of one metre are used in radar. Waves from 10 metres to 15,000 metres are used in radio (wireless) communication. Most waves used for communication are below 1,000 metres. The shorter waves carry much greater distances.

At the other end of the scale, in the region of very short waves, lie the X-rays, discovered by Röntgen in 1895, and the γ-rays, discovered by Villard in 1900. The nature of these rays was long in doubt, for until 1912 the view that they were neutral particles had its supporters, as well as the view that they were electromagnetic waves. In this year Laue, Friedrich and Knipping established the diffraction of X-rays by crystals, and shortly after W. H. and W. L. Bragg showed how the wave length of X-rays could be measured by reflection at crystal faces. (*See* X-RAYS, NATURE OF; SPECTROSCOPY, X-RAY.) In 1925 A. H. Compton and R. L. Doan demonstrated the diffraction of X-rays by ruled gratings similar to those used for measuring the wave length of light. To secure the necessary intensity of reflection from the grating it was necessary that the X-rays strike the grating at a very small grazing angle. The refraction of Röntgen rays was established at about the same time, by making the rays strike the face of a glass prism, near the apex, at a very fine glancing angle.

The value found for the refractive index by these experiments, as also by the total internal reflection which can be established, is less than unity, as given by the theoretical dispersion formula. Although no precise measurement of the velocity of X-rays has been made, rough measurements show that it is equal to that of light. X-rays exhibit the phenomena of reflection, refraction, interference and polarization. They are short electromagnetic waves of length usually between 0.1 Å.U. and 10 Å.U. Similarly γ-rays are short electromagnetic waves. In 1914 Rutherford and Andrade measured their wave length by the crystal method. They commonly have wave lengths from 0.01 Å.U. to 1 Å.U.

The Electromagnetic Spectrum.—Extending from wave lengths of some miles to wave lengths of a few hundredths of an Ångström unit (or a few ten-thousandths of an Ångström unit if we admit radiations which have not yet been measured by any direct diffraction method), there is a range of electromagnetic waves which is often spoken of as comprising more than 60 octaves, the term octave, by analogy from sound, being applied to a band of vibrations extending from a given frequency to double that frequency. Of this range only one octave is visible radiation, namely that comprising wave lengths from 8×10^{-5} to 4×10^{-5} cm., but all the other radiations are propagated with the same velocity as visible light and exhibit the characteristic phenomena which are associated with transverse waves, in particular reflection, refraction, polarization and interference in its many aspects. Many experiments have served to emphasize the common nature of radiations of widely different frequency: for instance E. V. Appleton has shown that interference phenomena can be obtained with the Hertzian waves used in wireless telegraphy by reflection from the Heaviside layer, and has repeated a variety of experiments on interference and polarization, usually performed in the laboratory with waves of length of the order 5×10^{-5} cm., over distances of miles with waves whose length is a few hundred metres. (*See* Wireless Telegraphy.)

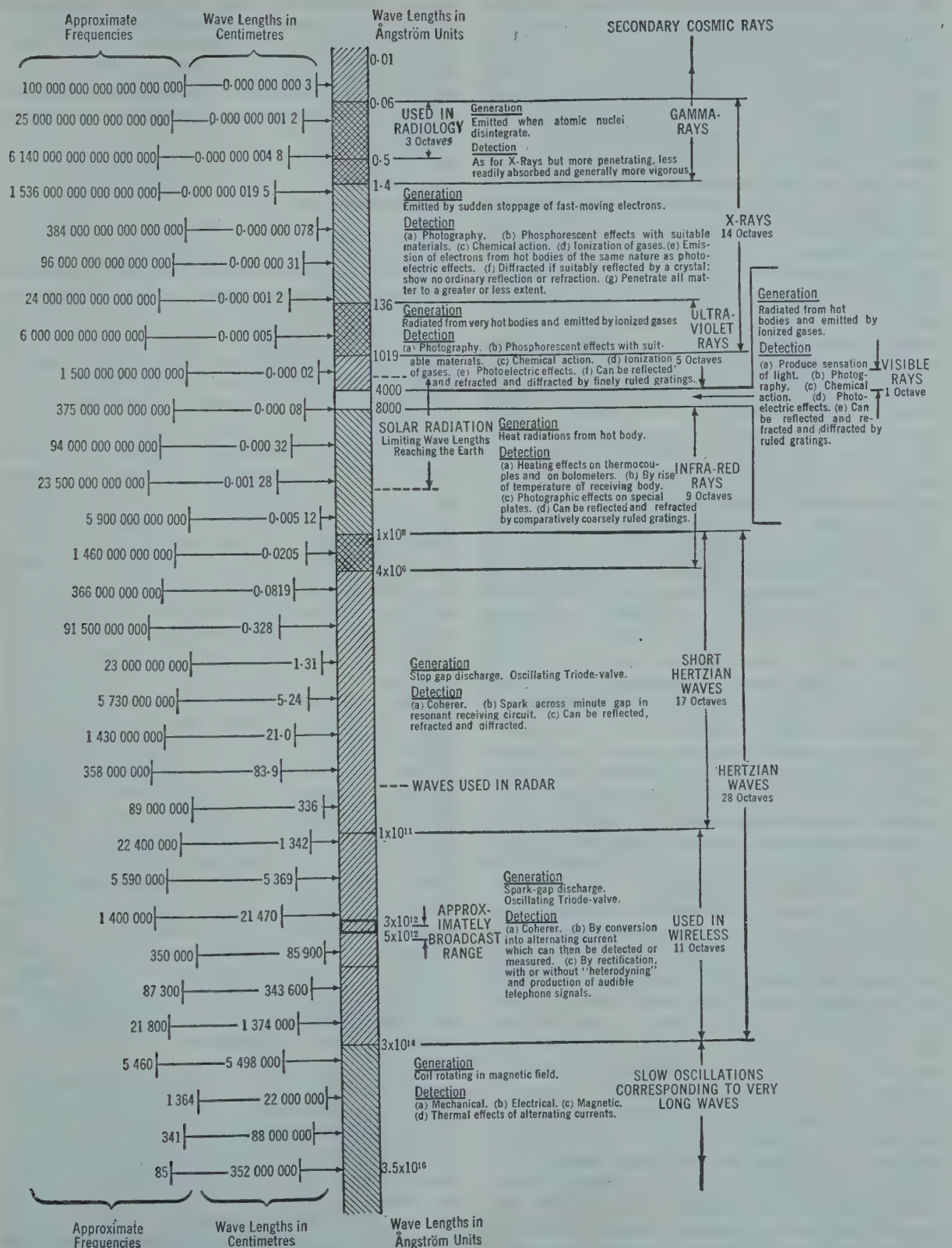
The whole electromagnetic spectrum is diagrammatically represented in the accompanying chart, in which the wave lengths are set out vertically on a logarithmic scale, to avoid the compression to vanishing point of the shorter wave length which would be inevitable if a linear scale were adopted. The ends of the spectrum are not definite: waves of frequency as low, that is, of wave length as great, as may be desired can be generated by rotating a coil in a magnetic field, while at the short wave length end of the range we have the electromagnetic wave component of cosmic radiation. Cosmic ray wave lengths, which extend down to 10^{-13} cm., can be estimated only from their absorption. Starting at the top of the chart with wave lengths of 0.01 Å.U., which are among the shortest γ-rays measured (0.005 Å.U.), we proceed by way of longer γ-rays to the X-rays. (Actually the X-rays produced by the 20,000,000 volt electrons generated by Kerst in 1942 are shorter than the shortest γ-rays observed, but in the main X-rays are longer than γ-rays.) The X-rays merge into the ultra-violet, which in its turn leads into the visible spectrum. On the other side of the visible spectrum we have the infra-red, which leads to a vast range of Hertzian radiations, 28 octaves in extent, succeeded by the ill-defined region of very long waves to which reference has already been made. The frequencies, obtained by dividing the velocity 3×10^{10} cm./sec. by the wave length in cms., are given on the extreme left: self-explanatory notes as to the method of generation and detection of the waves are added. Detailed information as to the various classes of radiation is given in the articles Radioactivity, Natural; X-rays, Nature of; Spectroscopy; Light; Heat; Electricity; Electric Waves; Wireless Telegraphy.

While the spectrum was first extended by investigation of the prolongation of the optical spectrum on either side, and thus showed a continuous range of wave lengths, the Hertzian waves as first investigated had wave lengths very much greater than those of any measured infra-red radiation, while the X-rays first measured, although forming a continuous range with the γ-rays on the short wave length side, proved, on the long wave length side, to be very much shorter than the shortest ultra-violet. The gaps between the Hertzian waves and the infra-red, and between the X-rays and the ultra-violet remained many years unexplored regions, in spite of the many efforts that had been made to produce and detect waves there. Since 1922, however, the gaps have been closed, and it is now possible to carry out experiments with waves at any part of the 60 odd octaves of the electromagnetic spectrum.

The gap between the infra-red and the Hertzian waves has been bridged by advances from both sides. The production of shorter and shorter Hertzian waves has been effected by the use of smaller and smaller oscillators. Lebedew (1895) and Lampa (1896) respectively obtained waves which they estimated as of wave length 6 mm. and 4 mm., but Möbius, who published his results in 1920, considers that these waves must have been of length 1 cm. and 7 mm. respectively. He himself obtained waves 7 mm. long, with which appeared overtones of much shorter wave length, but such measurements could not be reproduced exactly. The quest for short Hertzian waves was carried much further by Nichols and Tear, who published their final results in 1925. Lebedew and Lampa had constructed oscillators which consisted of minute platinum cylinders, 1.3 mm. long and .5 mm. thick, arranged axially end to end, with a gap between them. The current from an induction coil had to leap across small spark gaps to reach the oscillator. Nichols and Tear worked on similar lines, but with great experimental skill succeeded in reducing the dimensions of the oscillator still further. The two cylinders which formed the oscillator proper were of tungsten, each being .2 mm. long and originally (1923) .2 mm. long and .2 mm. in diameter, with an oil-immersed gap of .01 or .02 mm. between them. In the final apparatus (1925) the dimensions of each cylinder were reduced to .1 mm. long and .1 mm. in diameter, with a gap between them as before. Reduction in size leads to a shorter wave length. The waves proceeding from the gap were focused into a parallel beam by a lens of paraffin wax, and then fell on the interferometer used for measuring the wave length, which was of the simple form used by Boltzmann. This consists of two plane mirrors mounted one above the other, one stationary and the other movable in such a way that the two always remain parallel. Half the beam falls on each mirror. The reflected beam was brought to a focus by a second paraffin wax lens. The intensity distribution of the resulting radiation was measured, as heating effect caused by the rays falling on a conductor, by a modified form of radiometer (*q.v.*). With such apparatus Nichols and Tear obtained waves the length of whose fundamental was as low as 1.8 mm., and in certain cases very prominent harmonics of wave length .22 mm. These harmonics were apparently the fundamental wave length of the part of the minute oscillator cylinders which projected through the glass into the oil, and predominated, so that it may be claimed that Nichols and Tear extended the Hertzian spectrum down to .22 mm.

In 1924 A. Glagolewa-Arkadiewa extended the short wave limit further by the use of an entirely new type of generator. This consists of a suspension of fine metal filings in machine oil, kept in constant motion by a rotating disk. The spark from an induction coil passes through a mass of closely packed filings separated by oil. This disposition has the advantages: that the vibrators, consisting each of a pair of filings, are exceedingly small, which makes the wave length small; that there is a very large number of them, which gives the requisite intensity; and that they are constantly renewed, which prevents the spark burning them away at the end. The wave lengths are investigated with a Boltzmann interferometer, while as a detector special thermocouples are used. With this apparatus Glagolewa-Arkadiewa has measured wave lengths of from 50 mm. down to .1 mm. The short Hertz waves produced by the methods here outlined, the shortest of which is .1 mm., or 100μ, are far shorter than any which have yet been produced by vacuum tube oscillators.

The approach from the infra-red side was mainly carried out by Rubens and his collaborators. Important advances were made by the method of *Reststrahlen* ("rest-rays" or "residual rays"). The method depends upon the fact that certain crystals have a strong absorption, accompanied by metallic reflection, for a small range of wave lengths in the infra-red, at a frequency correspond-


Approximate Frequencies
Wave Lengths in Centimetres
Wave Lengths in Ångström Units
100 000 000 000 000 000 000
0·000 000 000 3
25 000 000 000 000 000 000
0·000 000 001 2
6 140 000 000 000 000 000
0·000 000 004 8
1 536 000 000 000 000 000
0·000 000 019 5
384 000 000 000 000 000
0·000 000 078
96 000 000 000 000 000
0·000 000 31
24 000 000 000 000 000
0·000 001 2
6 000 000 000 000 000
0·000 005
1 500 000 000 000 000
0·000 02
375 000 000 000 000
0·000 08
94 000 000 000 000
0·000 32
23 500 000 000 000
0·001 28
5 900 000 000 000
0·005 12
1 460 000 000 000
0·0205
366 000 000 000
0·0819
91 500 000 000
0·328
23 000 000 000
1·31
5 730 000 000
5·24
1 430 000 000
21·0
358 000 000
83·9
89 000 000
336
22 400 000
1 342
5 590 000
5 369
1 400 000
21 470
350 000
85 900
87 300
343 600
21 800
1 374 000
5 460
5 498 000
1 364
22 000 000
341
88 000 000
85
352 000 000
0·01
0·06
0·5
1·4
136
1019
4000
8000
1x10⁸
4x10⁶
1x10¹¹
3x10¹²
5x10¹²
3x10¹⁴
3.5x10¹⁶
SECONDARY COSMIC RAYS
USED IN RADIOLOGY
3 Octaves
Generation
Emitted when atomic nuclei disintegrate.
Detection
As for X-Rays but more penetrating, less readily absorbed and generally more vigorous.
GAMMA-RAYS
Generation
Emitted by sudden stoppage of fast-moving electrons.
Detection
(a) Photography. (b) Phosphorescent effects with suitable materials. (c) Chemical action. (d) Ionization of gases. (e) Emission of electrons from hot bodies of the same nature as photo-electric effects. (f) Diffracted if suitably reflected by a crystal: show no ordinary reflection or refraction. (g) Penetrate all matter to a greater or less extent.
X-RAYS
14 Octaves
Generation
Radiated from very hot bodies and emitted by ionized gases
Detection
(a) Photography. (b) Phosphorescent effects with suitable materials. (c) Chemical action. (d) Ionization of gases. (e) Photoelectric effects. (f) Can be reflected and refracted and diffracted by finely ruled gratings.
ULTRA-VIOLET RAYS
5 Octaves
Generation
Radiated from hot bodies and emitted by ionized gases.
Detection
(a) Produce sensation of light. (b) Photography. (c) Chemical action. (d) Photo-electric effects. (e) Can be reflected and refracted and diffracted by ruled gratings.
VISIBLE RAYS
1 Octave
SOLAR RADIATION
Limiting Wave Lengths Reaching the Earth
Generation
Heat radiations from hot body.
Detection
(a) Heating effects on thermocouples and on bolometers. (b) By rise of temperature of receiving body. (c) Photographic effects on special plates. (d) Can be reflected and refracted by comparatively coarsely ruled gratings.
INFRA-RED RAYS
9 Octaves
Generation
Stop gap discharge. Oscillating Triode-valve.
Detection
(a) Coherer. (b) Spark across minute gap in resonant receiving circuit. (c) Can be reflected, refracted and diffracted.
SHORT HERTZIAN WAVES
17 Octaves
WAVES USED IN RADAR
HERTZIAN WAVES
28 Octaves
Generation
Spark-gap discharge. Oscillating Triode-valve.
Detection
(a) Coherer. (b) By conversion into alternating current which can then be detected or measured. (c) By rectification, with or without "heterodyning" and production of audible telephone signals.
APPROXIMATELY BROADCAST RANGE
USED IN WIRELESS
11 Octaves
Generation
Coil rotating in magnetic field.
Detection
(a) Mechanical. (b) Electrical. (c) Magnetic. (d) Thermal effects of alternating currents.
SLOW OSCILLATIONS CORRESPONDING TO VERY LONG WAVES
Approximate Frequencies
Wave Lengths in Centimetres
Wave Lengths in Ångström Units

ing to the period of vibration of the crystal itself. (*See* LIGHT; SOLID STATE, THEORY OF; QUANTUM MECHANICS.) The reflection is strongly selective, that is, very much stronger for the particular narrow range of wave lengths than for wave lengths on either side. In consequence repeated reflection from a few (say four) surfaces leaves only the selectively reflected rays present in any intensity. With rock salt and sylvite (potassium chloride) rest-rays of wave length 52μ and 63μ respectively are obtained, while with thallium iodide rest-rays as long as 152μ result. An advantage of the method of rest-rays is that the experimenter has at his disposal a broad beam, with the consequent relatively high intensity.

A technique which led to the measurement of still longer wave lengths is the method of focal isolation employed by Rubens and R. W. Wood. The radiation from a suitable source is allowed to pass through a quartz lens, quartz being very transparent and also particularly refracting (refractive index 2.2) for the very long rays. The distance of the source from the lens is so arranged that while the shorter heat and the light waves actually diverge after leaving the lens the long heat rays come to a focus, which is isolated by a hole in a screen. A stop at the centre of the lens prevents the direct passage of practically unrefracted rays through the hole. To purify the radiation still further a second quartz lens with a central stop is used to refract the radiation passing through the hole. The wave length is measured by an interferometer with quartz plates, maxima and minima of intensity being obtained. With a Welsbach gas mantle wave lengths of 107μ or so were measured. Replacing the gas mantle by a quartz-enclosed mercury vapour lamp Rubens and Baeyer (1911) found two bands of very long wave length, one at about 218μ and the other at 342μ. They used an interferometer of Boltzmann type for the analysis of the radiation. Later (1921) Rubens used a grating made of wires a millimetre thick, with millimetre interspaces, to disperse the radiation into a spectrum, and confirmed the presence of strong radiations at these wave lengths, with measurable radiation extending to wave lengths as long as 400μ. This last method is entirely equivalent to the use of a ruled grating for studies in the visible and ultra-violet. The lines on a grating should be ruled a few wave lengths apart, for this spacing of lines spreads out into a conveniently measurable spectrum the wave being studied. The wires in the experiment described above are separated by only a few wave lengths of the long infra-red waves being measured.

It is interesting that in experiments described above the short Hertzian waves and the long infra-red waves have been measured by one and the same method, an interferometer method particularly adaptable to that wave length region. As a result of such experiments the gap between Hertzian waves produced by discharge between microscopic particles on the one hand, and infra-red rays produced from hot solids and vapours on the other hand has been closed with an ample overlap, the Hertzian waves extending down to 100μ, and the infra-red rays reaching up to 400μ.

The first great step in the modern extension of the ultra-violet was taken by Schumann, who, by using fluorite lenses and prisms and special plates, in which the emulsion was deliberately made very poor in gelatine, since gelatine has a marked absorption for the far ultra-violet, lowered the recorded limit to 1,220 Å.U. He showed (1893) that radiations between 1,800 and 1,200 Å.U. are strongly absorbed by air, and hence that it was necessary to work with the spectrograph *in vacuo*. (*See* SPECTROSCOPY.) At about 1,200 Å.U. fluorite becomes opaque to the radiation, so that for his work on the still shorter waves Lyman, who has made many important contributions in this field, used a concave grating without lenses or mirrors, the grating itself forming images of the slit on the photographic plate. The spectrograph was necessarily enclosed in a vacuum. Lyman extended the ultra-violet down to 500 Å.U. During the years 1923–28 Millikan and his collaborators made further very important advances into the extreme ultra-violet. The source used is the so-called "hot spark" between electrodes of the metal whose spectrum is being investigated: the spark gap is very short and situated in a highly evacuated space, of pressure .00001 mm. of mercury or less, and the discharge from a powerful battery of condensers charged by an induction coil is passed intermittently. Specially ruled gratings are used, and the pressure in the whole apparatus maintained at the lowest possible level. The limits reached with the line spectra of certain elements are as follows: carbon 360.5 Å.U., zinc 317.3 Å.U., iron 271.6 Å.U., silver 260 Å.U., nickel 202 Å.U., and aluminum 136.6 Å.U. This 136.6 Å.U. represents the extreme short wave limit measured by the ordinary methods of optical, as distinct from X-ray, spectroscopy.

Turning to advances made from the X-ray side, it is well to recognize first that there are several methods by which X-ray wave lengths have been measured. The oldest of these, and an extremely accurate one, is the method of crystal diffraction developed originally by W. H. Bragg and W. L. Bragg in 1913. The method consists of reflecting X-rays from the cleavage face of a crystal and observing the angle at which reinforcement of the diffracted X-rays occurs. (*See* X-RAYS, NATURE OF; SPECTROSCOPY, X-RAY.) The wave length can then be calculated in terms of the spacing between atomic planes within the crystal. A second method, equally precise, is that of reflection from a ruled grating, a method originated by Compton and Doan in 1925. In this method, as for the optical grating, the wave length is calculated from the known distance between lines on the grating and the observed angle at which reinforcement occurs for the reflected rays.

A third method, used extensively for short X-rays and γ-rays, is that of measuring the energy of the photoelectrons ejected by the radiation from some material for which the work function is known. (*See* PHOTOELECTRICITY.) Radiant energy is emitted and absorbed in discrete energy bundles. (*See* QUANTUM MECHANICS; SPECTROSCOPY; LIGHT.) One of these discrete amounts of energy is called a *photon,* or a *quantum.* The energy of a photon is given by $h\mu$, where h is Planck's constant and μ is the frequency of the radiation. According to the Einstein theory of the photoelectric effect, which has been found to apply not only to excitation by visible or ultra-violet light but also to excitation by X-rays or γ-rays, the kinetic energy with which a photoelectron is ejected from a surface is equal to the energy of the incident photon minus the energy necessary to get the electron away from the atom and out of the surface. The energy necessary for extraction of the electron is called the work function of the material. Photons of visible or ultra-violet light possess only a few electron-volts of energy. (An electron-volt is the energy that an electron would acquire in falling freely through a potential difference of one volt.) They are therefore capable of ejecting only those electrons which are essentially free. The corresponding work function is small, only a few electron-volts. (*See* PHOTOELECTRICITY.) On the other hand, X-ray photons commonly possess tens of thousands, and frequently hundreds of thousands, electron-volts of energy; some γ-rays possess several million electron-volts of energy. X-rays and γ-rays are therefore capable of ejecting photoelectrons which are firmly bound to the atom. The corresponding work function is large; it is 78,400 electron-volts for the most firmly bound electron of platinum. The energy of an ejected photoelectron can be measured by deflecting it in a known magnetic field. The energy of the X-ray photon which produced this photoelectron is obtained by adding the work function for the surface used to the observed energy of the photoelectron. Having the energy of the photon $h\mu$, the frequency, and thence the wave length, of the X-ray can be calculated.

A fourth method, particularly adapted to very long X-rays, consists of bombarding a metal surface with electrons which have been accelerated through a measured potential difference, and of detecting the presence of the radiation produced either by its photoelectric effect upon a second surface or by the ionization it produces in a gas. A curve connecting the voltage used to produce the radiation and the photoelectric current (or the ionization current) produced by the radiation is obtained. A sudden change in the slope of this curve indicates the appearance of a new radiation the wave length of which can be calculated from the corresponding voltage. Such a voltage is called a resonance potential (*q.v.*), and the resulting radiation a resonance radiation.

The frequency μ of the radiation is calculated from the relation $h\mu = V_e$, V being the observed resonance potential.

Many experimental difficulties are encountered in measuring X-ray wave lengths in the region where it is necessary to work in any attempt to close the gap between the X-ray and the ultra-violet. X-rays above 50 Å.U. are very easily absorbed, even by gas at low pressure. F. Holweck has shown that a sheet of celluloid .00027 mm. thick transmits only 3% of the X-rays of 310 Å.U. wave length. In measurements on extremely long X-rays it is therefore necessary to maintain an excellent vacuum in the apparatus; and if any solid windows are used to allow the X-rays to pass from one vessel to another, these windows must be exceedingly thin.

Of the four methods outlined above three have been used successfully to extend the long wave length limit of the X-ray region up to at least the ultra-violet lower limit of 136.6 Å.U. Crystals most commonly used for crystal diffraction measurements have spacings of only a few Ångstrom units between atomic planes, and the theory of X-ray diffraction shows that no reinforcement can be obtained for radiation having a wave length more than twice the spacing between crystal planes. By using a special crystal (a film of melissic acid on lead, for which the spacing is 87 Å.U.), however, M. A. Dauvillier in 1926 measured X-ray wave lengths of 121 and 138 Å.U. The latter, because of carbon, just overlaps the 136.6 Å.U. ultra-violet line.

T. H. Osgood in 1927 succeeded in measuring X-ray wave lengths longer than the shortest observed ultra-violet by the method of reflection from a ruled grating. A goodly number of lines having wave lengths from 20 to 200 Å.U. were observed. Several lines of approximately 160 Å.U. wave length, and one line of 215 Å.U. wave length because of iron, are all above the short ultra-violet limit.

As far as the upper limit to which the X-ray region has been extended is concerned, the fourth method described (that of detecting resonance radiation) has been even more successful than the crystal diffraction or the ruled grating method. O. W. Richardson (1921) observed X-rays of 43 Å.U. wave length from carbon. A. L. Hughes (1922) observed X-rays of 505 Å.U. wave length from boron. E. H. Kurth (1921) found X-rays of 990 Å.U. wave length from oxygen. C. H. Thomas (1925) measured an X-ray of 1,694 Å.U. wave length from iron. The last three of these, as well as others which have been measured, exceed by far the shortest ultra-violet wave length observed. Thus, the gap which originally existed between the ultra-violet and the X-ray regions has been closed with a highly satisfactory margin. Furthermore, it has been closed by measurements made by several methods. One of these methods, that of reflection from a ruled grating, is of exactly the same type as the method normally employed in the visible and ultra-violet.

On its shorter wave length side the X-ray region is overlapped greatly by the γ-ray region. Gamma-ray wave lengths extend from about .005 Å.U. up to approximately 1 Å.U., with the bulk of the significant radiation having wave lengths between .01 and .1 Å.U. The shorter of these γ-rays cannot be measured by crystal methods, for the spacing of atomic planes in a crystal is too large as compared to the wave length. Crystal measurements have been made down to about .05 Å.U., but all shorter γ-ray wave lengths have been measured by observing the energy of the photoelectrons they eject. This method is, however, both reliable and accurate.

The complete electromagnetic wave spectrum thus extends from the shortest γ-ray observed (about .005 Å.U.) up through the γ-rays, the X-rays, the ultra-violet, visible light, the infra-red and the Hertzian waves, the longest of which in actual use are from 15,000 to 20,000 metres in wave length. Over this entire region there is no gap. The one radiation overlaps and merges into the next. All of the radiations are identical except for frequency and, necessarily therefore, wave length. Waves longer than the longest in use in wireless certainly exist; there is no upper limit to the wave length we can produce if we are willing to go to the necessary trouble.

Below the γ-ray region there exists a cosmic radiation of still shorter wave length. A wealth of experimental evidence indicates clearly that most of the primary cosmic radiation coming from interstellar space is of the particle type rather than the electromagnetic wave type. For this reason a brief discussion of cosmic radiation will be included in a later section of this article. It should be remarked here, however, that as the primary cosmic rays strike the earth's atmosphere secondary radiations are produced. The secondary cosmic rays are composed in part of particles and in part of electromagnetic waves, or photons. The photon component is the same type of radiation as γ-rays, except that its wave length is much shorter. It has not been possible to make any certain measurements of these wave lengths. The absorption of the general cosmic radiation in the atmosphere and other materials has been repeatedly measured over most of the earth's surface and at high altitudes. Although it is difficult to tell when one is dealing with radiation of the particle type and when dealing with photon radiation, absorption measurements indicate strongly the presence of electromagnetic wave radiation of wave length as short as 10^{-13} cm. This is only 10^{-5} Å.U., or roughly 1/1000 the wave length of the short γ-radiation. Whether or not the present evaluations of wave length are entirely correct, it nevertheless appears certain that a photon component of at least secondary cosmic rays does exist, and that its wave length is at least very much shorter than that of the shortest γ-rays known.

Generation of the Radiations.—When we consider electromagnetic radiations in free space, any distinction into groups of different wave length is purely arbitrary, for the velocity and mechanism of propagation is exactly the same throughout the spectrum. When, however, we turn to the relationship between radiation and matter, and in particular the emission and absorption of radiation, there are certain distinctions which, while giving no sharp boundaries of wave length between different classes of radiation, do nevertheless divide the radiations into broad natural groups. These distinctions are based upon the nature of the vibrator, or of the quantum mechanism, which gives rise to the undulations.

Starting at the long wave length end of the spectrum, the Hertzian waves are generated by oscillations of electricity in macroscopic systems of conductors. The atomic or molecular nature, or even crystal structure of the metals constituting these conductors does not enter directly into the calculations from which the frequency of a given system can be derived: the conductors can be treated as uniform and homogeneous, and the problem of the oscillations as strictly analogous to those of mechanical oscillations of systems of springs and masses. The size and geometry of the system determines the wave length. The radio broadcasting stations, which commonly use antennas, produce wave lengths measured in hundreds of metres, while minute oscillators whose size is measured in fractions of millimetres produce wave lengths of the same order as their own linear dimensions.

The infra-red radiations are produced by a variety of oscillators, if we merely consider an arbitrary group of wave lengths from .8μ to 400μ say. The atomic mechanism of quantum jumps executed by an outer electron, which is responsible for line spectra (*see* ATOM; QUANTUM MECHANICS; SPECTROSCOPY), leads to certain lines situated well in the infra-red: for instance Brackett (1922) has measured two hydrogen lines, of wave length 4.05μ and 2.63μ, which can be represented by putting $n'=4$, $n=5$, 6 in the general Balmer formula $\nu = R\left(\frac{1}{n'^2} - \frac{1}{n^2}\right)$. Such lines, however, are not representative of infra-red radiations, but should be classed with the optical spectra. More typical are the band spectra consisting of nearly equidistant lines in the far infra-red (in the neighbourhood of 100μ), and the band spectra consisting of two branches of equidistant lines with a gap between them, observed in the near infra-red (in the neighbourhood of 5μ). (*See* BAND SPECTRUM.) These spectra are usually observed as absorption spectra, but emission and absorption are effected by the same mechanism. It has been established beyond doubt that the bands in the far infra-red are associated with molecular rota-

tion, the possible rotations being fixed by quantum conditions, and interchanges between stationary states leading to emission or absorption, while the bands in the near infra-red are associated with vibrations within the molecule, the distance between the nuclei of the constituent atoms varying periodically. These vibrations are superposed on the rotations, and likewise governed by quantum conditions. The details of their mechanism are described in the article BAND SPECTRUM; what it is desired to emphasize here is that the periodic changes in question, whose frequency is typical of the infra-red, are molecular in nature, the motion being of the molecule as a whole, often supplemented by motions of the atoms, treated as rigid wholes, within the molecule. As soon as changes within the atom itself are added to these motions the corresponding bands are no longer in the infra-red, but in the visible and ultra-violet.

Another case of vibrations of the infra-red class is offered by the rest rays, to which reference was made in the preceding section. The oscillations here in question are those of ionized atoms making up the structure of the crystal in question, and can be calculated, as shown by Born and his collaborators, by considering the possible vibrations of the crystal lattice. Here again we are dealing with vibrations of atoms considered as rigid wholes, governed by interatomic forces. It may be said, then, that frequencies of the orders usually associated with the infra-red are connected with the vibrations of atoms or molecules as a whole, under the influence of their mutual attractions and repulsions, and not with changes within the atom.

The radiations of a heated "black body" (*q.v.*) include theoretically the whole spectrum, but the only portions of measurable intensity with laboratory sources are the visible and infra-red. Planck's law giving the distribution of energy throughout the spectrum of black-body radiation at any temperature (*see* HEAT; QUANTUM MECHANICS) has been experimentally confirmed, within the limit of experimental error, from .5μ to 50μ, the validity in the long wave region 4μ to 52μ having been the object of a special research by Rubens (1921). The theoretical deduction of the formula, although Planck himself assumed the existence of resonators or vibrators within the solid, need not involve any assumption as to the nature of the vibrators involved in the proof, the reasoning being of a thermodynamical nature, which demands no precise mechanism. It is possible, as Einstein has shown, to deduce the formula on the assumption that the radiation is given out by atoms executing quantum jumps, as demanded by Bohr's theory, but as the distribution of radiation is quite independent of the atomic nature of the black body the precise character of the quantum jumps is immaterial. The radiation from a heated solid cannot be atomic, in the sense that the radiation from a gas is, for the behaviour of the atomic electrons must be influenced by the electric field and radiations of the surrounding atoms. It is, then, probably something which partakes of the nature of both an atomic and a molecular radiation, in that the atoms cannot be considered as rigid wholes, as they can for the infra–red bands, nor yet as independent entities within which quantum changes take place, as they can for the line spectra. Vibrating systems of every possible frequency are demanded by the theory, and they can be provided by some such scheme as that sketched, which is necessarily vague, as there is at present no precise knowledge of the mechanism of radiation from solids.

The generation of line spectra in the visible and ultra-violet region has been explained in terms of Bohr's quantum theory of spectra which is fully discussed under ATOM; QUANTUM MECHANICS; SPECTROSCOPY. Different stationary states of the atom are determined by the behaviour of the outermost electrons of the groups of electrons which surround the nucleus, and passage from one stationary state to another is accompanied by the emission of a radiation of given frequency. By this mechanism of quantum changes among the outer electrons a vast range of frequencies is emitted, for Brackett's hydrogen lines in the far infra-red, to which reference has already been made, are generated in this way, while Millikan's lines in the extreme ultra-violet are caused by such changes in atoms which are already multiply ionized, that is, have lost outer electrons. The band spectra in the visible and ultra-violet are likewise caused by quantum changes among the outer electrons in atoms constituting a molecule, the molecule executing changes of its own at the same time. The characteristic mechanism of the visible and ultra-violet is therefore an affair of the outer electron.

X-ray line spectra are given out as inner electrons of the atom transfer from one energy level to another. (*See* X-RAYS, NATURE OF.) Optical spectra and X-rays are thus emitted in the same manner, except that the outer electrons are responsible for optical lines whereas the inner electrons are responsible for X-rays. The energies associated with transitions of the inner electrons are much larger than those for the outer electrons. Hence X-rays are of much higher frequency, or shorter wave length, than optical spectra. The γ-rays associated with the α-ray or β-ray disintegration of an atom originate within the nucleus. Discrete energy levels exist within the nucleus, and the γ-ray results from a nuclear transition from one to another level. Nuclear γ-rays are often absorbed in the planetary system of the atom from which they come, with the resultant ejection of a photoelectron which constitutes one of the characteristic β-rays. (*See* RADIOACTIVITY, NATURAL.) The emission of extranuclear γ-rays, which in reality are characteristic X-rays, then follows as another electron falls into the level from which the photoelectron was ejected. Little is known of the origin of the cosmic rays. Millikan still adheres (1942) to his earliest theory that they result from the annihilation of matter. The theory has some little evidence to support it.

To sum up, then, corresponding to the wide range of wave lengths in the electromagnetic wave spectrum, there is a range of generators of widely different sizes. Long Hertzian waves are generated by systems having large inductances and condensers. Very short Hertzian waves are generated by an oscillator consisting of two minute metal electrodes. Then there are systems of vibrating molecules in crystals, and in solid bodies in general, which generate radiation by virtue of their thermal motion. Changes of vibrational and rotational energy of molecules produce radiation in the infra-red. At shorter wave lengths electronic transitions within the atom itself come into play, transitions of outer electrons producing the optical spectra and transitions of the inner electrons the X-ray spectra. Then for the production of γ-rays transitions within the nucleus come into play.

The ranges of wave length generated by the types of system just outlined overlap one another widely, as has been already indicated. Changes in the atom can generate lines in the far infra-red: some nuclear γ-rays are of longer wave length than the hardest X-rays, generated by the extranuclear electrons. From the purely empirical point of view it may be best to group the radiations according to wave length, or according to methods of measurement, especially as a sound theoretical basis is still to be sought in some regions: from the theoretical point of view it seems preferable to group the radiations according to their method of origin. A rough analogy from acoustics, which must not be pressed too far, may be offered. Air vibrations might be grouped according to wave length, or according to origin. In the latter case the division might be into inaudibly low notes originating in the vibration of planks: drum notes, piano notes, and whistle notes. Such a classification is quite without the theoretical meaning that attaches to the subdivision of electromagnetic radiations, according to classes of natural vibration, but may serve to distinguish the two points of view.

Absorption of Radiation.—In the article LIGHT, the absorption of light is explained in terms of damped oscillators of given free period, present in the absorbing substance, and the connection between absorption and dispersion is expounded. In the articles ELECTRICITY and ELECTRIC WAVES the properties of the Hertzian waves, as predicted by Maxwell's theory, are described. In the present section the actual course of absorption of the radiations, as the wave length is varied from one end of the range to the other, is discussed, stress being laid rather upon the facts of observation, the fundamental theories being considered in the articles quoted. The differences of absorption exhibited by the radiations of different regions constitute one of the most striking

features of the interaction of radiation and matter.

On Maxwell's theory, metals, in which the electrical conductivity is very high (meaning that an actual convection of electric charge, as distinct from a displacement current, is easily set up in the medium), reflect radiation very well, and also absorb very strongly that part of the radiation which is not reflected. The higher the conductivity, the larger the coefficient of absorption. It is an experimental fact that in the region of Hertzian waves the absorption by metals is very high: for instance Branly found that tinfoil .008 mm. thick did not let the waves through in measurable intensity. From the same theory it follows that perfectly insulating dielectrics should be perfectly transparent. This has also been to some extent confirmed experimentally, Righi having shown by a direct method that sulphur, ebonite, paraffin and selenite are quite transparent to waves 5 to 20 cms. in length, but glass, marble and wood absorb to some extent. The comparatively good transmission of long electromagnetic waves by substances which are, broadly speaking, nonconducting, is a familiar fact to people living in brick houses who use an inside aerial for the reception of broadcast waves.

According to Maxwell's theory absorption is entirely governed by the conductivity of the medium, and a relation can be worked out which gives the absorption coefficient in terms of the conductivity and the dielectric constant. Numerous measurements have been made by P. Drude and many others following him on the absorption of feebly conducting substances, such as electrolytes and low pressure gases. Qualitatively the relation holds in all cases. Quantitatively it has been confirmed for water solutions of salts, of which the conductivity is measured directly, while the dielectric constant is taken as being that of water. With many organic substances, however, especially those containing hydroxyl groups, the measured absorption is greater than that given by the theoretical formula. Drude tried to explain this by the presence of resonators of the type that account for optical absorption, with a large damping coefficient, but there seems no possibility of resonators of sufficiently large free period. A more promising theory is that of Debye, who attributes this behaviour to the presence of dipoles in the molecules, which tend to set themselves in the direction of the electric force. When the oscillations are comparatively slow, as in the Hertzian region, the dipoles can follow more or less the alternations of electric force, provided the medium is not too viscous, and dissipate the energy, but when the alternations are very rapid, as in the optical region, they have no time to orient themselves, on account of their great inertia. Some substances show narrow regions of anomalous dispersion in the Hertzian region which do not accord with this explanation. Speaking broadly the Hertzian waves do experience the strong absorption in good conductors and the feeble absorption in dielectrics which can be explained on Maxwell's theory without any consideration of the structure of the medium, or its chemical nature.

The longer infra-red waves are also well removed from the region where the oscillators of the type considered in optical dispersion make themselves felt, and many of the consequences of Maxwell's theory, based on the assumption of a structureless medium, have been confirmed with such waves by Rubens and others, such as the proportionality of the refractive index to the square root of the dielectric constant for nonconductors. For such experiments the long infra-red waves possess the advantage that they do not necessitate the large-scale apparatus required for Hertzian waves many centimetres in length. Considering the absorption of infra-red and optical radiations, a distinction must be made between the absorption associated with metallic reflection and that conditioned by the atomic oscillators. In the case of strong reflection, exhibited by such crystals as those used for isolating the rest-rays, as well as by metals, the absorption is in general so high that the radiations do not penetrate any appreciable distance into the substance. (The effect takes place with crystals only for a radiation whose frequency agrees with that of the free period of the natural vibration of the crystal.) The surface colour, using the term in a general sense, to apply to invisible as well as to visible radiations, is approximately complementary to the colour transmitted by an exceedingly thin layer, as exemplified by the green light transmitted by a gold leaf, which appears yellow by reflected light. In the case of the ordinary absorption associated with anomalous dispersion, the radiations penetrate further into the body, and the colour by reflected light is the same as the colour by transmitted light. Right down into the optical and ultra-violet region the opacity of metals holds, but it ceases in the X-ray region, where the oscillations are far too rapid to affect the electrons which are responsible for the conduction. It may be noted that there is a certain selectivity in the metallic reflection in the optical region which is not accounted for by the simple Maxwellian theory: for instance gold reflects red selectively as can be seen by reflecting light many times between two plane gold surfaces. The issuing light is deep red.

A large number of measurements of the absorption of radiation by metals has been made by Hagen and Rubens. The absorption coefficient, defined by them as the reciprocal of the thickness which reduces the incident radiation to one-tenth of its initial intensity, varies somewhat with the wave length, but has a value of the order of 10^5 cm.$^{-1}$ for gold and silver, for instance, in the visible and near infra-red.

While metals show the same opacity to the visual region as to the long waves, the behaviour of nonconducting or badly conducting substances in this region is widely different. All such substances show regions of marked selective absorption either in the visual region or in the neighbouring ultra-violet or infra-red, the theory of dispersion resting upon the presence of absorption bands in this range. A few of the most important examples will be given. Glass, which transmits the visible radiations so well, is opaque for the infra-red and the ultra-violet except in regions immediately adjoining the visible. The ordinary glass fire screen offers a familiar proof of the opacity for infra-red. This opacity also accounts in part for the high temperature existing in glass-houses. The visible radiations enter the glass-house and heat the soil, but the very long heat rays emitted by the soil cannot escape. Quartz is transparent in thicknesses of some centimetres to the infra-red beyond 70μ, but has a strong absorption from 4.5μ to somewhere about this value. It is also transparent in the ultra-violet down to 1,800 Å.U. Substances which transmit the infra-red well are sylvin, rock-salt, and fluorite down to about 23, 15 and 9μ respectively. The substances transparent to the visible are familiar to everybody, as are coloured glasses with selective absorption. The ultra-violet is often divided into groups by the absorption of various substances: 3,800–3,400 Å.U., glass ultra-violet, transmitted by ordinary glass; 3,400–3,000 Å.U., Jena glass ultra-violet, transmitted by Jena and other glasses specially prepared for the purpose; 3,000–2,200 Å.U., quartz-glass ultra-violet; 2,200–1,800 Å.U., quartz crystal ultra-violet; 1,800–1,200 Å.U., fluorspar ultra-violet. The absorption of glass both for the ultra-violet and the infra-red is a matter that is, to a certain extent, under the control of the glass maker. Crookes prepared glasses very opaque to the far red and near infra-red for the use of furnace-men, while there are many special glasses designed both to stop the ultra-violet as near the visible as possible and to transmit it as far into the short-wave region as possible. The position of the absorption bands of solids in the visible and the adjacent parts of the spectrum is not determined by atomic properties, but by molecular properties.

Of particular interest is the absorption of the atmosphere for radiation, as it determines the limits of the sun's radiations which reach us. At the long wave length end of the spectrum the intensity of the radiations has been carefully measured by Abbot up to 5.3μ where the energy is practically zero, probably owing to a strong absorption band of water vapour, which extends to 6.5μ. There are signs of a feeble transmission of infra-red between 10 and 13μ, but it is established that there are no measurable radiations between wave length 15μ and 300μ. This is in any case not entirely caused by atmospheric absorption, for if the sun be treated as a black body of temperature 6,000° absolute it can be calculated that the intensity of radiations of wave length greater than 15μ would only be about 3/10,000ths of the total energy. In the infra-red of wave length less than 6.5μ there are marked absorption bands caused by carbon dioxide and water vapour.

At the other end of the spectrum the atmosphere transmits the ultra-violet down to about 3,000 Å.U. The limit varies, of course, with the thickness of the atmosphere traversed, and hence is different in summer and in winter. Measurements made in Switzerland by Dorno show that according to the season and the time of day the shortest wave length of the sun's spectrum present in measurable intensity varies between 2,976 and 3,197 Å.U. It may be noted that it is quite a narrow range of wave lengths from about 2,800 to 3,100 Å.U., with a sharp maximum at about 3,000μ that can produce sunburn (light erythema), which accounts for the great variation in the burn produced by strong sunlight at different times of year, for the greatest action lies just in the region about which the limit of wave length transmitted by the atmosphere oscillates with the seasons.

The great absorption of all matter for the radiation of the extreme ultra-violet, on both sides of 300 Å.U., has already been emphasized. From this region onwards the penetrating power of the radiation increases as the wave length becomes shorter. With X-rays any distinction between conductors and nonconductors ceases, for the absorption here is entirely an atomic affair, and depends upon the binding of the inner electrons by the nucleus. Sharp absorption edges correspond to the frequencies at which the quantum energy of the radiation first suffices to eject an electron from a given inner group. (*See* X-RAYS, NATURE OF.) In the region of very short X-rays, shorter than the K absorption edges of the elements considered, the absorption of a given element is proportional to the third power of the wave length, while for a given wave length and different elements it is proportional to the fourth power of the atomic number of the element, and thus independent of the periodic physical and chemical properties of the absorbing substance.

Broadly speaking, then, in the Hertzian region the behaviour of the radiation incident on matter can be explained in terms of the macroscopic electric conductivity, without consideration of the mechanism by which the conduction takes place. In the extreme infra-red the free-period of the crystal lattice makes itself felt, and the phenomenon of metallic reflection by crystals is observed in restricted regions, but outside these regions the laws of the Hertzian waves are obeyed. In the visible and adjacent regions the phenomena of absorption and dispersion are governed by damped oscillators of determined free-period, the nature of which is discussed under LIGHT. The chemical constitution and physical state of the body is of prime importance in these regions, and each substance has its regions of high absorption. For the absorption of the very short waves of the X-ray and γ-ray region only the inner regions of the atom play a part, and conductivity in particular, and chemical and physical state in general, cease to have any important influence.

The question of the absorption spectra of gases and vapours is considered in full under BAND SPECTRUM and SPECTROSCOPY.

The Nature of Radiation.—The theoretical significance of the study of radiation for modern physics cannot be over-estimated, and most of the articles on physical subjects will be found to have some bearing on the subject. The hypothesis of an ether was created to account for the passage of radiation in interstellar space, and peculiarities of the behaviour of radiation—in this particular case visible light—led to the theory of relativity, as described in the articles RELATIVITY and ETHER (IN PHYSICS). The consideration of the distribution of energy in the spectrum of black body radiation, which comprises, as far as experiment is concerned, the visible and infra-red, led to the quantum theory (*see* QUANTUM MECHANICS), which has found significant application in such remote subjects as specific heat. The particular study of radiation termed spectroscopy (*q.v.*) is at the basis of the modern theory of the atom. The theory of Maxwell and the consequent discovery of long wave radiations by Hertz left their mark in every branch of theoretical physics. To attempt a full list would be to run over every branch of physical science.

The extension of the electromagnetic spectrum constitutes one of the great unifying principles of modern science, and is a part of the attempt to explain everything in terms of electric and magnetic forces. Until 1925 a number of well-known phenomena seemed to make it necessary to draw a sharp distinction between radiation and matter. The interaction of the two, both in the way of the emission of radiation by matter and the action of matter on radiation falling on it, has proved to be a subject full of difficulties and paradoxes, in spite of the continued assault of the best brains of science on the problems presented. One group of phenomena comprising diffraction and interference (*see* LIGHT) is sufficiently explained by a wave theory of radiation. Another group of phenomena seems to demand that radiation be of corpuscular character. (*See* PHOTOELECTRICITY; COMPTON EFFECT.) It appears that ultimately a satisfactory general solution of this problem will be found in the theory of wave mechanics (*see* QUANTUM MECHANICS) initiated in 1925 by L. de Broglie and E. Schroedinger. Great progress toward a solution has already been made. On this theory the distinction between matter and radiation becomes very shadowy; an electron, or any other particle, has many of the properties normally exhibited by waves. Experiments dealing with this behaviour will be discussed near the end of this article.

The electromagnetic theory of radiation was the great achievement of the last quarter of the 19th century. The interpretation of matter in terms of electric charges was the great achievement of the first quarter of the 20th century. As in the future we look back upon the second quarter of the 20th century it may well be that the outstanding achievement will have been the interpretation of electric charges and radiation on a common basis, as but different manifestations of something more fundamental. And while the present wave mechanics may not offer the complete solution, it certainly will at least have pointed the way.

CORPUSCULAR RADIATION

Corpuscular radiation consists of particles, or at least of entities which are ordinarily thought of as particles rather than waves. These particles may be corpuscles of electricity not associated with ordinary matter; examples are cathode rays, β-rays and positrons. Or the radiation may consist of small particles of matter, either charged or uncharged; examples are α-rays, positive rays and atomic or molecular rays. The more detailed properties of the various corpuscular radiations are dealt with in other articles, to which reference will frequently be made. Only a general survey of the various types of corpuscular radiations will be given here, together with a short discussion of their more general properties and interrelations.

Electron Radiation.—A radiation known as cathode rays was discovered by Julius Plücker in 1859 in the course of studies of the electrical discharge through a gas in a partially exhausted tube. After further evidence was obtained by Johann W. Hittorf in 1869, W. Crookes in 1879 first recognized that the radiation consisted of negatively charged particles leaving the cathode of a discharge tube. The rays travel from the cathode (the negative electrode) toward the anode (the positive electrode) in the tube. They produce ionization in a gas, causing a gas through which they pass to give off light. They cause many bodies, including the glass walls of a tube, to fluoresce. That the cathode rays travel from the cathode toward the anode, and that they travel in essentially straight lines, is shown by the fact that an object placed a little in front of the cathode casts a relatively sharp shadow on the anode side. It was found that the stream of rays leaving the cathode could be deflected by a magnetic field perpendicular to the direction of the rays' travel, and that the direction of deflection was such that the cathode ray particles must be negatively charged. The rays can also be deflected laterally by an electric field perpendicular to their line of travel; again they are deflected in a direction which shows them to be negative rather than positive charges. A body placed in the path of a cathode ray stream is heated upon stopping the particles. Thus the particles give up energy in stopping, and for this reason they must have mass. An electrical conductor on which cathode rays impinge accumulates a negative charge. In 1892 P. E. A. von Lenard showed that the cathode ray particles could pass through very thin metal foils. By using a window of thin foil they can therefore be obtained outside the tube in which they are generated,

The lateral deflection suffered by the negatively charged cathode ray particles in electric and magnetic fields depends upon the velocity with which the particle is moving and upon the ratio of the charge to the mass of the particle. By observing the lateral deflection produced in known fields it is possible to evaluate both the ratio e/m (charge/mass) for the particle and the velocity with which the particle is travelling. By such observations at the beginning of the 20th century, J. J. Thomson and others proved that cathode rays are streams of electrons, negatively charged corpuscles of electricity not associated with matter in the ordinary sense, leaving the cathode and travelling toward the anode with a velocity which depends upon the potential difference applied to the discharge tube. (*See* ELECTRICITY, CONDUCTION OF: *Conduction in Gases.*)

The energy of an electron, and therefore the velocity with which it travels, depends upon the potential difference through which the electron is accelerated. The energy of an electron is often expressed in electron-volts (hereafter abbreviated ev), it being understood that the energy in question is that which would be acquired by an electron in moving freely (without collision with gaseous atoms) through a potential difference equal to the number of volts specified. That is, an electron which moves freely from the cathode to the anode of an evacuated tube across which a potential difference of 10,000 volts is applied is said to have an energy of 10,000 ev. Since the mass of the electron is known (1/1,837 that of the hydrogen atom), the velocity of an electron with any specified energy can be calculated. Since electron velocities are always very high, and frequently quite comparable to the velocity of light, it is common to specify for an electron the ratio of its velocity to the velocity of light.

An abundant supply of electrons can be obtained in several ways. The electrons constituting the cathode ray streams may be ejected from the cold metal cathode of the tube as a result of positive ions of residual gas within the tube striking the cathode. This is the source of the electrons in the gaseous type X-ray tube. Electrons can also be drawn from metal surfaces by the application of an extremely high electric field at the surface of the metal, though this method is rarely if ever used as a source of electrons. Electrons are likewise emitted from the surface of a hot metal wire or strip. (*See* THERMIONICS.) The wire may be either a pure metal or a metal coated with barium and strontium oxides. Some form of hot cathode is used as a source of electrons in nearly all vacuum tubes used in radio, and also in the Coolidge type X-ray tube. Electrons are also emitted from metal surfaces illuminated by violet or ultra-violet light. (*See* PHOTOELECTRICITY.) This is known as the photoelectric effect, and is the basis of operation of all photoelectric tubes used so widely for industrial measurements and control. Electrons ejected by positive ion bombardment, by thermionic emission, or by photoelectric emission leave the metal surface with relatively small velocities. Energies of thermionic electrons and of photoelectric electrons ejected by violet light are of the order of one ev. Many of the ejected electrons have smaller energies. A beam of electrons of any desired energy can be obtained by accelerating these electrons through a potential difference after they are ejected.

Nearly homogeneous beams of electrons with an energy of only one ev have been obtained by Ramsauer and others with the aid of a magnetic deflecting field and properly located screens. The velocity of these electrons is only 6×10^7 cm./sec., 1/500 the velocity of light. Of a much higher energy are the electrons, called β-rays, shot off from many radioactive materials when they disintegrate. (*See* RADIOACTIVITY, NATURAL.) Some of these β-rays are shot off with energies of several million electron-volts (hereafter abbreviated Mev), though most of them have somewhat lower energies. An electron having an energy of three Mev has a velocity which is 0.990 that of light. The fastest β-rays shot off by radioactive materials have a velocity about 0.998 that of light, or slightly over 2.99×10^{10} cm./sec. The energy of an electron having this velocity is 7.6 Mev. Still higher energy electrons have been obtained by an induction accelerator devised by D. W. Kerst in 1942. Electrons of 20 Mev have been produced by this method, and Kerst in 1945 had plans for a 100-Mev induction accelerator. The 20-Mev electrons already produced in the laboratory have a considerably higher energy than the most energetic natural β-rays from radioactive materials, but their energy is still far below that of the cosmic ray electrons. The velocity of a 20-Mev electron is only slightly higher than that of the 7.6-Mev β-ray mentioned above. Regardless of how high the energy may be, the velocity never exceeds that of light. (*See* RELATIVITY.) It approaches the velocity of light as the energy becomes very large. On the other hand, the mass is much higher for a 20-Mev than for a 7.6-Mev electron. The mass of an electron, or of any other body, increases with velocity. Although the increase is not detectable for small velocities, it becomes very large indeed as the velocity approaches that of light. The mass m of a particle travelling with a velocity v is given by $m=m_0/\sqrt{1-v^2/c^2}$, where m_0 is the mass of the particle at very low speeds and c is the velocity of light.

Differences in absorption constitute one of the most striking distinctions among electrons of different energies. Slow electrons are absorbed readily; fast electrons penetrate surprising thicknesses of matter. Although there are certain regions of energy in which the absorption of electrons varies in an abnormal manner, in general the absorption decreases rapidly as the energy of the electron increases. It is convenient to designate the range of a particle by stating the thickness of some absorbing material through which the particle will pass before coming to rest. Ranges of electrons are frequently given in air at atmospheric pressure and 15° C. temperature. Electrons of 2,500 ev energy, for which the ratio v/c is 0.10, have a range of 0.04 cm. in air. Electrons of 25,000 ev energy, for which v/c is 0.30, have a range of 1.0 cm. in air. Electrons of 205,000 ev energy, for which v/c is 0.70, have a range in air of 37 cm. For electrons of 1,100,000 ev, or 1.1 Mev, energy, the ratio v/c is 0.95 and the range in air is 437 cm. Electrons of 3.1 Mev energy, for which v/c is 0.99, have a range of 1,300 cm. in air. This is equivalent to 43 ft. This same electron, which represents one of the faster β-rays, will penetrate approximately 6 mm. of aluminum before stopping. The very much higher energy electrons present in cosmic radiation will penetrate several inches of lead before stopping.

The effects of intense beams of high energy electrons are remarkable. They cause a purple glow in air through which they pass. They excite fluorescence and phosphorescence. Calcite emits a phosphorescent glow for several hours after exposure to the rays. Many effects of the rays upon tissue and bacteria have been observed. The effects on animal tissue, as exemplified by a rabbit's ear, vary with the intensity of the beam and the length of exposure. With a beam of certain intensity a very short exposure produces a tanning of the skin; a 1-sec. exposure leads to the formation of a scab, which afterward falls off with the hair, and is followed by a profuse growth of new hair which is, however, snow-white; a 50-sec. exposure leads to scabs which, when they fall, leave a hole through the exposed section of the ear. Bacteria, flies and beetles are killed by the radiation. Many chemical effects have been produced by the radiation; substances such as glue, gelatine and cane sugar break down when irradiated.

When electron radiation is stopped abruptly by matter, some of the energy is converted into electromagnetic radiation in the form of X-rays. (*See* X-RAYS, NATURE OF.) This is true regardless of the source of the electrons and regardless of the nature of the matter placed in their path to stop them. X-ray tubes consist of a cold or a hot cathode as a source of electrons, and a tungsten or other metal target upon which the electrons strike. Potential differences as high as several hundred thousand volts are commonly applied between the cathode and the target to accelerate the electrons. X-rays are emitted when the electrons strike the target. The higher the energy of the electrons the more penetrating are the X-rays produced. The wave length of the shortest X-ray produced is given by $\lambda=hc/Ve$, where h is Planck's constant, c the velocity of light, V the potential difference applied across the X-ray tube, and e the charge on the electron.

Positron Radiation.—Previous to 1932 no positively charged particle having the same mass as the negative electron had been

observed. Interest in cosmic rays led in 1930 to efforts to study individually the exceedingly high energy particles making up the cosmic radiation. If a chamber saturated with water (or other) vapour is expanded just after a charged particle has passed through the chamber, small water droplets condense on the gaseous ions produced by the particle along its path. Such a chamber is called a Wilson cloud chamber (*q.v.*). A line of droplets representing the path of the particle is visible, or with proper illumination it can be photographed. If the cloud chamber is placed between the poles of a strong magnet so a charged particle passing through the chamber must move perpendicular to a strong magnetic field, the particle is deflected laterally. It describes the arc of a circle the radius of which depends upon the ratio e/m of the particle, the velocity of the particle and the strength of the magnetic field. The direction of deflection depends upon whether the particle is positively or negatively charged. Cloud chamber photographs had for many years yielded valuable information concerning charged particles having energies less than 10 Mev. Since the charged particles in cosmic radiation have energy far in excess of 10 Mev, however, it was not possible to deflect them appreciably with magnetic fields of the strength and extent in use before 1932.

When much stronger and more extensive magnetic fields were applied across a cloud chamber in 1932, it was found by C. D. Anderson and others that positive as well as negative particles were present in the cosmic radiation. Some particles were deflected to the right and others to the left by the same magnetic fields. Since both particles left the same type of track in the cloud chamber, a track characteristic of a particle having the charge and the mass of the electron, it was obvious that the one particle was a negatively charged electron and the other a positively charged electron. The positively charged electron is commonly called a positron. The positron and the usual negative electron have the same mass and the same charge, except that the one is positive and the other is negative.

Positrons are not only present in cosmic rays, but they can be obtained in the laboratory. In 1933, J. Chadwick and others observed that if the element beryllium is bombarded with alpha-particles given off by the natural radioactive material polonium, positrons are emitted from the beryllium. The evidence indicated that these positrons were formed indirectly, formed by the gamma-rays resulting from the bombardment. It has since been found that positrons can be produced directly by allowing γ-rays of sufficiently short wave length to fall upon any of the heavier elements. Electrons as well as positrons are ejected. Cloud chamber photographs frequently show paired tracks, an electron and a positron arising simultaneously at a common point which is presumably the point of γ-ray absorption. Evidence of this character has shown clearly that sufficiently energetic γ-rays are capable of producing electron-positron pairs. The γ-ray is absorbed in the process. Positrons are also ejected by many of the artificial radioactive materials. (*See* RADIOACTIVITY, ARTIFICIAL.) Since the discovery of artificial radioactivity in 1933 by I. Curie and F. Joliot approximately 300 radioactive materials have been produced artificially in the laboratory. A majority of these disintegrate by ejecting electrons, but approximately 70 of them disintegrate by ejecting positrons.

It was stated above that when sufficiently short wave length γ-rays are allowed to fall upon a material, electron-positron pairs are produced. It has also been found that if any material is bombarded with positrons, it gives off gamma-rays of a predictable wave length. Evidence is convincing that the positron combines with an electron (one of the atom's planetary electrons) and becomes a photon. Thus electromagnetic radiation, as exemplified by gamma-rays, can be converted into electron-positron radiation; and electron-positron pairs can be converted into electromagnetic radiation. These processes are but another example of the creation and the annihilation of mass, the conversion of energy in some other form into mass and the conversion of mass into energy in some other form. Many examples of this conversion have been observed in studies of the artificial disintegration of matter. (*See* NUCLEUS.)

In the conversion of photons into electron-positron pairs and in the conversion of electron-positron pairs into photons, the interchange between mass and energy in some other form always takes place in accord with the relation $E=mc^2$, where E is the energy to be associated with the appearance or disappearance of a mass m. It is easily calculated that the energy which would be required to form the mass represented by one electron-positron pair is 1.02 Mev. In order to possess this much energy a photon of radiation, that is a γ-ray, must have a wave length of 0.012 Å.U. or less. Experiments show that gamma-rays with energies larger than 1.02 Mev do produce electron-positron pairs whereas gamma-rays of less energy do not produce pairs. If electron-positron pairs are produced by the 2.62 Mev γ-rays from thorium C″, 1.02 Mev of the energy goes to form the masses of the electron and positron while the remaining 1.6 Mev apparently goes to give the newly created electron and positron kinetic energy. In the reverse process, that is, in the annihilation of electron-positron pairs to form photons of electromagnetic radiation, the same energy relation holds. The annihilation of the mass of an electron-positron pair at rest yields 1.02 Mev of energy. This sometimes goes into the formation of one photon and sometimes into two photons. If it goes into one the energy of the photon should be 1.02 Mev, corresponding to a γ-ray of 0.012 Å.U. wave length. If it goes into two equal photons each should possess 0.51 Mev energy; this corresponds to a γ-ray of 0.024 Å.U. wave length. When matter is bombarded with positrons, with the consequent annihilation of electron-positron pairs, both of these gamma-ray wave lengths are observed.

Alpha- and Beta-Rays.—Approximately 40 of the heavier elements, among which are uranium, thorium and radium, are radioactive. (*See* RADIOACTIVITY, NATURAL.) A radioactive substance disintegrates spontaneously, and changes into another element. The rate of disintegration, which varies widely from one material to another, is independent of temperature, pressure, chemical combination, etc.; it is determined entirely by the nuclear structure of the radioactive atom. Radioactive materials disintegrate in either of two ways. Some disintegrate by ejecting an alpha-particle (α-ray) from the nucleus of the atom; others disintegrate by ejecting a beta-particle (β-ray) from the nucleus. Most of the beta-particle disintegrations, and a few of the alpha-particle disintegrations, are accompanied by the emission of γ-rays which, as we have seen, are short electromagnetic waves.

Alpha-particles are helium nuclei. The alpha-particle has a mass essentially equal to that of the helium atom, and it bears a double positive electronic charge. It is what remains of a helium atom after its two "planetary," or "external," electrons have been removed. These facts have been ascertained by various experiments. By allowing a known number of alpha-particles to strike a conductor and measuring the charge which accumulates on the conductor, the charge borne by each particle has been found to be 3.2×10^{-19} coulombs. The charge on the electron is 1.6×10^{-19} coulombs. Hence the alpha-particle bears a charge equal to two electrons. The charge on the alpha-particle is positive, as would be the case if a previously neutral helium atom lost two electrons. Streams of alpha-particles can be bent in strong magnetic fields and the ratio charge/mass, and thence the mass, has been determined from the amount of bending. The mass is essentially equal to that of the helium atom. Furthermore, if alpha-particles are allowed to enter an evacuated glass tube, previously carefully freed from helium, a gradual accumulation of helium in the tube becomes apparent through analysis of the characteristic spectral lines emitted when the contents of the tube are subjected to an electrical discharge. All these observations leave no doubt but what alpha-particles are helium nuclei.

Alpha-particles given off by the natural radioactive materials have exceedingly high energies, ranging from 4.1 Mev for those from thorium to 8.8 Mev for those from thorium C′. On the other hand, alpha-particles are easily absorbed; they are stopped by an ordinary sheet of paper. The alpha-particles from thorium have a range of only 2.59 cm. in air at atmospheric pressure and 15° C. temperature, while those from thorium C′ have a range

of 8.62 cm. In passing through a gas the alpha-particle gradually loses its energy by ionizing the gaseous atoms along its path. Although the number of ion pairs produced per mm. travel of an alpha-particle depends somewhat upon the energy of the particle, a typical ion production for a single alpha-particle is 3,000 pairs of ions per mm. travel. As a result of this high ionization an alpha-particle leaves a dense track in a Wilson cloud chamber. When alpha-particles are allowed to strike a screen coated with a fluorescent material such as zinc sulphide, each alpha-particle produces a flash of light, called a scintillation, where it strikes. Thus individual alpha-particles can be counted visually. The particles affect a photographic plate and can therefore be studied photographically also.

Alpha-particles produce disintegration of many elements upon which they impinge. (*See* NUCLEUS.) In fact it was by means of alpha-particle bombardment that Rutherford in 1919 first succeeded in producing an artificial disintegration of matter. Atoms of nitrogen and several other materials were at that time converted into other elements. Except for a few rare alpha-particles from radium C′ and thorium C′, which have energies of approximately 10.5 Mev, the most energetic alpha-particles given off in abundance by any of the natural radioactive materials are those of 8.8 Mev energy given off by thorium C′. These were the most energetic charged particles available for disintegration studies until the development of the cyclotron by E. O. Lawrence in 1930. From 1930 to 1945 approximately 30 cyclotrons were constructed at various universities and research laboratories. By 1939, 8 Mev protons, 16 Mev deuterons, and 38 Mev alpha-particles had been produced with the 60-inch California cyclotron. With these high energy particles, along with the neutron which will be mentioned shortly, practically every known atom has now been artificially transformed into some other atom. (*See* NUCLEUS.)

Beta-rays emitted by radioactive substances are high energy negative electrons. The energy with which the beta-particle is emitted depends upon the radioactive atom. With the exception of a few probable β-rays of about 10 Mev energy, the energies of most β-rays range from very low values up to 3 Mev. Radioactive atoms emit their β-rays in two groups. Some of the rays, called characteristic β-rays, are emitted with energies characteristic of the emitting atom. Other rays, called the continuous β-rays, are emitted with a distribution of energies ranging from zero up to a definite maximum. The continuous and the characteristic β-rays are identical except for their energy distributions.

The properties of beta radiation are identical with those of any other electron radiation. These properties have already been discussed. The ionizing power of β-rays is much smaller than that of α-rays. Whereas a 3 Mev alpha-particle produces about 4,000 ion pairs per mm. travel in air, a 3 Mev beta-particle produces only about 4 ion pairs per mm. On the other hand, the alpha-particle would have a range of 1.7 cm. in air whereas the beta-particle would have a range of 13 metres.

Atomic and Molecular Rays.—Beams of atoms or molecules, either charged or uncharged, are called atomic or molecular rays, or sometimes mass rays. Under certain circumstances, depending upon the nature and the method of producing the rays, they are called positive rays. Goldstein first observed in 1886 streams of luminous gas back of a perforated cathode in a gaseous discharge tube, as if, as is now known, ionizing particles were coming through the holes in the cathode and ionizing the gas through which they passed. The luminosity of the gas results from the ionization. These radiations coming through the holes in the cathode were first called *kanalstrahlen*, or canal rays. These rays heat bodies so placed as to stop them. They have very small penetrating power. They charge bodies upon which they impinge positively. They produce fluorescence, affect a photographic plate, and ionize gases. Beams of the radiation can be bent in electric or magnetic fields, and the direction of bending shows that the particles constituting the radiation are positively charged. Hence the particles are called positive rays (*q.v.*).

By bending a stream of positive rays in known electric and magnetic fields it is possible to determine both the velocity and the ratio charge/mass (e/m) for the particle. The positive charge carried by the particle is equal to one, two, three, four, etc. electrons. The mass of the particle is essentially the same as that of an atom of the gas in the discharge tube. The positive rays are actually atoms (or sometimes molecules) of the gas in the tube, which atoms have lost one or more of their planetary electrons. They are positively charged gaseous ions which are formed in the discharge and then, because of their positive charge and the potential difference applied across the discharge tube, are accelerated toward the cathode. Those which pass through a hole in the cathode are found to have various energies up to a maximum corresponding to the energy which the particle would attain by falling freely through the entire potential difference applied to the tube. Positive rays of any gas can be obtained by using a small amount of the desired gas in a discharge tube. Positive rays of a material which cannot be obtained as a gas or a volatile compound can often be obtained by packing a small cuplike anode with a paste made of powdered graphite and a salt of the positive ion desired. Upon heating the mixture electrically, or upon bombarding it with electrons, or upon subjecting it to both treatments simultaneously, positive ions are given off. These ions can be accelerated through any desired potential and then studied in the usual way.

In a beam of positive rays coming through a hole in the cathode the charged atoms are mainly positive, but some neutral and some negatively charged atoms exist also. If the beam is sent through a magnetic field which is perpendicular to the beam positive particles are deflected in one direction, the few negative particles are deflected in the opposite direction, and the few neutral atoms are undeflected. New neutral and negative particles are created in a positive beam. This can be shown by sending the positive beam separated out by one magnetic field through a second magnetic field; new negative and neutral particles appear. These changes of charge occur because of residual gas in the tube. Ionization of the gas furnishes a supply of electrons. A positive ion becomes neutral by picking up an electron; it becomes negative by picking up a second electron.

In the hands of J. J. Thomson, F. W. Aston, A. J. Dempster, K. T. Bainbridge and others, studies of positive rays have yielded valuable information. (*See* POSITIVE RAYS; ISOTOPES.) Attention will be called to two important lines of evidence. If positive ions of more than one mass are present in a positive ray beam, particles of different masses are deflected different amounts by electric or magnetic fields. It was from such studies that Thomson first discovered the existence of isotopes among the light elements. Thomson found neon atoms of two kinds, some of atomic weight 20 and some of atomic weight 22. Since the original discovery of isotopes approximately 600 different isotopes of the 96 elements have been found by positive ray and other methods. About half of these are stable and half radioactive. Accurate atomic weight determinations is a second important contribution of positive ray studies. Accurate measurement of the magnetic deflections suffered by positive rays of different masses allows the determination of relative atomic weights. The atomic weights so determined are those of the individual isotopes of an element rather than those of the commonly existing mixture of isotopes. Chemically determined atomic weights are those for the mixture. In general atomic weights determined from positive ray studies are far more accurate than those determined by methods normally employed by chemists. They are equalled in accuracy, and frequently surpassed, only by those values obtained from nuclear disintegration studies. (*See* NUCLEUS.) Highly accurate values of the atomic weights of individual isotopes have been of inestimable value in connection with the discovery and verification of the interchangeability of mass and energy.

Another class of mass rays is constituted by the much slower atoms obtained by evaporating a molten metal in a vacuum so high that the mean free path of the atoms leaving the metal surface is much greater than the dimensions of the vessel. By means of a suitable system of diaphragms having suitably arranged slits or holes, atoms flying off from the evaporating metal can be confined to a beam. If the temperature of the glass wall opposite the

molten metal surface, and against which the evaporated atoms strike, is maintained at a suitably low temperature, the atoms form a thin deposit on the wall. In cases where the deposit is too thin to be seen it can be "developed" by depositing silver on it from a silver nitrate solution by a special technique.

The velocities of atomic or molecular rays evaporated from a molten metal have been determined directly by methods utilizing mechanically rotated slits in the path of the beam. Rays of a given velocity get through a pair of slits only when the slits are rotating relative to each other at a speed such that a second slit is at the proper place to allow the rays to pass at the instant they arrive. Velocities found by these methods agree within the experimental error with those to be anticipated on the kinetic theory of gases for atoms at the temperature of the molten metal. By properly arranged rotating slits it is possible to sort out a beam of atomic or molecular rays of any velocity desired, and the results of many experiments have been greatly improved through use of a beam having particles of a single velocity. The velocity of a beam of silver atoms evaporated from molten silver at 1,500° K. is about 6×10^4 cm./sec. The energy of a silver atom even at this high temperature is only a few tenths of an electron-volt. Thus the energies of particles in atomic beams obtained by thermal evaporation are insignificant as compared to energies of tens of thousandths of electron-volts for the positive rays obtained in a discharge tube or as compared to the energies of alpha-particles of perhaps five Mev. Such low energy atomic or molecular particles have practically no penetrating power. They are extremely useful, however, in many experiments. For example, they have been used by Otto Stern and W. Gerlach and others in experimental determinations of the magnetic moments of atoms. (*See* MAGNETISM.) They have been used successfully also by several observers for reflection from a crystal surface, as a means of clarifying the De Broglie equation, an equation which predicts that any particle behaves as a wave of a given wave length. More will be said of this later.

Neutron Radiation.—An entirely new particle radiation, the neutron, was identified by J. Chadwick in 1932. W. Bothe and H. Becker in 1930 observed that if the α-rays from polonium were allowed to fall upon certain light elements such as beryllium, boron and lithium, there was emitted a very penetrating radiation. Since this new radiation was far more penetrating than the hardest γ-rays known, it was originally interpreted as a gamma radiation of unusually short wave length. It was not thought at first that the new radiation was a particle, for it did not leave a track in a cloud chamber. This observation showed at least that it was not a *charged* particle, for all charged particles leave tracks. It was also observed that, although lead and other materials commonly thought of as good absorbers of penetrating radiation had relatively little effect in absorbing this new radiation, paraffin, water or other material containing hydrogen was a relatively good absorber. This and other observations finally led Chadwick in 1932 to a definite and apparently correct interpretation of the nature of the new radiation. (*See* NEUTRON.)

The neutron is an uncharged particle which has a mass only slightly higher than that of the hydrogen atom. The atomic masses of the proton (a hydrogen nucleus), the hydrogen atom and the neutron are respectively 1.00757, 1.00812 and 1.00893. The penetrating power of the neutron is large by virtue of the fact that it carries no electrical charge, and therefore does not experience the retarding forces which would be experienced by a charged particle, and at the same time is of the same general size as the nuclei of atoms. The great difference in the penetrating powers of the proton and the neutron results largely from the fact that one possesses a charge whereas the other does not; they have essentially the same mass. Since the neutron has no charge it leaves no track in a cloud chamber; it does not produce ions along its path. Again since the particles are not charged, a beam of neutrons cannot be deflected in electric or magnetic fields. Neither can neutrons be accelerated to any desired energy by allowing them to fall through a known potential difference. Thus a supply of neutrons of desired energy is by no means as readily obtained as is a supply of electrons, protons, alpha-particles or other charged particles. The unusual absorption of neutrons by materials containing hydrogen is because the hydrogen nucleus (the proton) has a mass essentially equal to that of the neutron. It can be shown from the laws of conservation of energy and conservation of momentum that if a moving particle of given mass strikes head-on a second particle which has an equal mass and which is originally at rest, the first particle gives up all its kinetic energy to the second particle. The first particle stops and the second particle is projected forward with a velocity equal to that originally possessed by the first particle. It is through this process that hydrogen absorbs neutrons so much more effectively than any other material.

Neutrons are given off during the artificial disintegration of many elements. (*See* NUCLEUS.) These disintegrations are used as sources of neutrons. The energy of the neutrons given off depends upon the disintegration produced and upon how it is produced. One widely used source of neutrons is a mixture of radium and finely powdered beryllium. Alpha-particles given off by radium and its by-products in their natural disintegration produce an artificial disintegration of the beryllium. Neutrons are emitted during the disintegration of the beryllium. Neutrons are also frequently obtained by bombarding a heavy hydrogen target (usually heavy water, which contains the heavy hydrogen isotope) with energetic deuterons. The deuteron is a nucleus of the heavy isotope of hydrogen. Neutrons are given off in the resulting disintegration of the heavy hydrogen. Sources of neutron radiation have been invaluable in studies of the artificial disintegration of the elements. Practically any element can be disintegrated by bombarding it with neutrons. More kinds of atoms have been disintegrated by neutron bombardment than with bombardment by any other particle. Particularly is this true of the heavier atoms, for which the neutron is by far the most effective disintegrating particle. Peculiarly, even very low energy neutrons, even those having only thermal energies, are frequently capable of disintegrating matter. The unusual effectiveness of the neutron apparently results from the fact that since the particle possesses no charge it is much easier to get it into the nucleus of the atom which it is desired to disintegrate.

Mesotrons.—Another new and exceedingly penetrating particle was discovered by C. D. Anderson in 1936. The particle was definitely charged, for it left a track in the cloud chamber. In many respects it was similar to the usual electron, but it was far more penetrating. Even at the time of its original discovery Anderson felt that the particle bore the same charge as the electron but that it was considerably heavier than the normal electron. Because of this it was called the heavy electron. It has since become known as the mesotron.

The existence of mesotrons has been verified repeatedly by numerous observers. The particle does carry one electronic charge, and it may be either positive or negative. Many determinations of the particle's mass, which are unfortunately somewhat indirect, show that the mass of the mesotron is from 150 to 200 times the mass of the normal electron. The mass of the mesotron is therefore intermediate between that of the electron and the proton. Experiments have also shown that the mesotron is radioactive. When it disintegrates it becomes an ordinary electron or positron. What becomes of the excess energy (mass) is still not known. Some of it undoubtedly goes into kinetic energy of the ejected electron or positron. Some of it presumably goes into the formation of neutrinos, though this was still, in 1945, in the field of speculation. In fact the neutrino itself is still of a theoretical character, though more and more evidence for its actual existence has been presented. In any case the mesotron is definitely radioactive. It has a mean life of approximately two microseconds. Mesotrons are definitely present in cosmic rays, apparently being produced in the upper atmosphere. They constitute the extremely penetrating component of cosmic rays.

Cosmic Radiation.—Cosmic rays are discussed in detail in another section. They are mentioned here only for the sake of completeness and because they are made up of radiations which we have already discussed. The primary cosmic radiation coming from interstellar space and striking our upper atmosphere

is apparently composed mainly of charged particles, electrons, positrons and probably protons. As the primary radiation penetrates our atmosphere it is partially absorbed. In the absorption process other, and sometimes different, radiations are given off. These are referred to as secondary radiations. Effects of cosmic radiation near sea level are produced largely by secondary rays. The secondary radiation is made up of both electromagnetic radiation and charged particle radiation. Very penetrating photons are present, electromagnetic waves of wave lengths much shorter than the wave length of the most penetrating γ-rays given off by radioactive substances. Electrons and positrons are also present in abundance. These have far more energy, and are far more penetrating, than electrons accelerated in the laboratory or the electrons and positrons given off by the natural or artificial radioactive materials. Mesotrons are also present in the secondary cosmic radiation, and these particles constitute the extremely penetrating component of the cosmic rays. This penetrating component has been observed by J. Clay and others (1938) after it had penetrated to a depth of 440 metres of water. V. C. Wilson and A. van Gemert in 1938 independently observed the radiation in deep mines after it had penetrated approximately a quarter of a mile of earth. It is thought that the mesotrons which make up this extremely penetrating component of the cosmic radiation are formed in the upper atmosphere. Because of their short life, 2×10^{-6} sec., as radioactive particles, they can therefore hardly come to the earth as a part of the primary radiation. Evidence indicates that they are formed in the atmosphere as a direct result of the supposed proton component of the primary rays.

The energies of cosmic rays are far above any energies it has been possible to give particles in a cyclotron or other laboratory apparatus. While the energies of cosmic rays are distributed over a wide range, the average energy appears to be about 6×10^{9} ev, 6 billion (6,000,000,000) electron-volts. This is approximately 1,000 times the energy associated with radioactive radiations, and 150 times the energy of the most energetic particle yet produced in the cyclotron. It is 30 times the energy produced in the fission of uranium, the greatest energy yet observed in the artificial disintegration of atoms.

The source of the tremendous energies associated with cosmic ray particles is still unknown. In 1928 R. A. Millikan and G. H. Cameron advanced the theory that cosmic ray energies were released in an atom building process. They argued that if, for example, four protons and two electrons combined to form a helium nucleus a release of energy would accompany the decrease in mass in accord with the relation $E=mc^2$. (After the discovery of the neutron in 1932, nuclei were thought to be made up of protons and neutrons rather than protons and electrons, but the basic argument would remain the same.) With the realization of the enormous energies associated with cosmic rays, however, this hypothesis has proved inadequate. In 1942–44 R. A. Millikan, H. V. Neher and W. H. Pickering advanced another hypothesis and presented considerable evidence in support of it. They proposed that cosmic ray energies are released in an atom annihilation process. The six most abundant elements in interstellar space are hydrogen, helium, carbon, nitrogen, oxygen and silicon. It can be calculated that annihilation of these atoms would release photons having energies of .5, 1.9, 5.6, 7.1 (the mean for oxygen and nitrogen) and 13.2 billion electron-volts respectively. There is considerable evidence for the existence of cosmic ray bands corresponding in energies to all of these except hydrogen. A cosmic ray particle having an energy corresponding to the energy released by the annihilation of a hydrogen atom would not be able to reach the earth.

PARTICLES?—OR WAVES?

Although some radiations commonly exhibit properties normally associated with waves (diffraction and interference) and are therefore referred to as waves, while other radiations commonly exhibit properties normally associated with particles of matter (rectilinear propagation and mass) and are therefore referred to as particles, there is nevertheless no clear-cut distinction between a particle and a wave. An electromagnetic wave exerts a pressure on any surface it strikes; it has momentum and therefore mass. In this respect it resembles a particle. Furthermore, as L. de Broglie predicted theoretically in 1925, entities commonly thought of as particles exhibit under proper circumstances the properties of diffraction and interference. These are just those properties which lead us to call other radiations waves. L. de Broglie predicted that a particle of mass m travelling with a velocity v would behave as a wave having a wave length given by $\lambda=h/mv$, where h is Planck's constant, a constant introduced originally to explain the distribution of energy radiated by a body at a temperature higher than that of its surroundings.

The correctness of De Broglie's hypothesis has been repeatedly demonstrated by experiment. C. L. Davisson and L. H. Germer in 1927 first succeeded in showing that electrons reflected from the face of a nickel crystal reinforce in a particular direction. The entire phenomenon is analogous to the reflection of X-rays from a crystal face. (*See* X-RAYS, NATURE OF; SPECTROSCOPY, X-RAY.) In the same year G. P. Thomson succeeded in showing that after transmission through a crystal slab a narrow beam of electrons spreads out and produces an interference pattern just as would X-rays. In each case the electrons exhibited diffraction and interference phenomena characteristic of waves. Furthermore, from the interference pattern formed by reflection from the crystal or by transmission through the crystal the wave length of the radiation could be calculated. Experiments have shown repeatedly that this wave length is essentially that predicted theoretically by De Broglie.

It is remarkable that many observers have since obtained interference patterns formed by electrons which are almost as sharp and clear-cut as those obtained with X-rays. There can be no doubt that electrons do behave as waves under proper circumstances, and that the wave length is that given by De Broglie. The spacing of atoms in a crystal can be determined from electron diffraction studies just as it can be from X-ray diffraction studies. Because of the relatively low penetrating power of electrons, electron diffraction is particularly adaptable to studies of the surface structure of materials. Electron diffraction cameras designed for such studies are becoming more and more widely used. They have led to many important results.

Although a gas certainly has no crystalline structure, that is, no regularity of atomic spacing, it nevertheless does produce certain diffraction effects with X-rays. In an analogous manner it has been found that electron diffraction is produced by gases. According to the De Broglie theory, not only electrons but any particle should produce diffraction and interference effects under proper conditions. Numerous observers have found that upon reflection from a crystal face, atoms and molecules having thermal energies do produce interference patterns. The equivalent wave length can be calculated from the interference pattern and this wave length comes out equal to that predicted by De Broglie. There is every reason to believe that any particle, under proper circumstances, would exhibit this diffraction and interference phenomenon. It has been demonstrated for electrons, atoms and molecules. Any clear-cut distinction between a particle and a wave has therefore ceased to exist.

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RADIATION BALANCE OF THE EARTH. The earth receives from the sun 13×10^{23} calories of radiant energy each year. Since the mean temperature of the earth and its atmosphere does not change perceptibly from year to year, and since solar radiation is practically the sole source of energy received by the earth's surface and atmosphere, the same amount of energy must be radiated from the earth to space.

For simplicity in arithmetic let the annual income of 13×10^{23} calories of solar energy equal 100 units. The spectral composition and intensity of solar radiation is that of a black body radiator at nearly 6,000° K., although there is evidence that during certain solar disturbances the ultra-violet portion of the spectrum becomes greatly intensified. The maximum intensity is found at 0.48μ (μ, the "micron," equals 10^{-4} cm.), and roughly half the energy is contained in the visible band between 0.38μ and 0.77μ, the remainder in the invisible ultra-violet and infra-red bands. As the incoming solar radiation encounters the outer layers of the earth's atmosphere, some of the air becomes ionized, forming the multiple ionized layers known as the "ionosphere" (50–300 mi. high) which reflect radio waves of broadcast frequencies. Farther down, in the stratosphere, certain bands in the ultra-violet are absorbed by oxygen, some of which forms ozone, a strong absorber of ultra-violet radiation. Indeed, principally because of the presence of ozone, dangerous ultra-violet radiation of wave lengths below 0.3μ is not received at the earth's surface. Closer to the

earth's surface (within three miles) water vapour serves as a powerful absorbing agent. Total absorption of the solar radiation as it passes through the atmosphere is 14 units. Because of reflection from clouds and the earth's surface, and by scattering in the atmosphere, 43 units (the "albedo" of the earth) are returned to space without increasing the energy of the earth and its atmosphere. The remaining solar radiant energy, amounting to 43 units, reaches the surface of the earth and is used primarily to raise the temperature of the surface, although small amounts are utilized in evaporating water and in producing photochemical changes.

The earth radiating as a black body at its observed mean temperature of 288° K., has its maximum intensity at 10μ and practically all of its radiation (the "long-wave" radiation) is contained between 4μ and 120μ. Because of the peculiar absorbing properties of water vapour, the normal atmosphere is, comparatively speaking, very nearly transparent to the short-wave solar radiation but is practically opaque to the long-wave terrestrial radiation. Atmospheric water vapour, amounting to less than 0.3% of the mass of the atmosphere, absorbs 104 of the 115 units of long-wave radiation emitted by the earth. Eighteen additional units of heat are liberated in the atmosphere by condensation of water vapour. This energy plus 18 units of absorbed solar radiation amounts to 136 units taken in by the atmosphere. However, since the atmosphere radiates energy in two directions, upwards to space (40 units) and downwards to the earth (86 units), and transports by turbulence an additional 4 units to the earth, its mean temperature is lower than that of the earth's surface which radiates energy in one direction only, upwards, and whose exchange of heat with the interior of the earth is negligible. The 133 units of energy received at the earth's surface by direct and diffuse solar radiation (43 units), by atmospheric radiation (86 units), and by turbulence (4 units) is exactly balanced by the earth's black body radiation at a temperature of 288° K., the equilibrium temperature of the earth's surface.

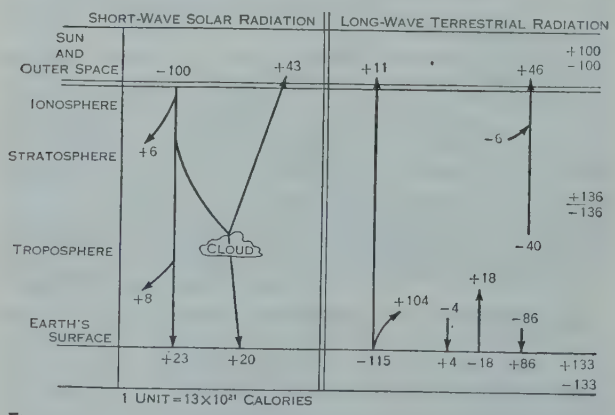
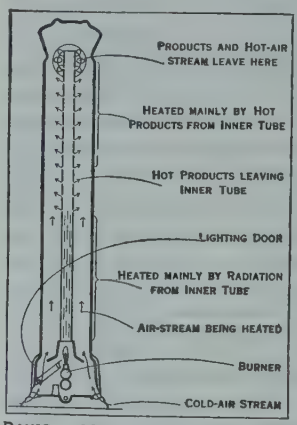


FIG. 1—HEAT BALANCE OF THE EARTH AND ITS ATMOSPHERE, SHOWING ANNUAL MEAN VALUES AVERAGED OVER THE NORTHERN HEMISPHERE

In fig. 1 there is presented a graphical summary of the various streams of energy and their totals. Note that there is a balance of incoming and outgoing energy at the outer limit of the earth's atmosphere, within the atmosphere, and at the surface of the earth, thus representing an equilibrium condition whereby the mean temperature of the earth's surface and its atmosphere remains essentially unchanged from year to year, at least within the period of systematic meteorological observations made over a large portion of the earth's surface. It is the lack of heat balance averaged over seasons that causes the seasonal variations in temperature and weather observed in extra-tropical latitudes. It is the lack of heat balance at various latitudes that causes the day-to-day weather changes. South of latitude 35° N. there is a net heating averaged over the year, and north of this latitude there is a net cooling. This lack of latitudinal heat balance is counteracted mainly by large exchanges of air masses between polar and tropical regions, resulting in a net transport of heat northward. This exchange is effected by large moving cyclonic and anticyclonic eddies, which create alternate periods of "stormy" and "fair" (fine) weather. (H. WR.)

RADIATOR, a device usually built of cast iron, steel, copper or brass, used in room or space heating for transferring heat from a heating medium such as steam, hot water, gas or electricity to the surrounding air in the room. Steam radiators act as condensers for steam received through pipes from a boiler outside of the room, the condensate returning through the same or separate set of pipes to the boiler. Water radiators cool the hot water received through pipes from a boiler outside of the room and permit this water to return to the boiler. Gas radiators are equipped with gas burners as a source of heat and are of the following types: gas warm air radiator; gas steam radiator; gas water radiator. A vented gas radiator is provided with a pipe connection from which the products of combustion can be conducted out of the room. In an "unvented gas radiator" the products of combustion are permitted to escape into the space being heated. In gas, steam and gas water radiators, the pressure of steam or temperature of water is used to regulate the amount of gas burned. Electric radiators are equipped with resistances or elements which generate heat when supplied with electric current. If the heat is transmitted directly from the resistance to the air of the room, they are sometimes called space heaters. If electric radiators use steam or water as a means of transferring heat from the electric element to the surface of the radiator they are known as electric steam or electric water radiators. (*See* HEATING AND VENTILATION; THERMOSTAT; COOLING SYSTEMS.) (C. FL.; X.)


PRODUCTS AND HOT-AIR STREAM LEAVE HERE
HEATED MAINLY BY HOT PRODUCTS FROM INNER TUBE
HOT PRODUCTS LEAVING INNER TUBE
LIGHTING DOOR
HEATED MAINLY BY RADIATION FROM INNER TUBE
AIR-STREAM BEING HEATED
BURNER
COLD-AIR STREAM

DAVIS GAS-HEATED STEAMLESS RADIATOR, SHOWING INNER STEEL TUBE WHICH HEATS THE CAST-IRON BODY

RADIĆ, STJEPAN (1871–1928), Yugoslav statesman, was born at Trebarjevo, near Fiume, on July 11, 1871. He studied in Zagreb and Prague, being once expelled from the Lycée and twice imprisoned in the former city for Croatian and anti-Hungarian demonstrations. From 1897–99 he studied in Paris and later lived for a time in Semlin as Balkan correspondent to various newspapers, coming into contact with Serb political leaders, and settled in 1902 in Zagreb. In the same year he began to publish the *Hrovatsko Misao,* in which he outlined the programme of the Croatian Peasant Party, which first entered the Croatian Sabor, with 9 seats, after the elections of 1910, but soon became the most powerful political force in Croatia. In 1911–12 Radić was again imprisoned by the Magyar Ban of Croatia. During the World War he became an Austro-Hungarian Legitimist, but on the collapse of Austria-Hungary converted his party, which followed him implicitly, to republicanism. In Feb. 1919 he demanded for Croatia self-determination, and union with Serbia and Montenegro "with equal rights." Disagreement with the Serbs, however, led him back to prison March 1919–Feb. 1920 and March–Nov. 1920.

Radić now condemned his party to a long and singularly sterile period of opposition and Parliamentary abstention, until, tiring of this, he left Yugoslavia in July 1923 for a prolonged visit to London, Moscow and Vienna. He returned to Zagreb in Aug. 1924 with fresh ideas on Panslavism and the cooperation of workmen and peasants, and was imprisoned in Jan. 1925. In March, however, his nephew Pavle Radić (*q.v.*) effected a reconciliation. Radić was released, his party entered the Government, he himself became an enthusiastic supporter of King Alexander, and for a time himself entered the Yugoslav cabinet. His habit of embarrassing his colleagues as often and as highly as possible led to his resignation. He returned to opposition, which he conducted with such verve that a Government Deputy named Račić shot him in the stomach in the Skupština on June 20, 1928. On

Aug. 8, 1928, he died at Zagreb from the effects of his wound.

RADIĆ, PAVLE (1880–1928), Yugoslav statesman, nephew of the above, was born at Trebarjevo, near Fiume on Jan. 1, 1880. He settled in Zagreb as a banker. The coalition of Serb Radicals and Croat Peasants which existed fitfully in 1926–27 was mainly his work; but when it broke down, he rejoined the Opposition. On June 20, 1928, he was murdered in an unsuccessful attempt to save his uncle's life.

RADICAL, in English politics a supporter of the more extreme section of the Whig or the Liberal party; in U.S. politics, anyone who desires to make *radical* (Lat. *radix*, root) changes in the social order—hence usually a Socialist or Communist. The first use of the word in a political sense is generally ascribed to Charles James Fox, who in 1797 declared for a "radical reform." It was thenceforward used as a general term covering all those, from Sir Francis Burdett to Richard Carlile, who supported the movement for parliamentary reform. After the passing of the Reform bill of 1832, the more adventurous of the reformers, of whom the chief organizers were Francis Place (London) and Joseph Parkes (Birmingham), remained in informal but continuous association. They exercised continual but vain pressure upon Lord John Russell and other Whigs, to agree to an extension of the franchise to the working class. Their most effective work was done after 1835 in the reformed administration of the provincial towns, some of which they controlled from the first democratic election, and in which they had to remove the effects of years of corruption and indolence. Their spokesmen formed for some years a recognized group in the house of commons, which included George Grote, Slingsby Duncombe, Thomas Wakley and Joseph Hume. They were out of sympathy and touch with the organized section of the working class owing to their support of the new Poor law (1834) and their hostile attitude to the Chartists (*see* CHARTISM).

From about 1839, consequently, their influence suffered a decline, but it revived after about 1850 when Chartism was practically extinct. The National Reform league, whose president and leader was Edmond Beales, was most active in promoting the reform of the suffrage, achieved in 1867 for the towns and in 1884 for the country: Frederic Harrison, J. S. Mill, and Edward Spencer Beesly being the most distinguished of its theorists. The Radicals, through the group of officials known as the *Junta,* gained also complete control of the political mind of the trade unions and from 1874 to 1892 every trade unionist who gained a seat in parliament sat as a Radical. *Reynold's Illustrated News,* the most popular Radical organ, somewhat exaggerated the respectable Radicals' view in its vehement Republicanism, its contempt for revealed religion and its advocacy of complete *laissez faire* in economics, but these principles were generally regarded as inherent in Radicalism. The London Radical clubs toward the end of the 19th century probably represented the most powerful single political grouping in the country.

They were only induced by the personal intervention and prestige of Charles Bradlaugh to merge their identity in the new machine of the National Liberal federation, controlled by Francis Schnadhorst; and from that time may be dated the disappearance of organized Radicalism. (R. W. P.)

RADICAL EMPIRICISM, in philosophy, is the theory that experience is the only test of reality and truth. This is the view of W. James (*q.v.*), and was so named by him.

See W. James, *Essays in Radical Empiricism* (1912).

RADIO is the combining form denoting relation to or connection with a ray, a radius, or radiation. In anatomy the term refers to the radius or outer of the two bones of the forearm as radiocarpal. In physics and chemistry it is used in connection with various forms of radiation as in radioactivity (*see* RADIOACTIVITY, ARTIFICIAL; RADIOACTIVITY, NATURAL). In electricity its general application is in association with electric waves (*q.v.*).

In its specific application to radio communication the word is used to denote the transmission and reception of signals by means of radiated electromagnetic waves. The signals translated may be the ordinary sounds sensed by the ear or they may be the signals of images sensed by the eye which have been translated into sound signals, as in television. Communication by radio in its various forms, including such phases as wired wireless, wireless telegraphy, wireless telephony, general types of broadcasting, television, is too broad a subject to be treated adequately in a single article.

A basic discussion of atmospheric electricity is given in the article ELECTRICITY, ATMOSPHERIC. A study of the theory of James Maxwell and others in the development of theory relative to electric waves is found in the article ELECTRIC WAVES. The theoretical concepts of wireless telegraphy are in the article WIRELESS TELEGRAPHY; the practical applications, including such data as international agreements and standard wave lengths, are in the same article under a subheading, *Communication.*

The principles of the action of heat on matter in generating atomic or subatomic electrically charged particles are found in the article THERMIONICS, while the article ELECTRON TUBE treats of the several distinct types of vacuum tubes. The more important and most frequently encountered radio terms, numbering several score, are defined and described under their respective headings.

The short radio subjects are in turn cross referenced in the main practical articles listed below.

Television is found under the heading TELEVISION and the transmission of motion pictures by this and other means is also discussed under the article TELEVISION.

Under TELEGRAPH and TELEPHONE is a study of transoceanic wireless telephone and wired wireless. All articles are supplemented by text illustration and photographs and, in many instances, by diagrams showing wiring arrangements and important technical data.

For the convenience of the reader the subject of broadcasting is to be found under that heading. In addition, the two major phases of broadcasting—reception and transmission—are dealt with in RADIO RECEIVER and MICROPHONE OR TELEPHONE TRANSMITTER.

So many new developments are occurring in radio that it is impossible for a survey to predict tendencies even a few years hence; it is believed helpful, however, to include here the most important peaks that have been made in wireless progress. The following data are taken from an official bulletin of the U.S. department of commerce:

In 1827 Savary found that a steel needle could be magnetized by the discharge from a Leyden jar. In 1837 the first patent for an electric telegraph was taken out by Sir William Cooke and Sir Charles Wheatstone (London) and by Samuel F. B. Morse (United States). In 1840 Joseph Henry first produced high-frequency electric oscillations. In 1867 Maxwell read a paper from the Royal society in which he laid down the theory of electromagnetism, which he developed more fully in 1873 in his electric waves that are now used in wireless telegraphy.

In 1870 Von Bezold discovered that oscillations set up by a condenser discharge in a conductor give rise to interference phenomena.

In 1879 David Hughes discovered the phenomena on which depends the action of coherers. In 1883 George FitzGerald suggested a method of producing electromagnetic waves in space by the discharge of a conductor.

In 1887 Heinrich Hertz showed that electromagnetic waves are in complete accordance with the waves of light and heat, and founded the theory upon which all modern radio signalling devices are based.

In 1896 Guglielmo Marconi lodged his application for the first British patent for wireless telegraphy. He conducted experiments in communicating over a distance of $1\frac{3}{4}$ mi. successfully. On Dec. 6, 1897, signals were transmitted from shore to a ship at sea, 18 miles distant.

On Dec. 17, 1897, the first floating wireless station was completed. On June 3, 1898, the first paid radiogram was transmitted (from the Needles [Isle of Wight] station).

On March 30, 1903, the first transoceanic radiogram was published in the *Times* (London). In 1906 Lee De Forest was granted a patent (Jan. 18) for a vacuum rectifier, commercially

known as the audion. In the same year Gen. H. N. C. Dunwoody discovered the rectifying proportions of carborundum crystals, and Pickard discovered the similar properties of silicon crystals. These discoveries formed the basis of the widely used crystal detectors. In 1912 Frederick August Kolster, of the U.S. Bureau of Standards invented and developed the Kolster decremeter, which is used to make direct measurements of wave length and logarithmic decrement. In 1912 the first practical trials with wireless apparatus on trains were made on a train belonging to the Delaware, Lackawanna and Western Railroad.

In Oct. 1914, E. H. Armstrong was issued a patent covering the regenerative circuit, also known as the feed-back and the self-heterodyne circuit. On July 28, 1915, the American Telephone and Telegraph Co., working in conjunction with the Western Electric Co., succeeded in telephoning by wireless from Arlington, Va., to Hawaii, a distance of nearly 5,000 miles. On Oct. 26, 1915, the wireless telephone experiments were continued, communication being effected across the Atlantic from Arlington to the Eiffel Tower, Paris.

In 1919 the successful trans-Atlantic flights of the American "NC4" and of Alcock and Brown, and of the British dirigible "R34" focused attention upon the great value of radio for aviation purposes. On March 2, 1923, Louis Alton Hazeltine, of Stevens Institute of Technology, presented a paper before the Radio Club of America on tuned radio-frequency amplification with the neutralization of capacity coupling. Professor Hazeltine was granted a patent for the non-radiating neutrodyne receiver. In 1925 radio-compass (direction finder) came into greater use on board vessels. In 1926 directional or beam transmission developed to a point where it was considered practical for commercial usage. In 1927–28 Bell laboratories experiments effected successful transmission by wire and radio of television signals. In 1927–28 extension of radio-telegraphy to the principal countries of the world was accomplished. (*See* BROADCASTING; ELECTRICITY; ELECTRIC WAVES; ELECTRON TUBE; RADAR; SOUND; TELEGRAPH; TELEPHONE; TELEVISION.

RADIOACTIVITY, ARTIFICIAL. Artificial radioactivity was discovered by Irène Curie and Frederic Joliot early in 1934. They made the exciting and important observation that the positrons which were emitted when aluminum was bombarded with alpha-particles (He^{++}) from polonium continued to be emitted after the source of alpha-particles was removed. The intensity of positrons decayed exponentially with a half-life of about three minutes. Immediately following the discovery of Curie and Joliot, many more artificial radioactivities were produced by several groups of workers, mainly as the result of bombardment with high-speed charged particles from artificial sources. Many substances were rendered radioactive by bombardment with protons and deuterons which were accelerated in various types of high voltage apparatus; H. R. Crane and C. C. Lauritsen used a "cascade transformer" potential source, J. D. Cockcroft, C. W. Gilbert and E. T. S. Walton employed a voltage-multiplier circuit, R. J. Van de Graaff and M. A. Tuve and L. R. Hafstad used the "electrostatic generator," while E. O. Lawrence and co-workers accelerated the charged projectiles in the magnetic resonance accelerator or "cyclotron" (*q.v.*). A large addition to the list of radioactivities was made during 1934 and 1935 as a result of the work of E. Fermi and his associates, who produced the activities by the neutron bombardment of the elements. Since the Coulomb field of the nucleus does not oppose the entry of a neutron, as it does that of a charged particle, a large number of elements throughout the entire range of the periodic table were rendered radioactive in this manner.

By the end of 1935 about 100 artificial radioelements were known, and a review of the subject of artificial radioactivity, which included a discussion of the methods of production, was published by L. N. Ridenour and D. M. Yost in *Chemical Reviews*. Further work with deuterons, neutrons and protons, and in addition, high-energy alpha-particles and gamma-rays, from artificial sources, made a large increase in the number of induced radioactivities. A number of tables of radioactivities have appeared in various physical journals listing the radioactive isotopes, their properties and methods of production. For example, J. J. Livingood and G. T. Seaborg published, in the *Reviews of Modern Physics* (Jan. 1940), a table which described the properties of about 330 artificial radioactivities and Seaborg compiled a table which appeared in the same journal in Jan. 1944, which described the properties of about 420 artificial radioactivities.

The large currents and high energies available, especially with the cyclotron, have resulted in the discovery of a large number of radioactive isotopes (*see* ISOTOPES). The accomplishment of the self-sustaining nuclear chain-reaction in uranium marked another milestone in the field of artificial radioactivity. As a result, by 1947 there were known more than 500 induced radioactivities, there being at least one radioactive isotope for each of the elements of atomic number 1 to 96 inclusive. Because of the prodigious number of neutrons generated by the chain-reactor, it is possible to produce easily weighable amounts of artificial isotopes, and hence tremendous intensities of radioactivities, where the transmutation can be induced by neutrons.

GENERAL CONSIDERATIONS

The decay of the artificial radioelements follows, of course, the well-known exponential law, just as for the natural radioactive bodies, and the decay rate for each element is described in terms of a half-life. (The half-life is the time required for one-half of the initial number of atoms to decay.) Likewise the growth of a radioactivity when an element is under constant bombardment follows the familiar growth law, that is, the fraction of the saturation number of atoms formed in a time t is equal to $1-e^{-\frac{0.69t}{T_{\frac{1}{2}}}}$, where $T_{\frac{1}{2}}$ is the half-life. After a time of activation long compared with the half-life of the substance, the activity reaches a saturation value which can not be increased by further activation (*see* RADIOACTIVITY, NATURAL).

Although the nomenclature for the artificial radioelements had not reached a standardized form by 1947, most of the investigators in the field had adopted the practice of using the contracted form "radioelement" rather than the more cumbersome term "radioactive element." For example, the well-known radioactivity of 14.8 hours half-life induced in sodium, as the result of bombardment with either neutrons or deuterons, is often referred to as being caused by "radiosodium" rather than the "radioactive isotope of sodium." The former, simpler nomenclature will be used here.

The radiations from the artificial radioelements are very similar in properties to those from the natural radioelements of the well-known uranium, actinium and thorium families (*see* RADIOACTIVITY, NATURAL and NUCLEUS). Single decay predominates, although numerous examples of chain decays, *i.e.*, cases where the product of the first decay is also radioactive, are known in artificial radioactivity. The beta-particles emitted during the decay of artificial radioactivities have the same continuous type of distribution in energy, with a definite upper energy limit, which has long been known to exist for the natural radioelements. (It is this continuous distribution of beta-particle energy which has led to the introduction of the neutrino, a particle of small or zero mass, one-half unit of spin ($\frac{1}{2}\cdot h/2\pi$) and no charge, in order to preserve the laws of conservation of energy and momentum in beta-decay.)

The upper energy limit for beta-particles decreases as the half-life increases; this Sargent relation (log half-life proportional to log energy) holds only roughly over a range of mass values and must be modified when the nuclear spin change accompanying the disintegration is greater than zero.

Decay by alpha-particle (He^{++}) emission is fairly common among the artificial isotopes of elements above bismuth just as it is among natural radioactive isotopes in this region of the periodic table. While only the negative beta-particles (electrons) are emitted by natural radioelements, some of the artificial radioelements emit negative beta-particles and some of them emit positive beta-particles (positrons). Examples of radioelements which decay by the emission of both negative and positive beta-particles are known. Some of the decays are accompanied by gamma-rays

(high-energy electromagnetic radiation) and some are not, just as in natural radioactivity, and these gamma-rays may be slightly or largely internally converted. (When a gamma-ray is "internally converted" or undergoes "internal conversion," it means that instead of the emission of a gamma-ray there is the ejection of an electron from the extranuclear structure of the same atom that contains the nucleus which is radiating, the kinetic energy of the ejected electron being equal to the difference between the energy of the gamma-ray and the binding energy of the electron.) Radioelements which give off gamma-rays can be detected through interposed material since gamma-rays cause much less ionization than charged particles, and hence are much more penetrating, than beta-particles of similar energy.

Positron emitters may decay by the alternative process of orbital electron capture, a method of decay which, up to 1947, had been observed only with the artificial radioelements. It was suggested by H. Yukawa and others, from considerations based upon the Fermi theory of beta-ray emission, that an unstable nucleus might reach stability by the capture of an extranuclear electron. The first experimental observation of decay by "K-electron capture" (often so called because by far the largest proportion of the orbital electrons captured by the nucleus come from the K-electron shell) was made by L. W. Alvarez, who found that an unstable gallium isotope of 83 hours half-life decayed by this mechanism. Many examples of this type of decay are now known. Decay by orbital electron capture may be unaccompanied by any detectable ionizing radiation except for the X-rays which must be emitted (since the vacant place in the inner shell must be filled with the emission of an X-ray or an Auger electron). However, many examples of orbital electron capture are known where the resultant nucleus is left in an excited state which drops to the ground state with the emission of a gamma-ray or a line of internal-conversion electrons or both. (The name "line of electrons" is often used to describe the monoenergetic electrons which are emitted from, *e.g.*, the K-electron shell, when gamma-rays undergo internal conversion. Some of the gamma-rays are converted in the L-, M-, etc., electron shells. The term "line" arises from the fact that with an electron magnetic spectrograph these groups of monoenergetic conversion electrons appear as lines on a photographic plate in contrast to the beta-particles from a beta-ray emitter, whose continuous distribution in energy darkens the plate continuously over a very broad energy range.) Some radioelements decay by both positron emission and orbital electron capture, some by orbital electron capture alone, and some entirely by positron emission.

Another class of radioactive substances, not peculiar to artificial radioactivity but most thoroughly studied here, are "nuclear isomers." Each member of a pair of nuclear isomers has the same atomic number and the same atomic weight (isotopic isobars); they represent two different energy states, the upper and the ground state, of the same nuclear species, differing in energy content and degree of stability. A theory which C. F. v. Weizsäcker proposed in order to account for the existence of nuclear isomers ascribes the long lifetime of the upper, metastable state to a difference of several units of angular momentum between the metastable and ground state. This large spin difference forbids the transition from the upper to the lower state in a manner analogous to the forbidden transitions in optical spectra. Each isomer of a pair may be radioactive and decay independently of the other by beta-emission with its own characteristic half-life, or the isomer corresponding to only one energy state may be beta-active, and that corresponding to the ground state may be stable. Some isomers are genetically related to each other; the upper state, rather than decaying by beta-particle emission to a neighbouring isobar, decays by an isomeric transition to the ground state with the emission of a gamma-ray. (The present theoretical explanation for the phenomenon of nuclear isomerism leads to the prediction that the gamma-rays corresponding to an isomeric transition will undergo high internal conversion when the energy is small—of the order of tens or hundreds of kilovolts.) The first evidence for nuclear isomerism in artificial radioactivity was presented in 1935 by B. Kourtchatow and co-workers, and in 1937 A. H. Snell and also W. Bothe and W. Gentner simultaneously showed that an 18-minute period and a 4.4-hour period must both be ascribed to a bromine isotope of atomic weight 80.

METHODS OF CHEMICAL IDENTIFICATION AND CONCENTRATION

The chemical identification of artificial radioelements is based on the fact that isotopes are not appreciably separated by ordinary chemical reactions and the radioactive isotopes of a given element behave in the same manner as the stable isotopes of the element. The property of radioactivity does not influence the chemical behaviour (except in the case of extremely strong activities and then in the same way as an external source would do). Thus, after a transmutation has taken place leading to the formation of a new and unstable nucleus, the new atom has properties determined solely by its new atomic number and will behave chemically in all respects like its stable isotope or isotopes. Often only a few millions of atoms of the unstable transmutation product are formed. The behaviour of an element at such low concentration may be uncertain in many chemical procedures. For this reason, in order to establish the chemical identity of the transmutation product, it is usually expedient and often absolutely necessary to add a small quantity of that element which is isotopic with the expected or suspected transmutation product. This added material is usually designated by the term "carrier." The carrier element is separated out chemically along with its unstable isotope and in this manner one can establish a radioactivity, with a characteristic half-life, which is isotopic with the carrier element.

In many cases, when the radioelement is not isotopic with the element from which it is formed, the radioactivity can be concentrated in a small amount of material by adding and separating out only a small amount of carrier. Such a high ratio of activity to carrier material (high specific activity) is desirable in many of the investigations which employ radioelements, especially in biological chemistry and physiological and biological studies. The *specific activity* may be defined as the ratio of the number of radioactive atoms to the total number of isotopic atoms with which the radioactive atoms are mixed.

When the radioactivity is isotopic with the element which is bombarded, the active isotope is necessarily mixed with a larger quantity of its inactive isotopes. However, it is sometimes possible to effect a separation of the radioactive isotope from the inactive isotopes and hence a concentration of the radioactive isotope in a small amount of material. L. Szilard and T. A. Chalmers were the first to show that radioactive iodine could be separated from ordinary iodine after irradiating with neutrons a nonionizing organic compound such as ethyl iodide. After the irradiation, a small amount of free iodine was added to act as a carrier for the free radioactive iodine, and after this iodine was reduced and precipitated as silver iodide it was found to contain practically all of the radioactivity. This method of concentration, which has subsequently been used to concentrate a number of radioelements, is now known as the "Szilard-Chalmers method." Its success depends upon the removal of the newly-formed radioactive nucleus from its chemical bond in the irradiated compound. The breaking of this bond is a result of the large amount of energy furnished by the recoil from the gamma-rays emitted during the neutron-capture process. The method is not limited to radioelements formed by irradiation with neutrons, but in principle can be applied to other methods of activation. It is, of course, essential that the radioactive atoms set free during the bombardment do not interchange with their isotopic atoms in the irradiated chemical compound. As examples of the application of this method, radioactive iodine, bromine and chlorine can be concentrated, using either organic compounds or the inorganic halogenates. Similarly, manganese dioxide precipitated from an irradiated permanganate is found to carry most of the radiomanganese under certain conditions. Whenever it is desired to use this method in order to produce a radioactive isotope with a high specific activity, a search is made for a compound which contains the element in a form which will not interchange with the freed

radioactive atoms and from which the radioactive atoms will be liberated during and separable after the irradiation process.

O. Erbacher and K. Philipp; C. S. Lu and S. Sugden; and S. Roginsky and N. Gopstein developed a number of excellent methods for the extraction with high yields of concentrated radioactive halogens from neutron-irradiated organic halides. One of the techniques employed by Erbacher and Philipp depended upon the adsorption of the radioactive atoms on active charcoal, and Roginsky and Gopstein used aluminum oxide and active charcoal as adsorbents. V. Majer used a trace of colloidal gold to supply condensation nuclei for the deposition of active gold atoms formed in a neutron-irradiated, alkaline gold chloride solution.

A method for the chemical separation of genetically related nuclear isomers, which is a modification of the Szilard-Chalmers method, was invented by E. Segrè, R. S. Halford and G. T. Seaborg. The element which contains the radioactivity corresponding to an upper isomeric energy state is made into a compound suitable for the application of the Szilard-Chalmers method of concentration; the daughter radioactivity, which corresponds to the ground state and which is liberated from this compound as a result of the isomeric transition, is then chemically separable from the parent radioactivity. Segrè, Halford and Seaborg used this method to extract the bromine radioactivity of 18 minutes half-life, in the form of hydrobromic acid, from its parent isomer of 4.4 hours half-life, which was present as tertiary butyl bromide. D. DeVault and W. F. Libby made the same separation by precipitating silver bromide from an ammoniacal solution which contained the 4.4-hour radioactivity in the form of the bromate, while L. J. Le Roux, Lu, and Sugden separated the 18-minute radioactivity as silver bromide from both ethylene dibromide and *n*-butyl bromide. A number of chemical separations of nuclear isomers have been made, employing this principle, and these have been of aid in isotopic assignments and establishing the genetic relationships between the isomeric pairs.

In some cases when the transmutation product is not isotopic with the target element, it is possible to separate it from the target element without the use of carrier. This often gives the pure radioactive element, or compound of the element, in much too small an amount to be seen, detectable only by its radioactivity. A few examples will serve to illustrate the type of physical and chemical properties which may serve to make such a separation feasible.

M. Haïssinsky separated pure radiocopper, produced by neutron bombardment of zinc, by means of electrochemical deposition on lead, while J. Steigman effected the same separation by electrolysis. Segrè found that the radiosodium present in a sample of magnesium hydroxide, after the deuteron bombardment of the magnesium, could be dissolved out of the hydroxide quantitatively by treating it with water.

Partition between solvents affords another method for separating the radioactive isotope in its pure form in the absence of carrier material. D. C. Grahame and Seaborg have used the partition between ether and 6 *N* hydrochloric acid to separate pure radiogallium from zinc as well as radiomanganese and radiocobalt from iron.

When there exists a large difference in the boiling points, this may be used to effect a separation. For example, a gaseous, radioactive transmutation product can easily be separated from a non-gaseous target element or parent element. Alvarez, A. C. Helmholz and E. Nelson have separated practically pure radiocadmium by collecting the vapour after heating deuteron-activated silver to its melting point.

When the radioactive transmutation product forms an extremely insoluble compound, it should be possible to collect the invisible precipitate on the walls of the containing vessel after centrifugation, as has been done for many of the naturally radioactive elements.

Another method of separation depends on the fact that the newly formed radioactive atom may have lost one or more of its extranuclear electrons at the moment of formation as a result of the recoil given to it by the gamma-ray emitted during the capture process. The charged atoms formed in this manner may be collected, during the bombardment of either a gaseous or a liquid substance, with the aid of an electric field. This method of concentration, which is sometimes applicable even when the radioactive product is isotopic with the target element, has been employed by Fermi and his associates and by F. A. Paneth and J. W. J. Fay and J. Govaerts. The collection of recoil radioactive atoms produced during bombardment with charged particles can also be used as a method for obtaining concentrated radioactive samples. A special use is sometimes made of the recoil technique in identifying the daughter isotopes of an alpha-emitter. Because of the great momentum of the alpha-particles, they impart enough recoil energy to the residual nuclei to dislodge them from the surface and allow collection free of other activities.

The use of adsorption techniques, analogous to "chromatography," has proved very effective. By the use of adsorbents of the ion exchange type in columns, and some organic types have proven especially effective, it has been possible to make difficult separations quite efficiently. This method was introduced and the early pioneering work done by G. E. Boyd and F. H. Spedding and W. E. Cohn and their co-workers. Cohn and E. R. Tompkins were the first to show the extreme power of the method by using it to separate neighbouring rare-earth elements.

The chemical work in connection with the identification and extraction of radioactive isotopes can usually be done in laboratories with rather usual facilities. However, in the extraction of radioactive isotopes at high levels of radioactivity special facilities are needed. Thus laboratory facilities for radiochemical research and production work can be classified according to the level of radioactivity involved in the operations—microcurie, millicurie and multicurie. (The "curie," originally the name for the amount of radon in equilibrium with one gram of radium, is now usually taken as the name for the general unit of intensity in radioactivity; a curie of any radioactive material undergoes the same number of disintegrations per unit time as one gram of radium, namely, 3.7×10^{10} disintegrations per second.) Since problems often require manipulations at more than one of these levels it may be necessary to have separate facilities for work at more than one level in a single laboratory. Ordinary chemical facilities are satisfactory for work at the microcurie level. Shielding material is needed between the operator and the equipment, thus requiring specially designed hoods, for work at the millicurie level. Manipulations at the multicurie level must be completely remotely controlled and carried out behind heavy, permanent shielding material.

METHODS FOR DETECTION OF RADIATIONS

There are a number of different types of instruments that are used for the measurement of the intensity of the radiations from radioactive substances. All of the common instruments depend upon the ionization, direct or indirect, produced by radiation. No attempt will be made to describe all of them, but some of those which were being used in 1947 by workers in this field will be mentioned briefly. The best type of instrument for a given problem depends upon the type and energy of the radiation and upon the sensitivity and stability which is required. A knowledge of the absorption curve for the radiation to be measured is often very important, especially if the radiation is of very low energy (*i.e.*, very soft), since this will make it necessary to pay particular attention to the effect of self-absorption in the sample and to use a detection device of the proper design.

One of the simplest instruments, widely used, is the Lauritsen modification of the electroscope, known as the "quartz-fibre electroscope." The electroscope is usually used inside an ionization chamber, which may be filled with any gas, although air is usually used for convenience, and the rate of drift of the fibre across a scale is measured. This instrument, which is suitable for the detection of all types of radiations from radioactive substances, is one compact unit and requires for its operation only a D.C. (direct current) potential source of the order of 200 volts. Its sensitivity is not as large as that of some of the other detection devices. The quartz-fibre electroscope can be used to best advantage with a radioactivity whose intensity is of the order of micro-

curies (10^{-6} curies), although intensities which are 1%, or even 0.1%, as strong as this can be measured.

A more sensitive arrangement of the integrating type, also suitable for the detection of all types of radiation from radioactive substances, is obtained with an ionization chamber connected to some kind of an electrometer. These chambers which usually consist of an outer cylinder with a central, coaxial electrode, normally use 300 to 400 volts of D.C. potential for their operation and may be designed so as to contain any gas. The gas may be at atmospheric pressure, which is necessary when a thin window is used, or higher pressures may be used to increase the detection sensitivity for penetrating radiation such as gamma-rays. The measurement of extremely soft radiation can be accomplished by introducing the sample into the inside of the ionization chamber. Any sensitive electrometer can be used; both the Edelmann electrometer and the Perucca electrometer have been used in practice and found to be satisfactory. Various vacuum tube electrometer systems have been used and this is the type which is generally used. The ionization current is amplified by a D.C. amplifier and is read as a deflection on a sensitive galvanometer; a modification in which the "rate of drift" of the galvanometer current is read increases the sensitivity for the measurement of the radiations from weak samples. Recently the vibrating reed electrometer has been developed. This device converts the D.C. voltage, obtained by passing the ionization current through a high resistance, into an A.C. (alternating current) voltage which can be greatly amplified with very high stability. The "rate of drift" method can also be used with this instrument to increase its sensitivity. In general, electrometers are characterized by being useful over a tremendous range of sensitivities from 10^{-4} microcuries (limited by the type of electrometer) to several curies (limited by the design of the ionization chamber).

An ionization chamber of a different design can be used to detect single, heavily ionizing particles, such as protons, alpha-particles, etc., when connected to a high-gain, multiple-stage, A.C. (pulse) amplifier. Complete electrical circuits for the operation of such ionization chambers were commercially available from several sources in 1947. Electrons and gamma-rays (which show themselves only by the electrons liberated from the material they pass through) are not recorded with this arrangement. In a special arrangement, known as the "alpha pulse analyzer," such a type of ionization chamber can be used in connection with a multichannel circuit in which alpha pulses are sorted electronically according to size, hence making it possible to detect and identify the individual components in mixtures of alpha-emitters.

The most sensitive detection device is the Geiger counter, also known as the "point" counter, an instrument which detects individual ionizing particles of all kinds. A modification of the original Geiger counter which was widely used in 1947 is the Geiger-Müller counter, which was also known as the "tube" counter and the "Zählrohr." With this instrument it is possible to detect the ionizing particles from a source as weak as 10^{-5} microcuries. The Geiger-Müller counter consists of a conducting cylinder and coaxial wire which is insulated from the cylinder. It is filled with some gas such as air or argon at reduced pressure, together with a "quenching" component such as an oxygen-containing gas like alcohol, and is operated with a negative voltage of 500 to 5,000 volts on the outer cylinder. The passage of an ionizing particle through the counter causes a temporary electrical breakdown (*i.e.*, an avalanche of ionization initiated by the first ion pair which is produced and greatly augmented by secondary ionization from collision processes, etc.) between the outer cylinder and the central wire, and this pulse is usually amplified by an A.C. (pulse) amplifier to a stage where it is capable of operating a mechanical recorder in a recording circuit. Complete electrical circuits, together with recorder, as well as counter tubes of many different designs are commercially available from many sources. The circuit which operates the mechanical recorder, and this is generally true wherever such a recorder is used, is usually the "scaling" type, *i.e.*, is so designed that the recorder needs to record only a certain known fraction of all the pulses from the counter and amplifier.

When the particle radiation from the radioactive element is of very low energy, the radioactive material, in the form of a gas, can be introduced into the interior of an ordinary ionization chamber or Geiger-Müller counter. An arrangement which allows a radioactive sample of solid material to be introduced into the interior of a counter and which allows background counts to be made while such a sample is inside, is the "screen-wall" counter described by Libby. Of course, when the low-energy particle radiation is accompanied by gamma-radiation it may not be necessary to introduce the sample into the interior of the counter or ionization chamber. However, the lower efficiency of gamma-ray detection makes it necessary to have strong samples for measurements which depend entirely upon gamma-radiation.

The "proportional" counter, first described by H. Geiger and O. Klemperer, is a modification of the Geiger and the Geiger-Müller counter which is operated at a lower voltage (and with a higher gain pulse amplifier), so that only heavily ionizing particles such as protons, alpha-particles, etc., are detected.

For most work involving the radioelements the choice of detection device will be made from the following group: (1) electroscope, (2) Geiger-Müller counter, (3) integrating ionization chamber or (4) nonintegrating ionization chamber with linear amplifier. These instruments can be used to obtain absorption curves in order to determine the energy of radiations from radioactive substances. The upper energy limits of beta-particles are usually determined with the help of the relationship of N. Feather, $R=0.543E-0.160$, where R is the range in grams per cm.^{2} of aluminum and E is the energy in Mev (good only for $E>0.6$ Mev), while for gamma-rays the correlation of energy with absorption coefficient as listed in the tables compiled by Gentner and others can be conveniently used.

Brief mention should also be made of other experimental arrangements which are used primarily for detailed studies of the properties and energy of radiations. The beta-ray spectrograph or spectrometer uses a magnetic or electric field to bend, to an extent dependent upon their energy, alpha-particles, beta-particles, internal-conversion electrons, or the secondary electrons from gamma-rays. The particles are detected either by a photographic method or by a counter or ionization chamber. Another arrangement involves two or more counters connected to an amplifier of a type which records the counts only when the counters discharge simultaneously. This "coincidence counter" arrangement is often used to determine the energy of gamma-rays by determining the absorption curve of the secondary electrons which are producing the coincidence counts. In addition, there is the expansion chamber or cloud chamber of C. T. R. Wilson (usually used with a magnetic field), in which can be seen and photographed the water drops which condense along the path of an ionizing particle.

Another instrument which should be mentioned is the secondary electron multiplier tube as adapted to counting purposes. This device, which detects single positive ions, electrons and photons by producing a large current of secondary electrons inside a single vacuum tube, is most useful for special problems in physics where work in a vacuum and an extremely low background (less than one count per minute) are paramount factors. A device proposed by P. J. Van Heerden is the "crystal counter" for detecting electrons. In this method the dielectric properties of a crystal of some material, *e.g.*, silver chloride, are used in such a manner that a pulse suitable for detection and recording can be generated upon the passage of an ionizing particle through the crystal.

An ingenious adaptation, introduced by A. J. Dempster and co-workers, of the mass spectrograph to the determination of the mass of radioactive isotopes has led to a powerful method for making the isotopic assignment of radioactivities. In this method a portion of the sample, containing a radioactivity whose mass number needs to be established, is placed on the filament source of a mass spectrograph. Operation of the instrument then separates the isotopes and deposits them on a detecting surface. The position of the radioactive isotope on this surface can be determined by the use of some radiation detection device, such as a counter or photographic plate, and the mass corresponding to

this position can be learned from calibration experiments. An increasing number of isotopic identifications are being made by this method.

TYPES OF REACTIONS AND METHODS OF PRODUCTION

The artificial radioelements are prepared chiefly from the stable isotopes of the elements (*see* NUCLEUS) with the help of various kinds of bombarding particles, such as neutrons, deuterons, alpha-particles (helium ions), protons, high-energy gamma-rays and X-rays. Any charged particle which can be accelerated to a sufficiently high energy to enter the nucleus is a potential projectile for producing nuclear transmutations. The long-lived, heavy, radioactive elements, such as uranium, plutonium (the synthetic element with atomic number 94), thorium, etc. serve as the source of many radioactive (fission product) isotopes as a result of the fission reaction. In some cases artificial isotopes, even though relatively short-lived, serve as the source for the production of other such isotopes; such higher order reactions are more common in the case of neutron irradiations because of the extremely high neutron intensities available. The artificial radioisotopes with mass numbers smaller than those of the stable isotopes of the same element reach stability by the emission of positrons (or by orbital electron capture); those with larger mass numbers attain stability by the emission of negative beta-particles. A radioelement whose mass number lies between the mass numbers of two stable isotopes is usually a negative beta-particle emitter although many examples exist in which the isotope decays in both directions.

In order to identify completely a radioactivity it is necessary to establish the mass number of the active isotope as well as the atomic number. The latter assignment is usually made by chemical separations. The mass number of the radioactive isotope can be deduced sometimes from a study of the known mass numbers of the stable isotopes of the target element after the chemical separation has established the type of reaction; often the identification must be made by the method of "cross bombardment," *i.e.*, the preparation of the radioactive isotope by several independent nuclear reactions. A new radioactivity is sometimes found to decay to or grow from, in one or more steps, a previously known radioactivity. In this case the mass number of the parent or daughter may be established through the genetic relationship. The bombardment of separated isotopes offers a powerful method for the isotopic identification of induced radioactivities, in view of the excellent isotope separation methods which have been recently developed. When a radioactive isotope is formed as the result of a reaction which involves a rare isotope, the bombardment of the pure, separated isotope will, of course, result in a larger yield. Isotope separation experiments performed after bombardment (*see* above) also are useful for isotopic identification. For the use of a radioactive substance as a tracer (*see* below) in a chemical or biological problem a knowledge of the atomic number is sufficient, and radioactive isotopes whose mass numbers have not been established are nevertheless valuable.

The types of reactions leading to the formation of the artificial radioelements will now be described (these reactions also often lead to the production of stable isotopes). For brevity it will be convenient to use a simplified notation, rather than to write out the entire reaction each time. For example, the bombardment of iron with neutrons to produce radiomanganese will be described by $Fe^{56}(n,p)Mn^{56}$, rather than by the more cumbersome equation

$$_{26}Fe^{56} + _0n^1 \rightarrow _{25}Mn^{56} + _1H^1$$

(where the superscripts denote mass numbers and the subscripts atomic numbers). The notation n=neutron, p=proton, α=alpha-particle, d=deuteron and γ=gamma-ray will be used.

The discussion which follows will also include a few statements regarding the yield of radioelements formed in the various reactions. It must be emphasized that only rough qualitative statements can be made, since the situation is too complex to allow a quantitative treatment in a few words. No summary of experimental data on the various reaction yields and the variation of the yields with energy and atomic number has been published; a summary of this type awaits more systematic data.

It may be helpful to point out that the considerations of Bohr have led to the view that the transmutation which occurs as the result of the impact of any particle with an atomic nucleus (with a few exceptions) proceeds by a mechanism which must be treated as two independent processes: namely, (1) the amalgamation of the particle with the nucleus to form an intermediate metastable compound nucleus, and (2) the eventual breaking up of the intermediate nucleus into the end products. All of the reactions in step (2) which are energetically possible will take place but the rates for the competing reactions may differ so greatly that some reactions can not be detected.

Neutron Reactions.—Neutrons are obtained from three types of sources: (1) chain-reacting piles; (2) indirectly from charged particle accelerators; and (3) those which utilize the radiations from the natural radioelements.

The neutrons from the latter type are usually produced by the reaction $Be^9(\alpha,n)C^{12}$ and the sources may be prepared by mixing powdered beryllium with alpha-particle emitters such as radium, radon or polonium. Neutrons produced in this manner have a more or less continuous distribution in energy extending up to about 13 Mev (million electron volts) for radon alpha-particles. (The electron volt, a unit of energy widely used in atomic and nuclear physics, is equal to 1.59×10^{-12} ergs, and is the amount of energy acquired by a particle of electronic charge when it falls through a potential difference of 1 volt.) The action of monoenergetic gamma-rays (of sufficient energy) on beryllium and on deuterium gives rise to monoenergetic neutrons, usually known as "photoneutrons," with energies of the order of hundreds of kilovolts when gamma-rays from the natural radioelements are used.

Artificial sources of indirectly produced neutrons are obtained by bombarding various elements with fast-moving charged particles, the energy of the neutrons depending upon the energy of the bombarding particles. However, the neutron energies have a strong dependence upon the reactions used for their production, so that, taking into account the experimental conditions used for their production, certain rough statements can be made with regard to the energies of neutrons from various artificial sources. Two common sources are (1) deuterons (say 5 to 10 Mev on beryllium (the Be+d source), giving neutrons with energies extending up to about 13 Mev and (2) deuterons on deuterium (the D-d source). The D-d source is used to most advantage when deuterons with energy of the order of a few hundred kilovolts are available and under these conditions gives rise to neutrons within the narrow energy range of 2.5 to 3 Mev. The bombardment of lithium or boron with deuterons (5–10 Mev) produces neutrons with energies extending up to about 25 Mev. Neutrons in this high energy range are produced also by the bombardment of beryllium with high energy (*e.g.*, 20 Mev) deuterons. With extremely high energy deuterons (200 Mev), neutrons with energy in the range of 100 Mev are produced, probably with all target materials.

The uranium chain-reacting "piles" give rise to sources of neutrons of intensities which are huge by comparison with these other sources. Such sources give rise to neutron fluxes which are larger than those mentioned above by orders of magnitude, and furthermore the area over which these fluxes are maintained is larger by many, many orders of magnitude. With such "neutron factories" it is possible to transmute elements on a weighable scale; in fact, it is possible to produce radioactive isotopes on a scale of not only micrograms or milligrams, but also grams, or even kilograms in some cases. Also it is possible to use second and higher order reactions in their production, *i.e.*, produce by transmutation an isotope which in turn can be used to produce another isotope by neutron absorption, and so on. Neutrons from this type of source extend in energy up to some 10 Mev, with all lower energies present, and often the pile is so designed as to give a high flux of predominantly "slow" neutrons (*see* next paragraph).

Previous to the advent of neutrons with energies in the 100

Mev area, common usage had evolved a rough classification of neutrons into groups on the basis of their energy; "very fast" neutrons, often called "fast" neutrons, were those, *e.g.*, from a lithium plus deuterons (Li+d) or boron plus deuterons (B+d) source, with energies extending from about 20 Mev to about 10 Mev, while neutrons with energies within the range starting at about 10 Mev and extending down to an indefinite energy region (of the order of thousands of electron volts) were known as "fast" neutrons or "medium fast" neutrons (especially those at the lower end of this energy range). "Slow" or "thermal" neutrons is the name given to those neutrons which have suffered a sufficient number of collisions usually with hydrogen or carbon nuclei as the result of passage through paraffin or water or graphite, to slow them to thermal velocities, *i.e.*, about 0.025 electron volt of energy. Slow neutrons were discovered by Fermi and co-workers, and these authors as well as many others give a discussion of their properties and of the slowing process. Neutrons in the energy range immediately above the thermal range are sometimes designated as "resonance" neutrons, a result of the fact that many nuclei absorb such neutrons only within extremely narrow energy ranges, that is, absorb them in a resonance fashion.

Reactions between medium fast neutrons and nuclei produce artificial radioelements by the following main types of transmutations: (1) the simple, radiative capture, known as the n,γ reaction; (2) neutron capture followed by proton emission, or the n,p reaction; (3) neutron capture with alpha-particle emission, the n,α reaction; and (4) neutron capture followed by the emission of two neutrons (net expulsion of one neutron), or the $n,2n$ reaction. With very fast or very high energy neutrons (10 to 100 Mev or higher) more than one proton, alpha-particle or neutron may be ejected, and in all combinations, the relative yields depending on the particular energy of the incident neutron and upon the atomic number of the target element. The n,γ and $n,2n$ and $n,3n$, etc. reactions give radioelements which are isotopic with the target element, and hence the Szilard-Chalmers method of concentration is used when it is desired to obtain a high ratio of active to inactive material, *i.e.*, a high specific activity. When the n,p or n,α or $n,p\alpha$, etc., reactions are used or the Szilard-Chalmers method employed, large amounts of material can be used effectively in order to obtain large specific activities. Radioelements formed by the $n,2n$ or $n,3n$, etc. reactions are largely positron emitters, while the n,γ reactions usually lead to negative beta-particle emitters.

The n,γ type of activation occurs most efficiently with slow neutrons and to a smaller extent with fast neutrons. It is the most common and widely studied of all nuclear reaction types. Elements throughout the entire range of the periodic table can be activated in this manner; the cross sections for slow neutron absorption, which are extremely large for some elements, vary in an irregular manner from element to element and from isotope to isotope. The n,p and n,α, etc. transmutations require fast neutrons (except for two or three cases in the lightest elements). The energy required increases regularly as one proceeds up the periodic table, since the outgoing charged particles must escape the nuclear potential barrier, and for atomic numbers as high as 50 only the neutrons with energy greater than 10 Mev are effective. The $n,2n$ reaction requires neutrons with energy above about 10 Mev for good yields because the net result is the expulsion of a neutron whose binding energy amounts to about 8 Mev for most of the elements.

There is another type of activation by fast neutrons which involves those isomers in which the ground state is stable. The kinetic energy of the captured neutron excites the nucleus to its upper, radioactive, isomeric state, a neutron being re-emitted, with reduced energy, after the excitation process. In keeping with our method of writing nuclear reactions, this method of excitation is known as an n,n process and a typical example is written $In^{115}(n,n)In^{115*}$. (The asterisk, as used here, denotes a radioactive isomer of a stable nucleus.)

Deuteron Reactions.—Moderately intense radioactivities can, in general, be induced as the result of bombardments with high-energy deuterons which are produced in the cyclotron of Lawrence and M. S. Livingston. Most of the cyclotrons which were in operation in 1947 were producing deuterons of 5- to 15-Mev energy and currents of 10 to 200 microamperes; the 60-in. cyclotron at Berkeley, Calif., was furnishing 20-Mev deuterons and the 184-in. cyclotron at Berkeley was furnishing 200-Mev deuterons. Other types of artificial deuteron sources induce radioactivities of lower intensities, since they produce deuteron beams of much lower energy.

Artificial radioelements, both negative and positive beta-particle emitters, are produced by deuterons of moderate energy (say up to about 10 Mev) in the following ways: (1) deuteron capture and proton emission, known as the d,p reaction, which is, since the net result is the capture of a neutron, equivalent to the n,γ reaction; (2) deuteron capture followed by neutron emission, or d,n reaction; and (3) deuteron capture with alpha-particle emission, the d,α reaction. The yields from all of these reactions increase with increasing energy of the deuterons up to a point and, for a given deuteron energy, decrease with increasing atomic number of the target element. This decrease is most marked for the $d,\ \alpha$ reaction, since the outgoing, doubly-charged alpha-particles must penetrate the Coulomb barrier of the nucleus (*e.g.*, with 8-Mev deuterons this reaction is not observed for nuclei of atomic number as high as 50, while the d,p and d,n reactions are observed throughout the entire range of the periodic table). It should be pointed out that the d,p reaction occurs largely by a mechanism known as the Oppenheimer-Phillips process, wherein the deuteron, upon approaching the nucleus, is polarized in such a manner as to give rise to the capture of the neutron without the usual amalgamation of the bombarding particle (deuteron) to form a temporary intermediate nucleus. This obviates the necessity for the deuteron to penetrate the potential barrier of the nucleus.

With energies in the range 10 to 200 Mev and higher, more than one proton, alpha-particle or neutron may be ejected, and in all combinations, depending on the particular energy of the incident deuteron and upon the atomic number of the target element. The name "spallation" reaction has been suggested for this type of nuclear transformation in which many small particles are chipped from the nucleus as the result of a collision with an extremely high energy particle.

A few examples will serve to illustrate the intensity of radioactivities which are induced with deuterons. The bombardment of copper for 20 minutes with 20 microamperes of 8-Mev deuterons produces Cu^{64} (half-life 12.8 hours), by the reaction $Cu^{63}(d,p)Cu^{64}$, with an intensity of about 5 millicuries (*i.e.*, 5×10^{-3} curies). Such a sample would give a discharge rate corresponding to about 10^7 times the natural background of an ordinary Lauritsen, quartz-fibre electroscope. In a typical experiment a 4-hour bombardment of phosphorus with 100 microamperes of 16-Mev deuterons produces about 50 millicuries of P^{32} (half-life 14.3 days or 1.24×10^6 seconds) by the reaction $P^{31}(d,p)P^{32}$. With the aid of the relation $-dN/dt=\lambda N$, where $-dN/dt$ is the number of disintegrations per second and λ the disintegration constant, we find for N, the number of active atoms, $3.7\times10^{10}\times0.05\times1.24\times10^6/0.69=1/3\times10^{16}$. (The disintegration constant, λ, defined by the equation $-dN/dt=\lambda N$, is equal to 0.69 divided by the half-life.) *See* RADIOACTIVITY, NATURAL. This corresponds to approximately one-sixth of a microgram of radioactive P^{32}.

Alpha-Particle (Helium Ion) Reactions.—Helium ions which are accelerated by electrical means are entirely equivalent to alpha-particles from the natural radioelements and therefore are often called alpha-particles. However, artificially accelerated helium ions, because of the larger intensity of particles available and the higher energies attainable, have largely displaced the natural alpha-particles for the production of radioelements. For example, 100 mg. of radium (with its decay products) emits about 10^{10} alpha-particles per second, spread out in all directions, while 1 microampere of alpha-particles corresponds to 3×10^{12} particles per second, directed upon the target. When the cyclotron is in adjustment for deuterons, it is also almost in adjustment for alpha-particles, since deuterons and helium ions have

nearly the same value of e/m; and, because the alpha-particles have the same velocity and twice the mass, they attain twice the energy that deuterons do when they are accelerated with the same voltage. Most of the cyclotrons in operation in 1947 furnished alpha-particles of 10- to 30-Mev energy. The 60-in. Berkeley cyclotron was producing 40-Mev alpha-particles and the 184-in. cyclotron at Berkeley was furnishing alpha-particles with 400 Mev of energy.

Artificial radioelements, both negative and positive beta-particle emitters, are produced as the result of alpha-particle capture followed by neutron emission, the α,n reaction, and by alpha-particle capture and proton emission, the α,p reaction. The yields increase with increasing energy of the projectile and, for a given energy, decrease with increasing atomic number. In the heavier elements, say above lead, a helium ion of less energy than about 20 Mev can not enter the nucleus; so no reactions are seen.

With higher energies more than one particle is ejected, and in all combinations, depending on the particular energy of the incident alpha-particle and upon the atomic number of the target element.

The excitation of nuclei by a process which might be designated as an α,α reaction is another method of activation which occurs with alpha-particles. Theoretical considerations suggest, however, that this activation often occurs as a result of an interaction between the electric fields of the alpha-particle and the nucleus and not as a capture and re-emission of the bombarding particle as in the case of the n,n reaction.

Proton Reactions.—Just as in the case of deuterons and alpha-particles, the cyclotron offers the best source of high-energy protons. Many investigators have prepared a large number of radioelements by means of proton bombardments.

A most common reaction is the capture of the proton followed by neutron emission, or the p,n reaction, producing mainly elements which decay by positron emission (or orbital electron capture). The yield increases with the energy of the proton and decreases with the atomic number of the target element. This type of transmutation is observed throughout the entire range of the periodic table when protons greater than about 10 Mev are used. If the radioactive substance formed in a p,n reaction emits positrons and thus returns to the target element, the energy threshold for the reaction is equal to the difference between the neutron and hydrogen mass (0.8 Mev), plus the mass of two electrons (1.0 Mev) plus the upper energy limit of the positron spectrum from the radioactive substance. (Similarly the energy threshold for the formation of a positron emitter from a $d,2n$ reaction is equal to 4.0 Mev plus the positron upper energy limit.) When the radioactive product decays by orbital electron capture, the energy threshold may be as much as 1 Mev lower than that which would be calculated for the formation of an emitter of zero-energy positrons.

The radiative capture of the proton, known as the p,γ reaction, is observed with the very lightest elements, and it has also been observed with a few elements of medium weight ($Z=30$). This reaction is important only at energies below or near the threshold for the p,n reaction. The yield from this reaction, especially for the very lightest elements, exhibits sharp maxima at certain sharply defined energies of the protons corresponding to definite "resonance levels."

As is the case for the other incident particles, at higher energies reactions occur in which numbers of particles are ejected, the number and type depending on the energy and atomic number. Also the utilization of the kinetic energy of protons to excite nuclei by the p,p reaction occurs, as in the case of the n,n and the α,α reactions.

Gamma-Ray Reactions.—Gamma-rays of sufficient energy are capable of ejecting neutrons from atomic nuclei to produce radioelements by the γ,n reaction, a type of transmutation also known as "photo-disintegration." Bothe and Gentner, who studied this reaction using the 17-Mev gamma-rays produced in the reaction of protons with lithium and the 12-Mev gamma-rays from boron plus protons, found that the yield varied irregularly from element to element. Mainly positron emitters are formed and the yield is comparatively low. The reactions giving rise to gamma-rays of high energy are of the resonance type, occurring at voltages below 1 Mev and hence the direct acceleration type of apparatus, operating at high beam currents, is the best source.

The betatron and synchrotron can be used to accelerate electrons to extremely high energy, in fact any energy up to hundreds of Mev and these electrons can in turn generate X-rays up to this energy. Such X-rays lead to the ejection of neutrons, protons, alpha-particles, and in all combinations, depending on the energy and atomic number.

Lower energy X-rays have been used to excite certain stable nuclei to their isomeric, radioactive states. This type of excitation has also been effected by bombardment with high-energy electrons.

The Fission Reaction.—In Jan. 1939, O. Hahn and F. Strassmann reported their important discovery that the bombardment of uranium with slow or fast neutrons resulted in the cleavage into pairs of radioactive products of medium atomic weight. The existence of this entirely new type of nuclear reaction was immediately confirmed in many laboratories throughout the world, and L. Meitner and O. R. Frisch, after confirming the reaction, suggested the name "fission" for the process. Subsequent work by a large number of investigators resulted in the chemical identification of many of the fission products. Hahn and Strassmann and others found that thorium also undergoes nuclear fission when bombarded with fast neutrons, and A. V. Grosse, E. T. Booth and J. R. Dunning found that the same is true for protactinium (slow neutrons are ineffective in these cases). The products of these cleavage processes, because of the high neutron to proton ratio of uranium, have an abnormally high neutron to proton ratio; hence all are negative beta-particle emitters and many chains of successive decay are found. Some of the radioactive isotopes formed in this manner can be formed in no other way and others can also be formed by some of the methods outlined in the sections above.

The events leading to the discovery of the fission process present an interesting history. In their original work Fermi and coworkers bombarded uranium with neutrons and obtained a series of radioactivities which, on the basis of chemical experiments, they were led to assign to "transuranium elements," *i.e.*, elements with atomic number greater than 92. The experiments of Hahn, Meitner, and Strassmann and others appeared to confirm this point of view, and for several years the transuranium elements were the subject of much experimental work and discussion. I. Curie and P. Savitch, in 1938, found a product of 3.5 hours half-life which had the chemical properties of a rare earth, but they failed to give a complete interpretation of this astonishing discovery. Early in 1939 Hahn and Strassmann described experiments which made it certain that they had observed the production of radioactive barium isotopes as the result of the bombardment of uranium with neutrons. Subsequent work has shown that practically all of the radioactivities formerly ascribed to transuranium elements are actually the result of fission products. N. Bohr suggested on theoretical grounds, and it was soon confirmed experimentally, that it is the rare isotope U^{235} which is the most susceptible to this fission process, *i.e.*, undergoes fission with the highest probability per incident neutron and does so even with neutrons of small energy (slow neutrons). More than 150 radioactive fission products are now known (1947). The fission of uranium and thorium by charged particles and by high-energy gamma-rays has also been observed.

It was soon shown by H. von Halban, Joliot and L. Kowarski as well as Szilard and W. H. Zinn, and confirmed by many others, that secondary neutrons are emitted during the fission of uranium. The secondary neutrons could themselves produce still more fissions and the possibility of the occurrence of a chain reaction, under the proper conditions, was immediately recognized. The large energy per fission (approximately 200 Mev) shows that the propagation of such a chain could involve the release of immense amounts of energy.

The attainment of the self-sustaining nuclear chain reaction

with natural uranium, mixed with material such as graphite for producing thermal neutrons by the neutron-slowing process, has been successful and such "piles," as they are called, serve as neutron sources of tremendous intensity. Such uranium piles are used to manufacture the famous Pu^{239} isotope of the synthetic element plutonium (atomic number 94) and, in conjunction with thorium, can be used to manufacture the new isotope U^{233} of uranium. The isotope Pu^{239} and presumably also U^{233}, share with U^{235} the property of readily undergoing the fission reaction with neutrons and therefore these three isotopes are the fuel material for much smaller piles, giving higher neutron intensities, than those which operate on natural uranium. The chain-reacting pile serves as a source for the production of radioactive isotopes, both the fission product isotopes and those which can be produced by neutron irradiation, in large amounts. Among the valuable fission product isotopes for tracer research is eight-day I^{131} which has been much used in biological studies.

In 1947 I. Perlman, D. H. Templeton and J. J. Howland made the observation that a number of elements well below the thorium-uranium region undergo the nuclear fission reaction when subjected to bombardment with very high energy particles. This work was done at the University of California and the source of their high energy particles was the 184-in. cyclotron. They observed that the elements starting with bismuth (atomic number 83) and on down to tantalum (atomic number 73) undergo the nuclear fission reaction when irradiated with 400-Mev helium ions and that a number of these elements also undergo this reaction when irradiated with 200-Mev deuterons or 100-Mev neutrons. For these elements the fission process is characterized by a distribution of the radioactive fission product isotopes leading essentially to one broad peak in the distribution-yield curve rather than the characteristic two peaks with a pronounced minimum between them in the curve for the fission products produced in the slow neutron irradiation of uranium and plutonium. The fission product distribution extends to lighter elements as might be expected in view of the lighter mass of these elements as compared with uranium and plutonium. Thus, some of the fission product radioactive isotopes formed in these reactions are different from any which are formed in the fission of the heavy elements such as uranium and plutonium.

It should be emphasized that this observation of the fission reaction in relatively common elements such as lead opens no possibility for the production of self-sustaining nuclear chain reactions with these elements and there is no possibility for their employment as sources of atomic energy. One reason for this stems from the fact that any secondary emitted particles which might conceivably be eligible for perpetuating such a chain reaction have much too small an energy to be able to do so.

APPLICATION TO CHEMISTRY AND MEDICINE

The artificial radioactive isotopes have found, and will continue to find, a wide application as research tools in many scientific fields such as chemistry, biochemistry, medicine, physics, biology, physiology, zoology, botany, industrial operations, etc. This application arises chiefly as a result of their use for tracer or "atom tagging" experiments. It is beyond the scope of this article to give a complete discussion of the results, but because of the importance of such work, a brief discussion of the results and possibilities in the fields of chemistry and medicine, and their related fields, will be given.

In the tracer or atom tagging method of investigation, the element is usually present largely in the form of its natural mixture of inactive isotopes and is "tagged" by the addition of an adequate amount of one of its radioactive isotopes. The mixture which has been "labelled" in this manner is then put into the experiment and the course of the added element, often present in some complicated molecule, is followed by means of the measurement of the radioactivity. By use of this principle it is possible, even in the presence of more of the element throughout the system, to trace the course of that particular amount and form of the element which is under investigation.

One of the most important and interesting uses to which artificially induced radioactive isotopes have been put has been the investigation of the properties of those elements which do not exist in nature. In most cases so far, this type of chemical investigation has used a "tracer" technique in which the chemical properties of the radioactive elements are investigated by using amounts so small as to be unweighable and the course of the element in the reactions is followed by means of its radioactivity rather than by chemical means. Thus the orders of magnitude of solubilities of the compounds of the radioactive elements are inferred on the basis of "carrying" experiments, it being generally true that tracer amounts are carried well only if the anion of the precipitate forms an "insoluble" compound with the cation being carried. Other chemical properties such as oxidation potentials can be deduced, making use of this technique. A great deal about the chemical properties of an element can be learned by this method of investigation which is the only possible method when only submicrogram amounts are available.

The most spectacular examples of the application of the tracer technique lay in the discovery and in the study of the chemical properties of *new* elements nonexistent in nature, *i.e.*, with the transuranium elements of atomic numbers 93, 94, 95 and 96. In the case of element 94 (plutonium) a long and complex process for its separation from uranium and fission products was to a considerable extent worked out before anyone had ever seen any plutonium even under the microscope. These studies also led to the elucidation of the electron structure of the heaviest elements, the evidence indicating that these form a series of actinide elements with the added electrons for most of the 14 successive elements starting with thorium going into the *5f*, an inner electron shell, similar to the addition of successive electrons to the inner *4f* shell in the case of the 14 previously known lanthanide earths.

The first transuranium element was discovered by E. M. McMillan and P. H. Abelson at the University of California in May 1940. Using the neutrons from the cyclotron, they were able to show, on the basis of their chemical and physical experiments, that a beta-particle emitting radioactivity of 2.3 days half-life formed during the irradiation of uranium with neutrons is caused by the isotope 93^{239} (neptunium), which is the decay product of the 23-minute U^{239} formed by radiative neutron capture in U^{238}. Their experiments on the tracer scale showed that element 93 (neptunium) has at least two oxidation states, an upper state (or states) and a lower state (or states), with chemical properties quite analogous to the VI and IV (or III) forms of uranium. For example, they showed that the Np^{239} under reducing conditions is carried and under oxidizing conditions is not carried from aqueous solution by lanthanum fluoride, indicating that the fluoride of the lower oxidation state of neptunium is insoluble and the fluoride of the higher state is soluble. They found that a greater oxidizing power is required to oxidize neptunium to its upper state than is the case for the corresponding oxidation of uranium.

After the discovery of neptunium, the next transuranium element to be investigated was the element with atomic number 94. This element was produced by Seaborg, McMillan, A. C. Wahl and J. W. Kennedy at the University of California late in 1940. The isotope involved was the one of mass 238 formed by the deuteron bombardment of uranium. These investigators were able to show that the deuteron bombardment of uranium in the cyclotron leads to a new isotope of neptunium, the 2.0-day beta-particle emitter, Np^{238}, formed from a $d,2n$ reaction on U^{238}. They found that this isotope of neptunium decays to an alpha-emitting isotope of element 94 (plutonium), namely, Pu^{238}, and that this alpha-emitter has a half-life of about 50 years. Early tracer experiments with this isotope showed that plutonium has at least two oxidation states, an upper state (or states) and a lower state (or states), and that it requires even stronger oxidizing agents to oxidize plutonium to the upper state than is the case for neptunium.

The experiments of Seaborg, R. A. James, L. O. Morgan and A. Ghiorso in the Metallurgical laboratory at the University of Chicago have led to the identification of isotopes of elements 95

(americium) and 96 (curium), making it possible to study the chemical properties of these elements by the tracer technique. Deductions from work on the tracer scale with these isotopes led to the conclusion that the III oxidation state is the most stable and by far the most important state for these elements in aqueous solution. In fact in the case of curium the evidence indicates that the III state is the only one that exists in aqueous solution, and its chemical properties are similar to those of the tripositive rare earths.

Of course in the meantime it has been possible to produce neptunium and plutonium in weighable amounts in the chain-reacting piles. The isotopes which have been produced in this manner are the neptunium isotope of mass 237 and the plutonium isotope of mass 239, the latter being the isotope which is so important in the atomic energy field. With these isotopes it has been possible, using the methods of ordinary chemistry, to greatly extend the knowledge of the chemical properties of these elements.

There are also a number of lighter elements which are now known to be extremely rare or nonexistent in nature, but whose chemical properties have nevertheless been rather well defined as the result of their production by artificial means and the investigation of their properties by the tracer technique. These are the elements with atomic numbers 43, 61, 85 and 87. Many experiments with these elements have been performed with unweighable amounts.

C. Perrier and E. Segrè were able to show in 1937 that the deuteron bombardment of molybdenum produces radioactive isotopes of element 43, and they used these to study the hitherto unknown chemical properties of this element. This is particularly interesting from an historical point of view because this is the first of the artificial elements to be discovered. Their experiments showed that the chemical properties resembled those of the heavier homolog, rhenium, to a much greater extent than they resembled those of manganese, the lighter homolog. They used rhenium as carrier for the radioactivity in order to show that element 43 is precipitated by hydrogen sulphide from alkaline or acid (less than 10 *N*) solution. They investigated other properties, including the volatility of the oxide and chloride and the conditions for the electrolytic deposition of the metal. R. P. Schuman and also D. C. Lincoln and W. H. Sullivan, working on the Plutonium project of the Manhattan District, independently observed the radioactivity (with long half-life) resulting from the lower isomeric state of 43^{99}, formed in the fission of uranium. This is interesting because it is possible now to isolate this isotope in weighable amounts. This particular isotope of element 43 was discovered by Segrè and Seaborg, who produced it from the deuteron and neutron bombardment of molybdenum and found that the upper isomeric state has a half-life of 6.6 hours and the lower isomeric state has a half-life of greater than 40 years. The discoverers, Perrier and Segrè, suggested the name "technetium," symbol Tc, for element 43.

A radioactive form of element 61 was positively identified in the experiments of J. A. Marinsky, L. E. Glendenin and others, on the Plutonium project of the Manhattan District, who found the isotopes, 61^{147} and 61^{149} with half-lives of about 3.7 years and 47 hours respectively, formed in the fission of uranium. This element is a rare earth and the chemical experiments on the tracer scale show that its behaviour is similar to that of the preceding element neodymium. Experiments involving selective adsorption and elution (removal by dissolution) on ion-exchange resins led to the unambiguous separation of the element from its neighbours. The availability of the isotope 61^{147} in large amounts from fission makes it now possible to isolate the missing element 61 in weighable amounts. Marinsky and Glendenin have suggested the name promethium, symbol Pm, for element 61 and this has a good chance to replace the previous name illinium.

The discovery of radioactive element 85 (isotope 85^{211}), from bismuth plus 32-Mev alpha-particles, by D. R. Corson, K. R. Mackenzie and Segrè, made it possible for these workers to investigate its properties. The general behaviour is that of a metal, with little resemblance to the other halogens. It is precipitated by hydrogen sulphide in 6 *N* hydrochloric acid solution with various carriers, and the sulphide is insoluble in ammonium sulphide. Volatility at comparatively low temperatures is observed; a piece of bombarded bismuth loses most of the activity before melting (275° C.). There is no precipitation upon the addition of silver nitrate to a dilute nitric acid solution using iodide as carrier. These investigators gave the name "astatine," symbol At, to this element.

A radioactive form of element 87 resulting from the alpha branching decay of actinium was discovered by M. Perey in France. This isotope, given the name AcK, has the mass 223 and decays by negative beta-particle emission with a half-life of about 21 minutes. The experiments of Perey showed that this element behaves as expected, like a heavy alkali metal; *e.g.*, it is carried by the compound caesium perchlorate. Perey gave the name "francium," symbol Fr, to this element.

Perhaps the most extensive application of the artificial radioelements in chemical work has been to the study of "exchange reactions." In exchange experiments the atoms of an element in one of its valence forms or types of chemical combination, are labelled by admixture with some radioactive isotope of the element which is the same form or chemical combination. To this system is added the element in another state of valence or form of combination, containing none of the radioactive isotope; the presence of radioactivity in this second chemical form, after it has been separated from the first, shows that an effective exchange of atoms between the two different states of the element has taken place. Experiments of this type give information on chemical bond types, the strength and reactivity of chemical bonds and the effect of solvents on these properties, the structure of ions and compounds, the mechanism of reactions and the mechanism of catalysis. In addition, exchange reactions often offer an excellent and convenient method for the introduction of radioactive atoms into compounds.

Although the subject of exchange reactions is too complicated to make accurate, complete generalizations possible, it seems profitable to make a few rough statements about homogeneous exchange reactions. If we consider exchanges of a given element between two sorts of molecules or ions in which it is held by electron-pair bonds to different numbers or kinds of other atoms, we may say in general that such exchange reactions do not proceed with appreciable rates except in those cases where there are reversible reactions which enable the exchanging atoms to reach equivalent states of chemical combination. For example, there is no exchange of atoms between phosphate and phosphite ions, sulphate and sulphite ions, sulphur and carbon disulphide, iodide ion and iodoform, etc. On the other hand, exchanges have been found between chloride and chlorate ion (caused by the oxidation-reduction equilibrium), between lead nitrate and lead chloride (an extreme example of the ionization exchange mechanism), and between iodide ion and iodine (through the formation of a symmetrical intermediate, I_3^-). When the two exchanging molecules differ only in their net charge, another exchange mechanism—the transfer of an electron from one to the other—may become possible. For example, exchanges have been observed between Fe^{++} and Fe^{+++} and between MnO_4^{--} and MnO_4^-. It is no doubt true that some exchanges occur through a simple transfer of atoms between molecules during a collision; such a mechanism is a special case of exchange through the formation of an intermediate. In many cases, the observation of exchanges of this sort suggests the existence of unstable intermediates which might not be known from other reaction studies.

Probably the most important isotope from the standpoint of future possibilities is the radioactive C^{14}. This isotope, discovered by S. Ruben and M. D. Kamen at the University of California, has a half-life of some thousands of years and therefore before the advent of the chain-reacting pile was practically unavailable because of the difficulty of its production in the large amounts needed to produce substantial radioactivities. However, the intense neutron source in the piles makes it possible now to produce this isotope in such quantity and high specific activity as to place it in a class along with the most available and suitable isotopes. It can be produced in either of two ways, the neutron

irradiation of carbon, preferably enriched C^{13}, by the reaction $C^{13}(n,\gamma)C^{14}$, or the neutron irradiation of nitrogen by the reaction $N^{14}(n,p)C^{14}$. Both of these reactions take place with slow neutrons. The reaction with nitrogen is of course preferable from the standpoint of producing C^{14} of the highest specific activity, it being in fact possible to produce isotopically pure C^{14} in this manner. The radiation is of relatively low energy, making it necessary for its detection to employ instruments designed with this in mind, and, in the investigations, to pay close attention to the self-absorption problem.

There is a whole vista of opportunity opened as a result of the availability of the C^{14} isotope. Organic chemists, biochemists, physiologists and men of medicine have dreamed for years of the day when a radioactive isotope of carbon suitable for tracer investigations should become available. A few of the possibilities which have opened through the availability of this isotope will be indicated below, but of course this field is so vast that it is certain that the best ideas are yet to come.

A great deal has been said in comparison of the potentialities of radioactive C^{14} and the separated stable C^{13} in these fields. Actually these isotopes complement each other and it is fortunate that both are available. There now exists the interesting possibility of tagging uniquely each of two different carbon atoms in a molecule or system and then *simultaneously* observing the course of each of these. Also the separated C^{13} makes possible the production of radioactive C^{14} of higher specific activity from the reaction $C^{13}(n,\gamma)C^{14}$.

Another isotope which has great potentialities is the radioactive H^3 which has a half-life of about 10 years. This isotope can be used in many of the ways indicated for the use of C^{14} if it is present in a molecule in a nonlabile position. The availability of the intense neutron sources makes it possible to produce this isotope in weighable amounts by means of the reaction $Li^6(n,\alpha)H^3$. The radiation consists of extremely low energy beta-particles and therefore its detection demands the use of special instruments, it being necessary to introduce the material in the form of a gas into the inside of the Geiger-Müller counter, ionization chamber or electroscope.

Besides radioactive C^{14} and H^3, such isotopes as the 14.3-day P^{32}, the 87.1-day S^{35}, the 180-day Ca^{45}, the 47-day Fe^{59}, the 250-day Zn^{65}, the 55-day Sr^{89}, the 8-day I^{131} and many others have offered and will offer many opportunities for important research.

The first and most obvious application in organic chemistry for C^{14} would be in an examination of the mechanisms of many isomerizations and rearrangements of organic molecules. There are a number of reactions in which carbon atoms or groups of carbon atoms move from one part of a molecule to another and the question of just how this migration is accomplished has been a subject for discussion among organic chemists for many years. By labelling the migrating groups in certain positions it should be possible to determine the precise sequence of events in such a reaction. In many types of rearrangements it is impossible to tell, by ordinary means, which carbon atoms are actually migrating. It is easy to see how a selective labelling of atoms would allow an unequivocal answer to these questions to be obtained.

This type of information is of interest not only for itself and the light it will throw upon the behaviour of organic substances, but it is a necessary preliminary to the synthesis of tagged compounds of biological interest and to the examination by degradation of metabolic products derived from administered labelled materials.

It is in this latter field of biochemistry that the carbon isotopes will have their greatest usefulness. The determination of the intermediary metabolism of the major structural and energy-transforming materials of living organisms such as fats, proteins and carbohydrates, as well as the catalytic or organizing substances such as vitamins, hormones and enzymes, will undoubtedly make great strides as a result of the availability of isotopic carbon and some of the other isotopes as well. Turning to biological systems there is a virtually unlimited field of important work for the organic chemist and workers in all branches of biology.

It is not out of the question that a complete understanding of the photosynthetic mechanism might give men the ability to synthesize food and fuel at will, using this principle. This could give rise to a literal harnessing of the sun's energy. With the aid of C^{14} this might be accomplished. A number of experiments have been performed with the 20.5-minute C^{11}, but this short half-life placed definite limits on the extent of progress which was possible. Nevertheless, Ruben, Kamen and W. Z. Hassid were able to use radioactive C^{11} in a study of photosynthesis in which considerable progress was made. Radioactive carbon dioxide was fed to the unicellular green alga *Chlorella* and also to higher plants under various controlled conditions in the light as well as in the dark. The results obtained by 1947 were quite interesting. The higher plants and the algae absorb carbon dioxide in the dark. This process takes place concurrently with the release of CO_2 by respiration, so that the net effect is an evolution of carbon dioxide. Only by the tracer technique was it possible to demonstrate a simultaneous uptake and evolution of carbon dioxide. The dark uptake of carbon dioxide is likely the first step in photosynthesis and can be represented by the equation $RH + CO_2 \rightleftharpoons RCOOH$. Decarboxylation experiments have shown that the bulk of the radioactive carbon is in the carboxyl group. Attempts to identify the radioactive substances formed in the dark and in the light had been unsuccessful up to 1947. It is of considerable interest to note that formaldehyde, which has played a prominent role in many proposed mechanisms, was not identified from the radioactive carbon dioxide introduced. Experiments with the ultracentrifuge and diffusion methods indicate the average molecular weight of the radioactive molecules to be about 1,000, which explains the failure to identify chemically these molecules with any small molecules.

The radioactive elements, in particular radioactive carbon, will of course receive widespread use in studying animal metabolism. Some examples may be used to illustrate in a general way the manner in which these elements may be used as an aid in the solution of such problems. Thus, in the highly intricate process of carbohydrate metabolism in man, present knowledge has been gained, for the most part, only as a result of painstaking analytical work by classical methods. In general these methods are not capable of high precision, and are not adapted for the determination of highly labile compounds. Thus it is quite likely that many important details of the process under investigation have not been revealed. Almost certainly, the use of radioactive tracers will bring these details to light. Aside from circumventing many analytical difficulties, the use of labelled elements can yield important information not possible by other methods. It is often the case in biological systems that reactions proceed under steady-state conditions. With radioactive tracers it is possible to follow the formation of a compound in the presence of a considerable amount of the previously synthesized compound or to measure synthesis while the net reaction constitutes breakdown. Such measurements will be of great value in determining the mechanisms of biological reactions. For example, B. Hastings and his collaborators at Harvard have used C^{11} in the study of glycogen formation in the liver, and have found that the incorporation of carbon dioxide into organic molecules takes place there. Many carbon dioxide incorporating reactions have been studied with C^{13} by H. G. Wood and C. H. Werkman. The present availability of C^{14} will make possible the elucidation of many mechanisms in the metabolism of carbohydrate and fat. Many biologists believe that artificial radioactivity has given biology and medicine what is probably the most useful tool for research after the discovery of the microscope because almost all of the elements and compounds in biological systems can be tagged and their course through living systems studied.

The most simple and direct use of an element as a tracer is accomplished by its administration as a simple inorganic compound, in which case the distribution of the tagged element in the various structures of the plant or animal is determined by measuring the radioactivity of the samples of tissues and body fluids. A large number of experiments of this type have been performed, principally to aid in the understanding of mineral metabolism. For example, the absorption of iron as related to anaemia has been studied by G. H. Whipple and P. F. Hann at the University of Rochester.

Radiophosphorus because of its availability has been the most widely

used of all the artificially prepared radioelements as a tracer for metabolic studies in biological systems. The distribution of administered phosphorus in human and animal tissues has been extensively studied. For example, it has been observed that the retention of a single dose of disodium phosphate varied in different tissues in the following decreasing order: bone, muscle, liver, stomach plus small intestines, blood, kidney, heart, lungs and brain. In other experiments there was found to occur a selective accumulation of radiophosphorus in leucaemic tissues. This was important in that it indicated that the leucaemic tissues could be subjected to a greater degree of beta-particle irradiation than would the normal tissues, which in turn indicated the application of radiophosphorus as a potentially valuable therapeutic agent.

The synthesis of the biologically important organic phospholipids has been studied by G. Hevesy and co-workers in Copenhagen, Denmark, and I. L. Chaikoff and co-workers in California. It is compounds like these that are now considered to be vital links in the complex low temperature oxidation mechanisms characteristic of living systems. Chaikoff and associates have shown the importance of the liver in such synthesis and transport; how the turnover of these substances through the liver can be altered by the administration of choline and certain amino acids and how newly synthesized molecules are absent altogether from the blood when the liver is removed. Using surviving tissue slices they have demonstrated the dependence of the synthesis upon the proper functioning of certain respiratory enzyme systems.

The first real insight into the mechanism of the action of insulin on carbohydrate metabolism has come from the studies of J. Sacks at Michigan with P^{32} on the effect of this hormone on the turnover of phosphorus compounds in muscle. All of these studies, of which only a few were mentioned, would have been impossible without the use of a labelling agent.

Extensive metabolic studies have been made with the use of radioactive iodine as an indicator. The pioneering work in this field was done by S. Hertz and his co-workers in Boston, Mass., and J. G. Hamilton and co-workers at California. The thyroid gland, through its synthesis of the iodine-containing hormone, thyroxine, controls the metabolic rate of the entire organism. Nevertheless, the quantities of iodine compounds produced and distributed are so small that even the finest micromethods are hardly adequate for the task of studying these processes. With the use of radioactive iodine the analytical difficulties can be largely overcome, and in addition, types of measurements can be made which are not possible from chemical analysis.

Among the measurements that have been made with radioactive iodine are the uptake of orally administered radioiodine by the intact thyroid glands of normal human subjects and by the thyroid glands of patients suffering from various types of thyroid disorder. The course of the uptake may be simply followed by placing a Geiger counter in the vicinity of the throat. The thyroids of patients with hypothyroidism were shown to accumulate iodine at a slow rate, while there was a relatively large uptake of administered iodine in the thyroid glands of patients with nontoxic goitres. In contrast to these behaviour patterns the thyroids of patients with hyperthyroidism were shown to take up administered radioiodine at a remarkably rapid rate, and also to discharge the iodine from the gland in a rapid fashion. It is seen from these studies of the behaviour pattern of the thyroid gland toward an administered dose of radioactive iodine that an aid toward diagnosing the condition of the thyroid gland is available.

A large amount of work on iodine metabolism has been done by Chaikoff, I. Perlman and M. E. Morton at the University of California. They were able to follow in some detail the distribution of organic iodine compounds from the thyroid gland through the blood to peripheral tissues in various states of thyroid activity. They were also able to demonstrate that, to a limited extent, tissues other than the thyroid gland are able to synthesize thyroxine; and by using isolated surviving tissues, they were again able to tie in the synthesis of an organic compound with the energy-producing enzyme systems.

B. C. Smith and E. H. Quimby at Columbia university have used the gamma radiations from intravenously injected $Na^{24}Cl$ to determine the rate of passage of sodium into the extracelluar phase of the tissues in cases of peripheral vascular disease, and thus determined the competency of the circulation, another example of use for diagnosis.

Many more possibilities for the use of radioactive isotopes in biochemical and physiological work might be suggested, but those given above suggest typical possibilities. Obviously, many of these problems are of profound significance in terms of human welfare.

The study of the mechanism of action of antibiotic substances, many of which act by means not completely understood at present, will be possible. For example, the synthesis of radioactive penicillin or streptomycin might give rise to a method for investigating the mechanisms by which these great substances operate. The mechanism of action of antibodies might also be investigated by the use of tracers.

Another possible use of tracers is, of course, in the study of cancer. Here, in addition to the possibilities cited in connection with the use of radioactive indicators in the investigation of mechanisms, there is the therapeutic possibility of effecting the selective deposition of the radioactive material in the cancerous tissue, as has been mentioned in the case of leucaemia. It has occurred to many investigators that it should be possible in the future to synthesize some compound containing a radioactive substance, this compound having the property of being selectively absorbed by the cancerous tissue so that the radioactive rays can act directly at this spot without giving harmful effects on the body's healthy tissue.

Another possibility is that of tagging bacteria with radioactive C^{14}. This does appear to be feasible and to open great possibilities in the study of disease. In fact, Chaikoff and A. Kaplan have made a beginning by tagging the tuberculosis bacillus with radioactive phosphorus.

The therapeutic uses of radioactive substances have already been mentioned and the application of radioactive I^{131} in the work of Hertz and of Hamilton and M. H. Soley, to the treatment of patients suffering from hyperthyroidism has been outlined. Another place where therapeutic value has been established is in the work of J. H. Lawrence and co-workers who have had some success in the application of radioactive P^{32} to the temporary control of the blood diseases, polycythaemia vera and leucaemia. A large number of other therapeutic uses will surely be found. It will be possible to apply alpha-particles, beta-particles and gamma-rays to this purpose and it is worth pointing out that all of these radiations are represented in isotopes which can be produced in quantity so that it is quite likely that the use of radium and its descendents in this type of therapy will soon be superseded by the artificial radioactive elements.

The present availability of the large quantities of radio-activities has opened the possibility of their use in industry and industrial processes. It will be possible to use radioactive indicators to follow the course of products and impurities in large industrial processes. Applications should be found in the testing of the efficiency of distillation apparatus, in testing for leaks, and in many other ways. The intense sources of gamma-rays will find application in the field of radiography to look for imperfections in metal products, to study the path of fast moving parts and other applications.

With respect to chemical problems of direct interest to industries, many examples could be cited. Among these may be mentioned studies, with C^{14}, of the mechanism of catalytic cracking, isomerization and alkylation of hydrocarbons which are of profound interest to the oil industry.

The future seems to hold unlimited possibilities for the application of radioactive tracers to scientific problems. It is certain that the applications of radioactive tracers which have been made so far are just the beginning of what is going to become an extremely large and successful field of research.

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RADIOACTIVITY, NATURAL. The subject of radioactivity deals with phenomena exhibited by a special class of elements of high atomic weight of which uranium, thorium, radium and actinium are the best known examples. These substances spontaneously emit radiations of a special character which are able to penetrate through matter opaque to ordinary light. The study of radioactive bodies has proved of great importance in the development of modern physics and has thrown a flood of light on the structure of the atom and the processes which may occur within it. It showed for the first time that the atoms of certain heavy elements are not permanently stable but break up with explosive violence and great emission of energy, leading to the production of a whole series of new elements which have a limited life. The disintegration of these atoms is accompanied by the expulsion of special types of radiation of great individual energy which have been of great service in throwing light on the processes which take place in their absorption by matter. For many years, until the development of the cyclotron (*q.v.*) in the hands of E. O. Lawrence, the alpha-particles were the most energetic particles readily available for experimental purposes. They proved invaluable for probing the inner structure of atoms; they were the means of first effecting the artificial disintegration of some of the common elements; and it was from the study of one of these artificial transmutations, that of beryllium, that the existence of the neutron was discovered. A study of the scattering of alpha-particles by matter first disclosed the nuclear structure of atoms and provided us with methods of determining the charge carried

by the nuclei of the elements. The examination of the chemical behaviour of the radioactive elements first indicated the isotopic constitution of certain elements, *i.e.*, the existence of elements with almost identical physical and chemical properties but yet with different atomic weights and radioactive properties. This has led to the proof of the isotopic constitution of the ordinary elements. The remarkable series of transformations occurring in uranium and thorium and the properties and effects of the radiations, especially of the alpha-particles, have provided information of great value on that most fundamental of all problems—the constitution of matter and the nature of the elementary particles of matter.

The beginning of radioactivity dates from 1896, and was an indirect consequence of the discovery of the X-rays made a few months before by W. Röntgen. It was known that the production of X-rays in a vacuum tube was accompanied by a strong phosphorescence of the glass, and it occurred to several investigators that ordinary substances made phosphorescent by visible light might emit a penetrating radiation similar to X-rays. Following out this idea, H. Becquerel, a distinguished French physicist, exposed among other substances a phosphorescent compound of uranium, uranium-potassium sulphate, enveloped in paper beneath a photographic plate. A weak photographic effect was obtained. This was shown to be caused by a penetrating radiation capable of passing through sheets of matter opaque to ordinary light. Further investigation showed that this photographic action was exhibited by all compounds of uranium and by the metal itself, and had nothing to do with phosphorescence. It was shown that if the uranium were kept in darkness its action did not vary appreciably with time. Becquerel showed that the rays from uranium like X-rays were capable of discharging a body whether positively or negatively electrified. A uranium compound brought close to the charged plate of a gold leaf electroscope causes a rapid collapse of the gold leaves. This property of uranium, and also of the radioactive bodies in general, has supplied a delicate and quantitative method of accurate comparison of the intensity of the radiations from substances under varying conditions. A modified form of gold leaf electroscope (*see* INSTRUMENTS, ELECTRICAL) has come into general use for comparison of the radioactivity of substances. Lord Rutherford made a systematic examination of the discharging effect produced by the rays from uranium and showed that it was caused by the production of charged carriers or ions in the volume of the gas through which the radiations pass. In an electric field, the positive ions travel to the negative electrode and vice versa, thus causing a discharge of the electrified body. If a sufficiently strong field is used, the ions are all swept to the electrodes before appreciable loss of their number can occur by recombination. The rate of discharge then reaches a steady maximum value which is not altered by a large increase in voltage. This maximum current through the gas is called the saturation current. The ions produced in gases by the rays from uranium and other radioactive substances are in general identical with those produced by X-rays, and the mechanism of conductivity of the gas is very similar in both cases (*see* ELECTRICITY, CONDUCTION OF: *Conduction in Gases*).

Some time after Becquerel's discovery, Mme. M. Curie made a systematic examination by the electric method of a large number of chemical elements and their compounds to test whether they possessed the "radioactive" property of uranium. Only one other element, thorium, was found to show this effect to a degree comparable with that of uranium—a result independently observed by G. C. Schmidt. Mme. Curie examined the activity of the various compounds of uranium and found that their radioactivity was an atomic property, *i.e.* the activity was proportional to the amount of the element uranium present, and was independent of its combination with other substances. In testing the activity of the minerals containing uranium, Mme. Curie found that the activity was always four to five times as great as that to be expected from their content of uranium. If the radioactivity were an atomic phenomenon, this could only be explained by the presence in these minerals of another substance more active than uranium itself. Relying on this hypothesis, Mme. Curie made a chemical examination of uranium minerals in order to try to separate this new radioactive substance. In these experiments, the Austrian government generously provided Mme. Curie with a ton of the residues from the state manufactory of uranium at Joachimsthal (Jáchymov), Bohemia. At that place there are extensive deposits of pitchblende or uraninite which are mined for the uranium. After separation of the latter, the residues are three to five times as radioactive weight for weight as the uranium. From this residue Mme. Curie separated a substance far more radioactive than uranium, which she called polonium in honour of the country of her birth. This substance is usually removed with bismuth in the mineral, but by special methods can be separated from it. A further examination revealed the presence of a second radioactive substance which is normally separated with the barium, to which the name "radium" was given. This name was happily chosen, for in the pure state radium bromide has a very great activity—about 2,000,000 times as great as an equal weight of uranium. By means of successive fractionations of the chloride, the radium was gradually concentrated, until finally the radium was obtained so that the barium lines showed very faintly. The atomic weight was found by Mme. Curie to be 226.45. Radium was found to give a characteristic spark spectrum of bright lines analogous in many respects to the spectra of the alkaline earths. F. O. Giesel in the early days took an active part in the preparation of pure radium compounds, and was the first to place preparations of pure radium bromide on the market. He found that the separation of radium from the barium mixed with it proceeded much more rapidly if the crystallizations were carried out using the bromide instead of the chloride. He stated that six to eight crystallizations are sufficient for an almost complete separation. From the chemical point of view radium possesses all the characteristic properties of a new element. It has a definite atomic weight, a well-marked and characteristic spectrum, and distinct chemical properties. Its comparative ease of separation and great activity have attracted much attention to this substance, although we shall see that similar radioactive properties are possessed by a large number of distinct substances.

In addition to polonium and radium, a number of other radioactive substances have been separated from uranium and thorium minerals which have an activity comparable with that of radium, although they have not been isolated in a pure state. Among these may be mentioned actinium, discovered by A. Debierne and Giesel, ionium, discovered by B. B. Boltwood and radiothorium and mesothorium discovered by O. Hahn.

Besides these substances in which the duration of the activity is measured by years a large number of radioactive bodies have been found which have a transient activity lasting for only a few minutes or hours. It will be seen that from the scientific point of view these short-lived radioactive substances are just as important as those which have a much longer life.

Emanations or Radioactive Gases.—In addition to their power of emitting penetrating radiations, the substances thorium, actinium and radium possess another striking and important property. Rutherford in 1900 showed that thorium compounds (especially the oxide) continuously emitted a radioactive emanation or gas. This emanation can be carried away by a current of air and its properties tested apart from the substance which produces it. These emanations all possess the property of ionizing a gas and, if sufficiently intense, of producing marked photographic and phosphorescent action. The activity of the radioactive gases is not permanent but disappears according to a definite law with the time, viz., the activity falls off in a geometric progression with the time. The emanations are distinguished by the different rates at which they lose their activity. The emanation of actinium is very short-lived, the time for the activity to fall to half value, *i.e.*, the period of the emanation, being 3.9 seconds. The period of the thorium emanation is 54.5 seconds and of the radium emanation 3.825 days. This property of emitting an emanation is shown in a striking manner by actinium. A compound of actinium is wrapped in a sheet of thin paper and laid on a screen of phosphorescent zinc sulphide. In a dark room the phosphorescence, marked by the characteristic scintillations, is seen to extend on all sides from the active body. A puff of air is seen to remove the emanation and

with it the greater part of the phosphorescence. Fresh emanation immediately diffuses out and the experiment may be repeated indefinitely. The emanations have all the properties of radioactive gases. They can be transferred from point to point by currents of air. The emanations can be separated from the air or other gas with which they are mixed by the action of extreme cold. Rutherford and F. Soddy showed that under ordinary conditions the temperature of condensation of the radium emanation mixed with air was −150° C.

The emanations are produced from the parent matter and escape into the air under some conditions. Rutherford and Soddy made a systematic examination of the emanating power of thorium compounds under different conditions. The hydroxide emanates most freely, while from thorium nitrate, practically none of the emanation escapes into the air. Most of the compounds of actinium emanate freely. Radium compounds, except in very thin films, retain most of the emanation in the compound. The occluded emanation can in all cases be released by solution or by heating. On account of its slow period of decay, the emanation of radium can be collected like a gas and stored, when it retains its characteristic properties for a month or more. A more detailed account of the properties of the radium emanation, which has proved of great practical importance, will be given later.

Active Deposits.—The radioactive emanations possess another interesting and important property. The surface of any body exposed in the presence of an emanation acquires a temporary activity. Like the emanations this *induced activity*, as it was first termed, decays with the time though at quite a different rate from the emanation which causes it. The bodies made active behave as if they were covered by a very thin film of intensely active matter. The active substance can be removed partly by rubbing of the surface and can be dissolved by strong acids. On evaporating the acid, the active matter remains behind unchanged in amount. The active deposit obtained on a platinum wire or plate can be volatilized at a white heat and is again deposited on the cooler bodies in its neighbourhood. The activity can be concentrated to some extent on the negative electrode in a strong electric field, indicating that the radioactive matter carries a positive charge. It will later be seen that this activity produced on bodies is caused by a deposit of nongaseous matter derived from the transformation of the emanations. Each emanation gives a distinctive active deposit which decays at different rates. The active deposits of radium, thorium and actininum are extremely complex, and consist of several types of matter. Several hours after removal from the emanation the active deposit from radium decays to half-value in 27 minutes, from actinium half-value in 36 minutes, from thorium half-value in 10.6 hours.

Radiations from Radioactive Substances.—All the radioactive substances possess in common the property of emitting radiations which darken a photographic plate and cause a discharge of electrified bodies. Very active preparations also possess the property of causing marked phosphorescence in some substances. Bodies which phosphoresce under X-rays usually do so under the rays from radioactive matter. Barium platinocyanide, the mineral willemite (zinc silicate) and zinc sulphide are the best-known examples.

There are in general three types of radiation emitted by the radioactive bodies, called the α-, β- and γ-rays. Rutherford in 1899 showed that the radiation from uranium was complex and consisted of (*a*) an easily absorbed radiation stopped by a sheet of paper or a few centimetres of air which he called the α-rays and (*b*) a far more penetrating radiation capable of passing through several millimetres of aluminum, called the β-rays. Later P. Villard found that radium emitted a very penetrating kind of radiation, called the γ-rays, capable of passing before absorption through 20 centimetres of iron and several centimetres of lead. A large amount of work, of which a more detailed account will be given later, has been carried out to determine the nature of these radiations.

The Alpha-rays.—The α-rays consist of a stream of material particles which are projected at high speed from the radioactive matter. The α-particles from all types of radioactive matter are identical in mass and consist of charged atoms of helium projected with velocities of about 10,000 mi. a second. The α-particles are expelled with a characteristic speed from each radioactive substance and have a definite distance of travel or "range" in matter before they are stopped. The range of the α-particles for different radioactive substances varies between about 3 cm. and 11 cm. in air at atmospheric pressure and temperature. Most of the energy emitted from radioactive bodies is in the form of α-rays.

The Beta-rays consist of a stream of electrons which are projected with high velocities, approaching in some cases that of light. Unlike the emission of α-particles, a radioactive body emits β-particles over a considerable range of velocity.

The Gamma-rays, which are of a very penetrating character, have been shown to be a type of X-rays of very high frequency. Usually the γ-rays accompany the emission of β-rays. Unlike the α- and β-particles, the γ-rays are undeflected by a magnetic or electric field. It will be shown that in general the γ-rays from a radioactive body consist of groups of electromagnetic radiations of widely different frequencies. The three types of radiation from active bodies are thus analogous in many respects to the radiations produced by the passing of an electric discharge through a vacuum tube at low pressure, but the individual intensity is on a much higher scale. In order to produce electrons of speed corresponding to those emitted by radium C, a voltage of 3,000,000 would have to be applied to the tube, and to excite X-rays of the frequency of the γ-rays at least 2,000,000 volts would be necessary. Similarly the energy of the α-particle from radium C corresponds to nearly 8,000,000 electron volts. The α-rays from a deposit of radium C equivalent in activity to ten milligrams of radium, are of great intensity; they blacken a photographic plate in a fraction of a second and produce intense luminosity in phosphorescent substances like zinc sulphide and willemite. Similarly the β- and γ-rays from such a source cause an evident luminosity in willemite and barium platinocyanide.

Theory of Radioactive Transformations.—It has been seen that the radioactive bodies spontaneously and continuously emit a great number of α- and β-particles. In addition, new types of radioactive matter like the emanations and active deposits appear, and these are quite distinct in chemical and physical properties from the parent matter. The radiating power is an atomic property, for it is unaffected by combination of the active element with inactive bodies, and is uninfluenced by the most powerful chemical and physical agencies at our command. In order to explain these results. Rutherford and Soddy in 1903 put forward a simple but comprehensive theory. Unlike the atoms of the ordinary elements the atoms of radioactive matter are unstable, and each second a definite fraction of the number of atoms present breaks up with explosive violence, expelling either an α- or β-particle with great velocity. Taking as a simple illustration that an α-particle is expelled during the explosion, the resulting atom has decreased in mass and possesses chemical and physical properties entirely distinct from the parent atom. A new type of matter has thus appeared as a result of the transformation. The atoms of this new matter are again unstable and break up in turn, the process of successive disintegration of the atom continuing through a number of distinct stages. On this view, a substance like the radium emanation is derived from the transformation of radium. The atoms of the emanation are far more unstable than the atoms of radium, and break up at a much quicker rate. We shall now consider the law of radioactive transformation according to this theory. It is experimentally observed that in all simple radioactive substances, the intensity of the radiation decreases in a geometrical progression with the time, *i.e.*, $I/I_0 = e^{-\lambda t}$ where I is the intensity of the radiation at any time, t, I_0 the initial intensity, and λ a constant. Now according to this theory, the intensity of the radiation is proportional to the number of atoms breaking up per second. From this it follows that the atoms of active matter present decrease in a geometrical progression with the time, *i.e.*, $N/N_0 = e^{-\lambda t}$ where N is the number of atoms present at a time, t, N_0 the initial number, and λ the same constant as before. Differentiating, we have $dN/dt = -\lambda N$, *i.e.*, λ represents the frac-

tion of the total number of atoms present which break up per second. The radioactive constant λ has a definite and characteristic value for each type of matter. Since λ is usually a small fraction, it is convenient to distinguish the products by stating the time required for half the matter to be transformed. This will be called the period of the product, and is numerically equal to $\log_e 2/\lambda$. The average life of the atoms of a product before transformation is given by $1/\lambda$. As far as our observation has gone, the law of radioactive change is applicable to all radioactive matter without exception. It appears to be an expression of the law of probability, for the average number breaking up per second is proportional to the number present. From this point of view, the number of atoms breaking up per second should have a certain average value, but the number from second to second should vary within certain limits according to the theory of probability. The theory of this effect was first put forward by E. Schweidler, and has since been verified by a number of experimenters, including K. W. F. Kohlrausch, St. Meyer, and E. Regener and H. Geiger. This variation in the number of atoms breaking up from moment to moment becomes marked with weak radioactive matter, where only a few atoms break up per second. The variations observed are in good agreement with those to be expected from the theory of probability. This effect does not in any way invalidate the law of radioactive change. On an average the number of atoms of any simple kind of matter breaking up per second is proportional to the number present. We shall now consider how the amount of radioactive matter which is supplied at a constant rate from a source varies with the time. For clearness, we shall take the case of the production of emanation by radium. The rate of transformation of radium is so slow compared with that of the emanation that we may assume without sensible error that the number of atoms of radium breaking up per second, *i.e.*, the supply of fresh emanation, is on the average constant over the interval required. Suppose that initially radium is completely freed from emanation. In consequence of the steady supply, the amount of emanation present increases, but not at a constant rate, for the emanation is in turn breaking up. Let q be the number of atoms of emanation produced by the radium per second and N the number present after an interval t, then $dN/dt=q-\lambda N$ where λ is the radioactive constant of the emanation. It is obvious that a steady state will ultimately be reached when the number of atoms of emanation supplied per second are on the average equal to the atoms which break up per second. If N_0 be the maximum number, $q=\lambda N_0$. Integrating the above equation, it follows that $N/N_0=1-e^{-\lambda t}$. If a curve be plotted (fig. 1) with N as ordinate and time as abscissa, it is seen that the recovery curve is complementary to the decay curve. The abscissae represent multiples of the time T for half the product to be transformed. The activity, which is proportional to the number of atoms present, falls to $\frac{1}{2}$ in the time T, $\frac{1}{4}$ in time $2T$, and so on.

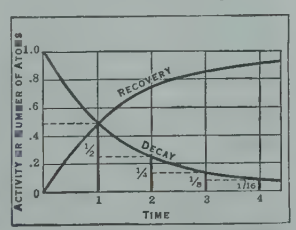


FIG. 1.—CURVES ILLUSTRATING THE EXPONENTIAL LAW OF DECAY AND RECOVERY OF RADIOACTIVITY

This process of production and disappearance of active matter holds for all the radioactive bodies. We shall now consider some special cases of the variation of the amount of active matter with time which have proved of great importance in the analysis of radioactive changes.

(*a*) Suppose that initially the matter A is present, and this changes into B and B into C, it is required to find the number of atoms P, Q and R of A, B and C present at any subsequent time t.

Let λ_1, λ_2, λ_3 be the constants of transformation of A, B and C respectively. Suppose n be the number of atoms of A initially present. From the law of radioactive change it follows:

$$P=ne^{-\lambda_1 t},$$

$$dQ/dt=\lambda_1 P-\lambda_2 Q, \qquad (1)$$

$$dR/dt=\lambda_2 Q-\lambda_3 R. \qquad (2)$$

Substituting the value of P in terms of n in (1),

$$dQ/dt=\lambda_1 ne^{-\lambda_1 t}-\lambda_2 Q;$$

the solution of which is of the form

$$Q=n(ae^{-\lambda_1 t}+be^{-\lambda_2 t}),$$

where a and b are constants. By substitution it is seen that $a=\lambda_1/(\lambda_2-\lambda_1)$. Since $Q=0$ when $t=0$, $b=-\lambda_1/(\lambda_2-\lambda_1)$.

Thus
$$Q=\frac{n\lambda_1}{\lambda_1-\lambda_2}(e^{-\lambda_2 t}-e^{-\lambda_1 t}). \qquad (3)$$

Similarly it can be shown that

$$R=n(ae^{-\lambda_1 t}+be^{-\lambda_2 t}+ce^{-\lambda_3 t}) \qquad (4)$$

where

$$a=\frac{\lambda_1\lambda_2}{(\lambda_1-\lambda_2)(\lambda_1-\lambda_3)},\quad b=\frac{\lambda_1\lambda_2}{(\lambda_2-\lambda_1)(\lambda_2-\lambda_3)},\quad c=\frac{\lambda_1\lambda_2}{(\lambda_3-\lambda_1)(\lambda_3-\lambda_2)}.$$

It will be seen from (3) that the value of Q, initially zero, increases to a maximum and then decays, finally, according to an exponential law, with the period of the more slowly transformed product, whether A or B.

(*b*) A primary source supplies the matter A at a constant rate, and the process has continued so long that the amounts of the products A, B, C have reached a steady limiting value. The primary source is then suddenly removed. It is required to find the amounts of A, B and C remaining at any subsequent time t.

In this case of equilibrium, the number n_0 of particles of A supplied per second from the source is equal to the number of particles which change into B per second, and also of B into C. This requires the relation

$$n_0=\lambda_1 P_0=\lambda_2 Q_0=\lambda_3 R_0$$

where P_0, Q_0, R_0 are the initial number of particles of A, B, C present, and λ_1, λ_2, λ_3 are their constants of transformation.

Using the same notation as in case (1), but remembering the new initial conditions, it can easily be shown that the number of particles P, Q and R of the matter A, B and C existing at the time t after removal are given by

$$P=\frac{n_0}{\lambda_1}e^{-\lambda_1 t},$$

$$Q=\frac{n_0}{\lambda_1-\lambda_2}\left(\frac{\lambda_1}{\lambda_2}e^{-\lambda_2 t}-e^{-\lambda_1 t}\right),$$

$$R=n_0(ae^{-\lambda_1 t}+be^{-\lambda_2 t}+ce^{-\lambda_3 t}),$$

where

$$a=\frac{\lambda_2}{(\lambda_1-\lambda_2)(\lambda_1-\lambda_3)},\quad b=\frac{-\lambda_1}{(\lambda_1-\lambda_2)(\lambda_2-\lambda_3)},\quad c=\frac{\lambda_1\lambda_2}{\lambda_3(\lambda_1-\lambda_3)(\lambda_2-\lambda_3)}.$$

The curves expressing the rate of variation of P, Q, R with time are in these cases very different from case (1).

(*c*) The matter A is supplied at a constant rate from a primary source. Required to find the number of particles of A, B and C present at any time t later, when initially A, B, and C were absent.

This is a converse case from case (2) and the solutions can be obtained from general considerations. Initially suppose A, B and C are in equilibrium with the primary source which supplied A at a constant rate. The source is then removed and the amounts of A, B and C vary according to the equation given in case (2). The source after removal continues to supply A at the same rate as before. Since initially the product A was in equilibrium with the source, and the radioactive processes are in no way changed by the removal of the source, it is clear that the amount of A present in the two parts in which the matter is distributed is unchanged. If P_1 be the amount of A produced by the source in the time t, and P the amount remaining in the part removed, then $P_1+P=P_0$ where P_0 is the equilibrium value. Thus

$$P_1/P_0=1-P/P_0.$$

The ratio P/P_0 can be written down from the solution given in case (2). Similarly the corresponding values of Q_1/Q_0, R_1/R_0 may be at once derived. It is obvious in these cases that the curve plotted with P/P_0 as ordinates and time as abscissae is complementary to the corresponding curve with P_1/P_0 as ordinates. This simple relation holds for all recovery and decay curves of radioactive products in general.

We have so far considered the variation in the number of atoms

of successive products with time when the periods of the products are known. In practice, the variation of the number of atoms is deduced from measurements of activity, usually made by the electric method. Using the same notation as before, the activity of any product is proportional to its rate of breaking up, *i.e.*, to $\lambda_1 P$ where P is the number of atoms present. If two products are present, the activity is the sum of two corresponding terms $\lambda_1 P$ and $\lambda_2 Q$. In practice, however, no two products emit α- or β-particles with the same velocity. The difference in ionizing power of a single α-particle from the two products has thus to be taken into account. If, under the experimental conditions, the ionization produced by an α-particle from the second product is K times that from the first product, the activity observed is proportional to $\lambda_1 P + K\lambda_2 Q$. In this way, it is possible to compare the theoretical activity curves of a mixture of products with those deduced experimentally.

Analysis of Radioactive Changes.—The analysis of the successive changes occurring in uranium, thorium, radium and actinium has proved a very difficult matter. In order to establish the existence of a new product and to fix its position in the scheme of changes, it is necessary to show (*a*) that the new product has a distinctive period of decay and shows some distinctive physical or chemical properties; (*b*) that the product under consideration arises directly from the product preceding it in the scheme of changes, and is transformed into the product succeeding it.

In general, it has been found that each product shows some distinctive chemical or physical behaviour which allows of its partial or complete separation from a mixture of other products. It must be remembered that in most cases the amount of radioactive matter under examination is too small to detect by weight, but its presence is inferred from its characteristic radiations and rate of change. In some cases, a separation may be effected by ordinary chemical methods; for example, thorium X is separated from thorium by precipitation of thorium with ammonia. The ThX remains in the filtrate and is practically free from thorium. In other cases, a separation is effected by a separation of a metal in the solution of active matter. For example, polonium (radium F) always comes down with bismuth and may be separated by placing a bismuth plate in a solution. Radium C is separated from radium B by adding nickel filings to a solution of the two. Radium C is deposited on the nickel. In other cases, a partial separation may be effected by electrolysis or by differences in volatility when heated. For example, when radium A, B and C are deposited on a platinum plate, on heating the plate, radium B is volatilized and is deposited on any cold surface in the neighbourhood. A very striking method of separating certain products has been observed depending upon the recoil of an atom which breaks up with the expulsion of an α-particle. Some of the residual atoms acquire sufficient velocity in consequence of the ejection of an α-particle to escape and be deposited on bodies in the neighbourhood. This is especially marked in a low vacuum. This property was independently investigated by Russ and Makower and by Hahn. The latter has shown that by means of the recoil, actinium C″ may be obtained pure from the active deposit containing actinium A, B and C, for C emits α-rays, and actinium C″ is driven from the plate by the recoil. In a similar way a new product, thorium C″, has been isolated and radium B may be separated from radium A and C. The recoil method has proved of great value in settling whether an α-ray product is simple or complex.

In the great majority of cases the radiation, whether alpha or beta, emitted by the radioelement is readily observed, but some were at first thought not to emit any characteristic radiation and were called "rayless products." Closer investigation has shown that in these cases also a radiation is emitted, a β-radiation so easily absorbed that its presence is difficult to detect. The most obdurate case was that of actinium, the radiation of which was not definitely established for many years, although its β-rays are not so feeble as those of some other products. It may be worth noting that the presence and properties of a product emitting a very feeble radiation can be readily inferred if it is transformed into a product emitting a marked radiation, for the variation of the latter affords a means of determining the amount of the parent product. In the table below a list is given of the remarkable series of transformations occurring in uranium, thorium and actinium. The system of nomenclature is not ideal. In general, products of average life greater than one year have been given a distinctive name and are printed in italics. The successive products following the emanations are in all cases denoted by the letters A, B, C, etc. In some cases intermediate products have been discovered after a system of nomenclature has been accepted and have had to be named to indicate as far as possible their positions in the series. As the radioactive emanations are now known to be isotopic elements, the names radon, thoron and actinon have been suggested as distinctive and indicative of the similarity of these products.

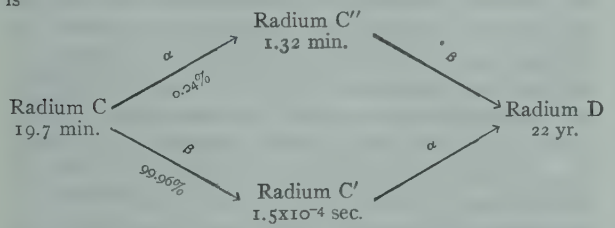
Table of Radioactive Elements

Radioactive Element	Mass No.	Atomic No.	T	Type of Change	Mean Range of α-Rays in Air (15° C. and 760 mm.)
Uranium-Radium series.					
Uranium I	238	92	4.51×10^9 yr.	α	2.65
Uranium X_1	234	90	24.5 days	β	..
Uranium X_2	234	91	1.14 min.	β	..
Uranium Z	234	91	6.7 hr.	β	..
Uranium II	234	92	2.33×10^6 yr.	α	3.21
Ionium	230	90	8.3×10^4 yr.	α	3.16
Radium	226	88	1,590 yr.	α	3.26
Radon (Ra emanation)	222	86	3.825 days	α	4.05
Radium A	218	84	3.05 min.	α	4.66
Radium B	214	82	26.8 min.	β	..
Radium C	214	83	19.7 min.	α, β	4.08
Radium C′	214	84	1.5×10^{-4} sec.	α	6.91
Radium C″	210	81	1.32 min.	β	..
Radium D	210	82	22 yr.	β	..
Radium E	210	83	5.0 days	β	..
Radium F. (Polonium)	210	84	140 days	α	3.84
Radium G (end product uranium-lead)	206	82	..	..	..
Thorium series.					
Thorium	232	90	1.39×10^{10} yr.	α	2.68
Mesothorium I.	228	88	6.7 yr.	β	..
Mesothorium 2	228	89	6.13 hr.	β	..
Radiothorium	228	90	1.90 yr.	α	4.00
Thorium X	224	88	3.64 days	α	4.39
Thoron (Th emanation)	220	86	54.5 sec.	α	5.00
Thorium A	216	84	0.158 sec.	α	5.64
Thorium B	212	82	10.6 hr.	β	..
Thorium C	212	83	60.5 min.	α, β	4.73
Thorium C′	212	84	*c.* 3×10^{-7} sec.	α	8.57
Thorium C″	208	81	3.1 min.	β	..
Thorium D (end product thorium-lead)	208	82	..	..	..
Actinium series.					
Actinouranium	235	92	*c.* 7×10^8 yr.	α	2.90
Uranium Y	231	90	24.6 hr.	β	..
Protoactinium	231	91	3.2×10^4 yr.	α	3.62
Actinium	227	89	13.5 yr.	α, β	3.5
Actinium K	223	87	21 min.	β	..
Radioactinium.	227	90	18.9 days	α	4.68
Actinium X	223	88	11.2 days	α	4.37
Actinon (Ac emanation)	219	86	3.92 sec.	α	5.69
Actinium A	215	84	1.83×10^{-3} sec.	α	6.46
Actinium B	211	82	36.1 min.	β	..
Actinium C	211	83	2.16 min.	α, β	5.43
Actinium C′	211	84	5×10^{-3} sec.	α	6.56
Actinium C″	207	81	4.76 min.	β	..
Actinium D (end product actinium-lead)	207	82	..	..	..

In this table, T is the "half-life period" of the product or the time required for the product to be half-transformed. It will be seen that the value of T, which is a measure of the relative stability of atoms, varies between 1.39×10^{10} years (thorium) and *c.* 3×10^{-7} second (thorium C′). The atomic weights of uranium, radium, uranium-lead, thorium, thorium-lead, protoactinium have been directly determined by chemical methods and the atomic numbers of all except protoactinium have been determined by X-ray methods. The mass numbers and atomic numbers of the others are deduced on the assumption that the expulsion of an α-particle (helium nucleus) reduces the atomic number of the element by two units and the mass number by four units. The expulsion of a β-particle raises the atomic number by one unit, but does not change the mass number.

Branch Products.—In the great majority of cases each of the radioactive elements breaks up in one definite way, each atom giving rise to one α-particle or to one β-particle and to one atom of the new product. Clear evidence, however, has been obtained that in a few cases the atoms break up in either of two alternate ways; they may emit either an α-particle or a β-particle. The two substances thus produced then transform in such a way as to give a common product.

The most striking cases of branching occur in the "C" products of radium, thorium and actinium, each of which breaks up in two distinct ways. In the radium series, the scheme of transformation is



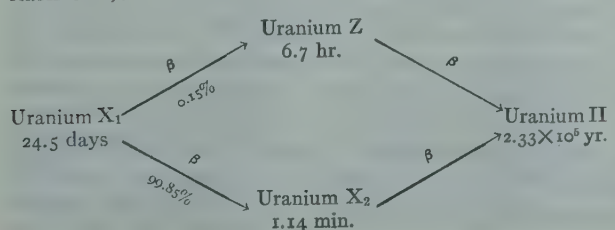
where the main branch is by way of a β-disintegration to radium C′, which emits an α-particle and changes to radium D. Only 0.04% of the radium C atoms emit an α-particle, forming radium C″ which emits a β-particle. Radium C′ has an exceedingly short period of transformation, which was first measured approximately by J. C. Jacobsen.

In the case of thorium C, two sets of α-particles were early observed, one third of the total number having a range of 4.8 cm. and the main group 8.6 cm. Here, as in radium C, the main branch proceeds by a β-ray change to the C′ product, which has an even shorter period than radium C′.

In the actinium series, the predominant (99.7%) process is by an α-change to the C″ product, only 0.3% taking the β-change route to actinium C′.

One case of branching is of special interest as it differs from all others. This occurs in uranium X_1 which transforms by a β-change mainly into uranium X_2, but which was shown by Hahn also to give rise, in a small fraction of the transformations, to a different product uranium Z.

As uranium X_2 and uranium Z arise from the same substance by the same type of change they must have not only the same atomic number but also the same mass number; their nuclei contain the same particles but in different configuration. This was the first case of *nuclear isomerism,* but several are now known to occur among the artificial radioelements (*see* RADIOACTIVITY, ARTIFICIAL). The scheme of transformations is



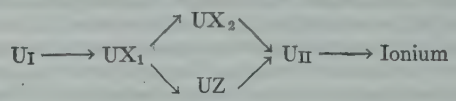
Chemistry of the Radioelements (*see* RADIUM; URANIUM; etc.).—Apart from uranium and thorium, and a few special cases like radium and polonium, the radioactive products of short life exist in too small quantity to examine by the ordinary chemical methods; but by the use of the radioactive method of analysis, it was possible to form some idea of their chemical behaviour. Certain interesting points soon came to light. Soddy found that the two elements, radium and mesothorium, although quite dissimilar in radioactive properties, were chemically so identical that it was impossible by chemical methods to separate one from the other. Other cases of this kind had long been suspected, viz., thorium and radiothorium, thorium and ionium and radium D and lead. He named such inseparable elements isotopes, since they appeared to occupy the same place in the periodic classification of the elements. (*See* ISOTOPES.)

Following the chemical study of the radioelements by Soddy, A. Fleck and G. Hevesy, an important generalization connecting the chemical properties of the radioelements was announced independently in 1913 by A. S. Russell, K. Fajans and Soddy. After the expulsion of an α-particle from a radioactive substance, the resulting product shifts two places in the direction of diminishing mass when the elements are arranged in families according to the Mendeléyev classification. The expulsion of a β-particle causes a shift of one place in the opposite direction. For example, by the loss of an α-particle from ionium of group IV, the resulting product, radium, belongs to group II, while the loss of another α-particle gives rise to the emanation which occupies the group O, and so on. These "displacement laws" received a simple explanation when viewed in another way. From the work of H. G. J. Moseley, the properties of an element are defined by the atomic number (*q.v.*), which represents the resultant positive charge of the nucleus. The loss of an α-particle of mass 4, carrying two positive charges, lowers the atomic number by two units, while the emission of a β-particle raises it by one unit. Thus, once the atomic number and the mass number of one element of a radioactive series have been determined, these quantities can be deduced for all other members of the series from a knowledge of the radiations emitted in the transformations. It is instructive to arrange the members of the different radioactive series as in figs. 2–4 where the atomic numbers are plotted as abscissae and the mass numbers as ordinates. It will be seen that the three series exhibit a remarkable similarity after the three bodies of atomic number 88, viz., radium, thorium X and actinium X.

The atoms of the three series have atomic numbers which lie between 81 and 92. All elements with atomic numbers from 84 to 92 are radioactive, while the ordinary stable elements thallium, lead and bismuth have atomic numbers 81, 82 and 83 respectively, so that several of the radioactive products are isotopes of common elements. Several products are isotopic with one another and these are often indicated by corresponding names; thus all the A-products and C′-products are isotopes of polonium; the C-products are isotopes of bismuth; the B-products of lead; and the C″-products of thallium. The isotopes of lead are of special interest as they include the stable end products of the three series —a question which will be discussed more fully later.

Transformation of Uranium.—In 1900 the late Sir W. Crookes found that the β-ray activity of ordinary uranium could be removed by a single chemical operation and concentrated in an active residue. This is caused by the separation of the product uranium X_1, of period 24.5 days, which emits β-rays and γ-rays. A complete analysis of the transformations of uranium has been a matter of much difficulty. Boltwood showed that the α-ray activity of uranium was about twice as great as that of a corresponding α-ray product in the uranium-radium series, indicating that uranium contained two successive α-ray products. This was confirmed by Geiger, who showed that the α-rays from uranium consist of two groups, equal in number, but with ranges of roughly 2.8 cm. and 3 cm. These two α-ray substances, called uranium I and uranium II, are isotopic, with mass numbers 238 and 234 respectively. Following the generalization connecting the radiations and chemical properties of the series of radioelements, Fajans predicted the presence of a new product with properties analogous to

tantalum, and promptly succeeded in isolating it experimentally. This product uranium X_2 has a period of 1.14 min. and emits swift β-rays. Some years later Hahn found a product uranium Z, which he showed to arise from uranium X_1, also by a β-change as does uranium X_2. The position of uranium Z in the series was unclear for some time but it is now recognized that uranium X_2 and uranium Z are nuclear isomers. The series of changes is thus:—



The growth of uranium II from uranium X_1 has been observed by C. H. Collie.

Another β-ray substance arising in the transformations of uranium was discovered by G. N. Antonoff. This substance, uranium Y, of period 24.6 hr., has the same chemical properties as uranium X_1. Its amount is only a few per cent of the equilibrium amount of uranium X_1 so that it can not be in the main line of succession. For some time it was regarded as a branch product, probably of uranium II, and it was believed to be the starting point of the subsidiary actinium series. It is now clear that uranium Y is the product of the α-change of the uranium isotope of mass 235, which is to be regarded as the parent of the actinium series.

The mass-spectrographic analysis of uranium has been carried out by A. O. Nier. There are three isotopes, mass numbers 238, 235 and 234. The U^{238}/U^{235} ratio is 139, and the U^{238}/U^{234} ratio about 17,000. From these results, and using a measurement of the number of α-particles emitted by 1 gram of uranium per sec. (2.50×10^4), Nier calculated the period of uranium I (U^{238}) to be 4.56×10^9 years, and that of uranium II (U^{234}) to be 2.7×10^5 years. The latest values of these periods which are slightly different from Nier's, are given in the table on radioactive elements on p. 896D.

Transformation of Radium.—Radium is transformed directly into radon which in turn goes through a rapid series of transformations called radium A, B and C. The complete analysis of these changes has involved a large amount of work. Radon changes first into radium A, a substance of period 3 minutes emitting only α-rays. Radium A changes into radium B, a product of period 27 minutes emitting β-rays of penetrating power small compared with those emitted from the next product radium C. The products included under the title radium C have proved of considerable importance, for they not only emit very penetrating α-rays and β-rays, but are the origin of most of the γ-rays arising from radium in equilibrium. We have already seen that radium C breaks up in a complex way. When a wire charged negatively has been exposed for some time in the presence of radon, it becomes coated with an invisible film of radium A, B and C. After removal from radon for 20 minutes, radium A has practically disappeared and the α-rays arise entirely from radium C. Radium C has proved very valuable in radioactive measurements as providing an intense source of homogeneous α-rays. Twenty-four hours after removal, the activity caused by radium B and C has become exceedingly small. There still remains, however, a very small residual activity, first noted by Mme. M. Curie. This residual activity measured by the α-rays rapidly increases with the time and reaches a maximum in about three years. The active deposit of slow change was examined in detail by Rutherford and by Meyer and Schweidler. It was shown to consist of three successive products called radium D, E and F. Radium D emits slow β-rays and is half transformed in about 22 years. Radium D changes into E, a β-ray product of period 5 days, and E into F, an α-ray product of period 140 days. The product radium F is of special interest, for it is identical with polonium—the first active body separated by Mme. Curie. In a similar way it has been shown that radium D is the primary source of the activity observed in lead or "radiolead" separated by K. A. Hoffmann. Radium D is a radioactive isotope of lead of atomic weight 210. It is always separated with the inactive lead present in a uranium mineral. It is interesting to note what valuable results have been obtained from an examination of the minute residual activity observed on bodies exposed in the presence of radon. On account of their special importance as sources of intense radiation a more detailed account will be given of radium and its origin, of radon and polonium.

Radium.—The amount of radium in an unaltered primary uranium mineral is always proportional to the content of uranium in the ratio of 3.4 parts of radium by weight to 10,000,000 parts of uranium. Its extraction is a tedious task but it is not disturbed by the presence of any isotope of radium. Since the chemical properties of radium are closely related to those of barium, the radium is normally separated with the barium from the other constituents of the mineral. It can then be completely purified from barium by fractional crystallization of the chloride or of the bromide. In this way, Mme. Curie first obtained preparations of pure radium salts, and determined the atomic weight of radium to be 226.45. More recent determinations by O. Hönigschmid have given an atomic weight 226.05. Mme. Curie and Debierne isolated metallic radium by electrolysis of the fused salt, using a mercury cathode. The metal resembles metallic barium, being white in colour and tarnishing rapidly on exposure to the air. It melts at about 700° C. The chemical properties of radium and its compounds have been studied by the usual methods. All the evidence, whether from its spectrum or from the solubility of its salts, etc., shows it to be a higher homologue of barium.

In general, the salts of radium are available in quantities of only a few milligrams, possibly mixed with barium. It is therefore most convenient to measure the amount of radium by radioactive methods, for then, in contrast to the method of weighing, the purity of the radium salt is not significant. The unknown preparation is compared with a radium salt of known radium content which has been standardized directly or indirectly by means of the international radium standards. When the amount of radium present is not less than $\frac{1}{100}$ mg. the intensity of the γ-radiation (emitted by the active deposit and mainly by radium C) is used as the basis of measurement. The tube containing the radium is placed at a suitable distance from an electroscope which is surrounded by a lead screen at least 3 mm. thick. The effect in the electroscope is then caused only by the penetrating γ-radiation. By comparison of the rate of discharge with that caused by a known amount of radium at the same distance, the quantity of radium in the unknown preparation can at once be deduced, provided the radium is in equilibrium. This is usually the case if the radium preparation is one month old. This method is simple and direct, and has the great advantage that the radium can be tested in a sealed-off glass or metal tube, the usual mode of packing. For very weak preparations of radium, use is made of the property of producing an emanation to provide an exceedingly delicate method, not only of detection but of estimation of quantities of radium. The preparation is generally brought into solution and the radon, when in equilibrium with the amount of radium present, is driven by boiling into a suitable electroscope. The rate of discharge of the electroscope caused by the radon gives a quantitative measure of the amount of radium in solution. The electroscope is calibrated by using known quantities of radon. With this method quantities of radium as small as 10^{-12} g. can be measured to within a few per cent. This emanation method has been employed with great success in measuring the quantity of radium in minerals and in rocks.

In 1912 a preparation consisting of 21.99 mg. of pure radium chloride, sealed up in a thin glass tube, was adopted as the international radium standard and deposited in the Bureau International des Poids et Mesures at Sèvres, near Paris. At the same time a preparation made by Hönigschmid was adopted as a secondary standard and preserved in Vienna. Arrangements were made for the issue of duplicate standards to all governments who wished to purchase them. These duplicates were prepared in the Radium Institute of Vienna, and compared by the γ-ray method with the official secondary standard in Vienna and with the international standard in Paris. Later, two further standards were prepared by Hönigschmid from the purest radium chloride, free from any detectable trace of barium. One of these was deposited at Sèvres, and the other is kept in the Vienna Radium institute. The purchase and sale of radium are generally conducted on the

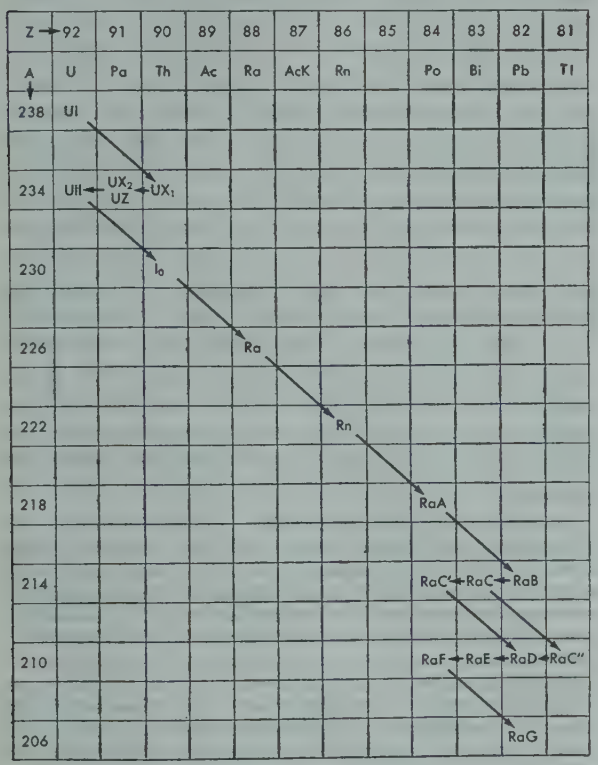
basis of certificates given in terms of the international standard.

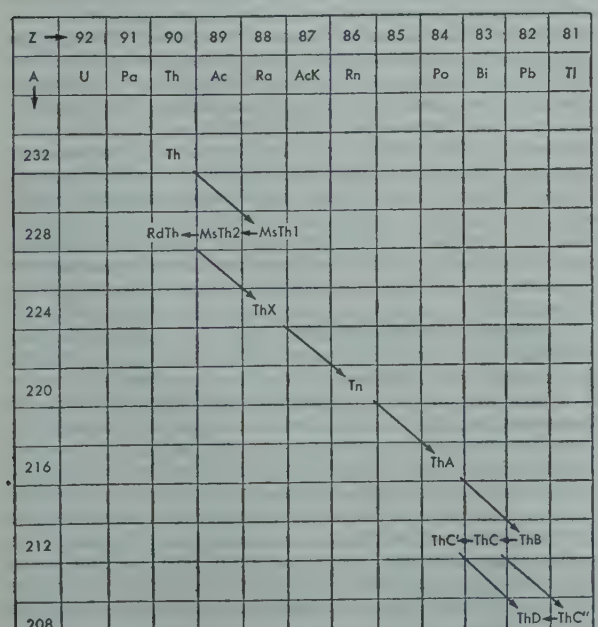
One of the most important constants of radioactivity is the number of α-particles emitted per second from one gram of radium, and many attempts have been made to determine it with accuracy. The earliest measurement was that of Rutherford and Geiger (1908) who found a value of 3.57×10^{10}, but the number now generally accepted is 3.70×10^{10}. This value is for one gram of radium free from its disintegration products; when the radium is in equilibrium with the short-lived active deposit, the number is four times as large. This number is in good agreement with the heating effect of radium and its products, and with the rate of production of helium by radium.

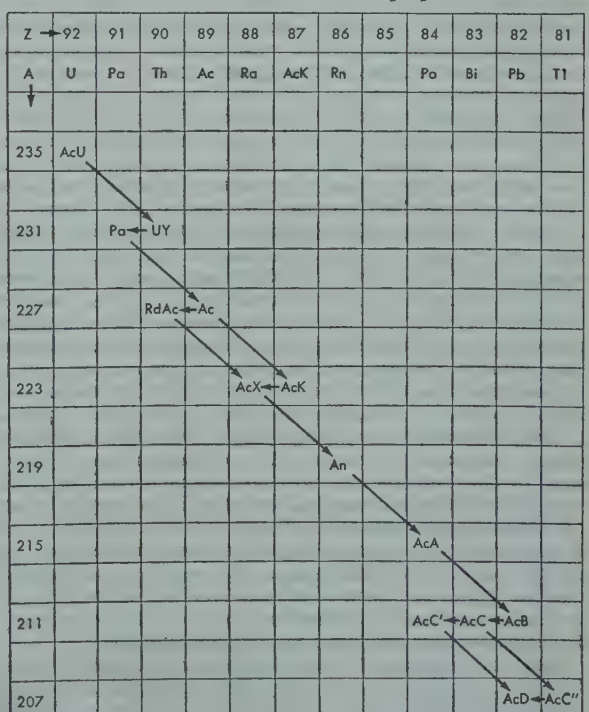
The wide use of radium for therapeutic purposes and its high cost, which has varied from £4 to as much as £30 per mg., have led to close search for uranium deposits. The most important uranium deposits in Europe are those of Joachimsthal (Jáchymov) in the Erzgebirge, originally under the control of the Austrian government. The production of this pitchblende mine has amounted to some three or four grams of radium per annum. In the early years of radioactivity, some of the radium was generously lent by the Austrian government to representative workers in England. A part of the radium obtained in those days was in charge of the Radium Institute of Vienna, which is specially devoted to radioactive investigations.

The increasing demand for radium led to the working of low grade ores, containing on an average only about 2% of uranium oxide, of which there are extensive deposits in Colorado. From about 1915 until 1922 the greater part of the world supply of radium was produced in America, but in the latter year very rich deposits of pitchblende were found at Katanga in the Belgian Congo. As these deposits were developed, the American and Joachimsthal production practically ceased and the Belgian producers obtained a virtual monopoly. This monopoly came to an end after the discovery in 1930 of an extensive occurrence of pitchblende on the shores of the Great Bear lake, Northwest Territories, Canada. The Belgian Congo and Canada now share the world market for radium. The total production by 1939 probably amounted to more than 1,000 g.

During World Wars I and II large quantities of radium were used for gun sights, night compasses, instrument dials, etc. The radium is mixed with phosphorescent zinc sulphide to form a paint which becomes continuously luminous but, owing to the destruction of the zinc sulphide by the rays, this luminosity gradually decays. Active preparations of mesothorium and radiothorium have also been used for a similar purpose.


Z → 92 91 90 89 88 87 86 85 84 83 82 81
A ↓ U Pa Th Ac Ra AcK Rn Po Bi Pb Tl
238 UI
234 UII ← UX2 UZ ← UX1
230 Io
226 Ra
222 Rn
218 RaA
214 RaC' ← RaC ← RaB
210 RaF ← RaE ← RaD ← RaC''
206 RaG


Z → 92 91 90 89 88 87 86 85 84 83 82 81
A ↓ U Pa Th Ac Ra AcK Rn Po Bi Pb Tl
232 Th
228 RdTh ← MsTh2 ← MsTh1
224 ThX
220 Tn
216 ThA
212 ThC' ← ThC ← ThB
208 ThD ← ThC''


Z → 92 91 90 89 88 87 86 85 84 83 82 81
A ↓ U Pa Th Ac Ra AcK Rn Po Bi Pb Tl
235 AcU
231 Pa ← UY
227 RdAc ← Ac
223 AcX ← AcK
219 An
215 AcA
211 AcC' ← AcC ← AcB
207 AcD ← AcC''

FIGS. 2-4.—IT IS INSTRUCTIVE TO ARRANGE THE NUMBERS OF THE DIFFERENT RADIOACTIVE SERIES AS IN THESE FIGURES, WHERE THE ATOMIC NUMBERS ARE PLOTTED AS ABSCISSAE AND THE MASS NUMBERS AS ORDINATES. IT WILL BE SEEN THAT THE THREE SERIES EXHIBIT A REMARKABLE SIMILARITY AFTER THE THREE BODIES OF ATOMIC NUMBER 88, VIZ., RADIUM, THORIUM X AND ACTINIUM X

Origin of Radium.—According to the transformation theory, radium, like all other radioactive products, must be regarded as a changing element. Preliminary calculations showed that radium must have a period of transformation of a few thousand years. Consequently in order that any radium could exist in old minerals, the supply must be kept up by the transformation of some other substance. Since radium is always found associated with uranium minerals, it seemed probable from the beginning that uranium must be the primary element from which radium is derived. If this were the case, in old minerals which have not been altered by the action of percolating waters, the ratio of the amount of radium to uranium in a mineral must be a constant. This must evidently be the case, for in a state of equilibrium the rate of breaking up of radium must equal the rate of supply of radium for uranium. If P, Q be the number of atoms of uranium and radium respectively in equilibrium, and λ_1, λ_2 their constants of change, then

$$\lambda_2 Q = \lambda_1 P \quad \text{or} \quad Q/P = \lambda_1/\lambda_2 = T_1/T_2$$

where T_2 and T_1 are the half-periods of transformation of uranium and radium respectively. The work of Boltwood, Strutt and H. N. McCoy showed conclusively that the ratio of radium to uranium in old minerals is a constant. In order, however, to obtain a direct proof of the genetic relation between uranium and radium, it is necessary to show that radium appears after some time in a uranium compound from which all trace of radium has been initially removed. It can readily be calculated that the growth of radium should be easily observed by the emanation method in the course of one week, using a kilogram of uranium nitrate. Experiments of this kind were first made by Soddy, but initially no definite evidence was obtained that radium grew in the solution at all. The rate of production of radium, if it took place at all, was certainly less than $\frac{1}{10,000}$ part of the amount to be expected if uranium were transformed directly into radium. It thus appeared probable that another product of slow period of transformation existed between uranium and radium. Since uranium must be transformed through this intermediate stage before radium appears, it is evident that the initial rate of production of radium under these conditions might be extremely small. This conclusion has been confirmed by Soddy, who has shown that radium does ultimately appear in the solution which has been placed aside for several years and as theory predicts the amount increases as the square of the time.

Since the direct parent of radium must be present in radioactive minerals, one of the constituents separated from the mineral must grow radium. This was shown to be the case by Boltwood who found that actinium preparations produced radium at a fairly rapid rate. By the work of Rutherford and Boltwood, it was found that the growth of radium was not caused by actinium itself, but by a new substance separated in some cases with the actinium. This new substance, which emits α-rays, was separated by Boltwood and called by him "Ionium." It has chemical properties very similar to thorium and as we now know is an isotope of thorium of atomic weight 230. Ionium is always separated mixed with the thorium which is present in the mineral.

It has been shown directly that uranium produces ionium, and from the activity of the ionium grown in a known time the period has been estimated to be 83,000 years. Since ionium produces radium, the period of transformation of radium can be determined by direct experiment, and Boltwood, and later Ellen Gleditsch, obtained results in good agreement with the accepted value.

Polonium and Radium D.—Polonium (radium F) has proved of much importance in experimental work as a source of α-rays entirely free from β- and γ-rays. The weight of polonium in equilibrium with one gram of radium is only about one-fifth of a milligram, so that it is difficult to obtain a sufficient quantity of this material for an atomic weight determination.

Mme. Curie separated the polonium from several tons of pitchblende and obtained an exceedingly active preparation of a few milligrams, but was unable to obtain it in a pure state, although several of its spectrum lines were detected. It was hoped by this experiment to decide whether polonium was transformed directly into lead, but this was found difficult to establish owing to the presence of impurities with the very small quantity of polonium. The most convenient source for obtaining strong sources of polonium is the radium D+E+F which accumulates in old radium preparations. These substances can be separated from the radium solution by chemical or electrolytic methods. A solution of the radium D thus obtained grows polonium and is thus a convenient source for obtaining active plates coated with polonium. In this way, also, strong sources of radium D and radium E are obtainable.

Radon (*Radium Emanation*).—Radon is to be regarded as a typical radioactive product or transition element which exists in a gaseous form. It is produced from radium at a constant rate, and is transformed into radium A and helium. Its half-period of transformation is 3.825 days. Radon has been purified by condensing it in liquid air, and pumping out the residual gases. The volume of radon at normal pressure and temperature to be derived from one gram of radium in equilibrium is 0.65 cubic millimetres. This small quantity of gas contains initially more than three-quarters of the total activity of the radium before its separation. In a pure state, radon is 100,000 times as active weight for weight as pure radium. Pure radon in a spectrum tube gives a characteristic spectrum of bright lines. The discharge in the gas is bluish in colour. Notwithstanding the minute volume of radon available, its boiling-point has been determined at various pressures. At atmospheric pressure its boiling point has the value $-62°$ C., its freezing point $-71°$ C.; its critical temperature is $+105°$ C. Liquid radon appears colourless when first condensed; when the temperature is lowered, the liquid freezes, and at the temperature of liquid air glows with a bright rose colour. The density of liquid radon has been estimated at 5 or 6.

Since the radium atom in breaking up gives rise to one atom of radon and one atom of helium, the atomic weight of radon should be $226-4=222$. Radon appears to have no definite chemical properties, and in this respect belongs to the group of inert monatomic gases of which helium and argon are the best-known examples. It is partially soluble in water, and readily absorbed by charcoal.

Radon has proved of great service not only in radioactive researches but also in therapeutic work. The radium salt is dissolved in an acid solution and the emanation is pumped off with the large quantity of hydrogen and oxygen liberated by the action of the radiations on water. After sparking the mixture, the radon can be purified by condensation with liquid air. An intense source of β- and γ-radiation can be obtained by introducing the purified radon into fine capillary tubes. Such radon needles have been widely used for therapeutic purposes, while the use of thin-walled tubes provides a powerful line source of α-rays. The β- and γ-activity of such tubes rises to a maximum about four hours after introduction of the radon, and then decays with the period of radon, viz., 3.825 days. The quantity of radon liberated from one gram of radium is called a *curie* and from one milligram a *millicurie*. The quantity of radon in a tube can be accurately determined by comparison of its γ-ray activity with that of a radium standard, since the penetrating γ-rays, both from the radium and the radon in equilibrium, arise mainly from the same product radium C.

Transformations of Thorium.—The first product observed in thorium (*q.v.*) was the emanation of period 54.5 sec., and this gives rise to the active deposit, which has been shown to consist of at least four successive products called thorium A, B, C, C″. The emanation, after the emission of an α-particle, changes into a product of short life emitting α-rays. Its period was found by Geiger and Moseley to be about $\frac{1}{10}$ sec. The succeeding product, thorium B, emits only weak β- and γ-rays with a period of 10.6 hr., changing into thorium C of period 60.5 min. We have seen that thorium C breaks up in a complex way. Thorium C″ is readily separated from C by the method of recoil. It emits penetrating β- and γ-rays with a half period of 3.1 min. The active deposit as a whole decays ultimately with the period of thorium B, viz., 10.6 hr.

A special interest attaches to the product thorium X, first separated by Rutherford and Soddy, since experiments with it

laid the foundation of the general theory of radioactive transformations.

A close analysis of thorium has led to the discovery by Hahn of a number of other important products. When the thorium X is separated from a thorium mineral or old thorium preparation, there appears with it another product called mesothorium I, of period 6.7 years, which is transformed with the emission of weak β-rays into mesothorium 2, of period 6.13 hours, which emits swift β-particles and penetrating γ-rays. This changes into an α-ray product, radiothorium, of period 1.90 years, which is transformed into thorium X.

Radiothorium is an isotope of thorium, while mesothorium I is an isotope of radium. The radiothorium can readily be separated from a solution of mesothorium and obtained in a concentrated form. Mesothorium when first separated would show a weak activity, but in consequence of the growth of its subsequent product radiothorium, its activity would increase for several years. After reaching a maximum it would ultimately decay with the period of mesothorium I, viz., 6.7 years.

Large quantities of mesothorium have been obtained as a by-product in the separation of thorium from monazite sands. This substance emits only β-rays but soon grows radiothorium and subsequent products which emit α-rays and penetrating β- and γ-rays. As a source of powerful β- and γ-radiation, this substance is analogous to radium. Since radium and mesothorium are isotopic elements, they are always separated together. Most commercial sources of thorium contain also uranium and radium, and consequently radium is always separated with the mesothorium and in relative amount depending upon the proportion of uranium to thorium in the mineral. Since mesothorium has a short radioactive life compared with radium, it commands a smaller price. The amount of mesothorium is standardized by comparison of its γ-ray effect with a radium standard. Radiothorium, separated from preparations of mesothorium, is widely used instead of radium as sources of β- and γ-rays for therapeutic purposes.

Origin of Actinium Series and Its Transformations.—The origin of the actinium series has long been a matter of great interest and it is only in recent years that the question has been answered satisfactorily. While actinium is always found in uranium minerals in constant proportion with the uranium, Boltwood showed that the activity of the actinium with its whole series of α-ray products in a uranium mineral was much less than that given by a single α-ray product of the main radium series. This suggested that the actinium series originated from a branching in the main uranium series, and some support was given to this hypothesis by the observation of a product, uranium Y, which was not in the main series. However, the discovery of protoactinium, the determination of its atomic weight as 231, and the observation of the presence of an isotope of mass 235 (actinouranium) in uranium provided an alternative explanation, and it is now generally accepted that the actinium series descends in direct line from this isotope of uranium. The end product of the actinium series should therefore be a lead isotope of mass 207, and this deduction has been confirmed by an isotopic analysis of the lead found in uranium metals.

Actinouranium is present in common uranium to the extent of 0.7%. It emits α-particles of mean range about 2.9 cm. and transforms into uranium Y. Its period of transformation is not known accurately. On the basis of his measurements of the proportion of actinium-lead in old uranium metals Nier gives a value of about 7×10^8 years, but other estimates are as high as 9×10^8 years. Uranium Y changes with β-emission into protoactinium. The growth of protoactinium in a uranium Y preparation has been directly observed. Protoactinium was isolated from uranium minerals by Hahn and Soddy and shown to be the direct parent of actinium. One thousand kilograms of uranium contain roughly 200 mg. of protoactinium. On account of the great interest in the origin of the actinium series, methods of purification of protoactinium were developed by Hahn and others with a view to determining its atomic weight. This determination was carried out by A. von Grosse, who obtained a value of 231. This showed definitely that the actinium series could not originate by branching from the uranium series. Protoactinium emits α-particles and changes, with a period of transformation of 3.2×10^4 years, into actinium. While the transformations subsequent to actinium have long been established, the nature of the radiations emitted by actinium itself was not successfully examined until recently. It is now known that actinium undergoes a dual transformation, 99% of the atoms emitting a soft β-radiation and changing to radioactinium, and the remaining 1% emitting an α-radiation and changing to a substance which has been called actinium K. This actinium K decays with a period of 21 min. and the emission of a β-radiation. The main product of actinium, radioactinium, is an α-ray body and has a period of 18.9 days. It changes into actinium X, an isotope of radium and thorium X, and from this point the series of transformations resembles closely those in the uranium and thorium series, passing through an emanation and an active deposit to the end product actinium D, an isotope of lead. As in the other series, the C-product exhibits branching. In this case, however, the great majority (99.68%) of the C atoms transform by the α-branch to actinium C″, and only a small fraction pass by the β-branch.

End Products of the Transformations.—After the radioactive transformations have come to an end, each of the elements uranium, thorium and actinium should give rise to an end or final product, which may be a known element or an unknown element of slow period of transformation. Since the expulsion of an α-particle lowers the mass of the atom by four units, and there are eight α-ray products, the atomic weight of the end atom should be $238-8\times4=206$. The atomic weight of radium by this rule should be $238-3\times4=226$, a result in good accord with experiment. The atomic weight of the end product of uranium is close to that of lead, viz., 207, and Boltwood early suggested that lead was the end product of radium. Since in old minerals the transformations have been in progress for intervals measured by millions of years, the end product should collect and be an invariable companion of the radioelement. Boltwood showed that lead is always present in old radioactive minerals, and in amount to be expected from their uranium content and geological age.

This problem has been definitely attacked in the light of the chemical generalization already given. It was clear from this that the end products of uranium, thorium and actinium should all be isotopes of lead but with atomic weights 206, 208 and 207 respectively. In other words, uranium-lead if uncontaminated with ordinary lead should show a smaller atomic weight than ordinary lead (207.21), while thorium-lead should give a higher value. These conclusions were definitely confirmed by the work of T. W. Richards, Soddy and Hönigschmid. A uranium-lead separated from a mineral containing no ordinary lead gave an atomic weight of 206.03, and a thorium-lead from a thorite containing very little uranium yielded an atomic weight of 207.9. Even more conclusive proof was forthcoming from the mass-spectrographic analysis of these radiogenic leads and the comparison with ordinary lead. The latter consists of four isotopes 204, 206, 207 and 208 with abundances of 1.5, 23.5, 22.7 and 52.3% respectively. A uranium-lead examined in this way was shown to contain only traces of 204 and 208, consisting of 94.3% of the 206 isotope and 5.6% of the 207 isotope. It is clear that the latter must be identified with the end product of the actinium series. Similarly, a thorium-lead was shown to consist to the extent of 93.6% of the 208 isotope. These results give a clear proof of the nature and atomic weight of the end products. In minerals containing both uranium and thorium the atomic weight of the mixed end product will depend on the relative amounts of uranium and thorium and their relative rates of transformation. In unaltered minerals the determination of the amount of lead coupled with its average atomic weight or, better still, a mass-spectrographic analysis allows us to determine the amount of uranium-lead even if some ordinary lead be present. In this way it is possible to make reliable estimates of the age of selected minerals and thus indirectly the age of the geologic strata (*see* GEOLOGY). The amount of helium in the minerals gives a minimum estimate of its age, for, except in the most compact minerals, some of the helium must undoubtedly escape.

Production of Helium.—In 1902 Rutherford and Soddy suggested that the helium which is invariably found in radioactive minerals was derived from the disintegration of radioactive matter. In 1903 W. Ramsay and Soddy definitely showed that helium was produced by radium and also by its emanation. From the observed mass of the α-particle, it seemed probable from the first that the α-particle was an atom of helium. This conclusion was confirmed by the work of Rutherford and Geiger, who showed that the α-particle was an atom of helium carrying two unit charges of electricity. In order to prove definitely this relation, it was necessary to show that the α-particles, quite independently of the active matter from which they were expelled, gave rise to helium. This was done by Rutherford and J. T. Royds, who allowed the α-particles from a large quantity of emanation to be fired through the thin glass walls of the containing tube. The collected particles gave the spectrum of helium, showing, without doubt, that the α-particle must be a helium atom.

Since the particle is an atom of helium, all radioactive matter which emits α-particles must produce helium. This has been found to be the case for every α-ray product that has been examined. The rate of production of helium by radium in equilibrium was measured with accuracy by J. Dewar, Boltwood and Rutherford. In terms of the international radium standard, the rate of production of helium by one gram of radium in equilibrium with its three α-ray products has been found to be 172 cu.mm. per year. This value is in excellent accord with that calculated from the rate of emission of α-particles. The rate of production of helium by radon, ionium and polonium has been found by Boltwood to be in fair agreement with calculation. Soddy has observed the production of helium by purified uranium, while R. J. Strutt showed that the rate of production of helium in uranium and thorium minerals was in good accord with calculation.

Strutt has made a systematic examination of the amount of helium present in many minerals and rocks which contain minute quantities of radium, and has utilized the results to estimate the age of the geological deposits. On account of the tendency of the helium to escape from minerals in the course of geologic ages, this method gives only a minimum estimate of the age of the mineral, except in the case of dense and compact specimens. The measurement of the lead content has proved a more reliable method of estimating the age.

Heat Emission of Radioactive Matter.—In 1903 it was shown by P. Curie and A. Laborde that a radium compound is always hotter than the surrounding medium, and radiates heat at a constant rate of about 100 g.-calories per hr. per g. of radium. The rate of evolution of heat by radium has been measured subsequently by a number of observers. These observations have made it clear that the evolution of heat by radium and by other radioactive substances is caused by the energy of the absorbed radiations, and not by any additional interatomic processes. Since the α-particles have a large kinetic energy and are easily absorbed by matter, all of these particles are stopped by the radium itself or by the envelope surrounding it, and their energy of motion is transformed into heat. The transformation of the kinetic energy of the α-particles accounts for the greater part of the heat. To this must be added the energy supplied by the recoil of the radioactive atom after the expulsion of the α-particle, together with some of the energy of the β- and γ-rays absorbed in the envelope.

This view has been fully confirmed by the measurements of Rutherford and H. R. Robinson, and others, who found that each of the α-ray products of radium gave a heating effect equal to that calculated from the energy of the α-particles and the absorbed β- and γ-rays. Radon and its products when removed from radium were responsible for three-quarters of the heating effect of radium in equilibrium. The heating effect of radon, radium A and radium C decayed at the same rate as their activity. Accurate measurements give for the total heating effect of radium in equilibrium (with the short-lived products) surrounded by sufficient material to absorb all the radiations a value of 140.1 calories per hr. per g. Of this, 124.4 calories are caused by the α-particles and recoiling atoms, 6.3 by the β-particles and 9.4 by the γ-rays. The energy of the β- and γ-rays comes from radium B and radium C. On account of its great penetrating power, it is difficult to measure the energy of the γ-radiation accurately but the results show clearly that the energy of the γ-rays is greater than that of the β-rays, and that the two together contribute rather more than 11% of the total heating effect of radium in equilibrium.

Measurements have been made of the heating effect of several other radioactive substances, such as uranium, thorium, thorium C, polonium, etc., and also of uranium and thorium minerals. In every case, the evolution of heat is of the magnitude to be expected from the energy of the radiations.

Experiments on the evolution of heat from radium have brought to light the astonishing amount of energy accompanying the transformation of active matter, especially where α-particles are emitted. For example, 1 curie of radon in equilibrium with its products emits heat initially at the rate of about 114 calories per hour. The total heat emitted during its transformation is about 15,000 calories. The volume of 1 curie is 0.65 cu.mm. and its weight 6.5×10^{-6} g. Thus 1 g. of radon emits during its life about 2.3×10^{9} calories of heat. Contrasting this with the 8,000 calories obtained from the combustion of 1 g. of carbon, we see that the evolution of heat is enormous compared with that emitted in chemical reactions. It is evident that the atoms of matter must contain a great reservoir of energy which becomes available, even partially, only by the disintegration of the atoms. This energy is released in the re-arrangement of the particles in the atomic nucleus which takes place in the disintegration process and is accompanied by a change of mass. Albert Einstein showed in 1905 that, according to the theory of relativity, there is no essential difference between mass and energy, but that energy has mass and mass represents energy. The relation deduced by Einstein that the energy $E=m(\text{mass})\times c^2$, where c is the velocity of light, has in fact been confirmed by experiments on the artificial transmutation of atoms. It appears that in the transformation processes, both natural and artificial, matter is partially converted into energy, and that a very small change in mass corresponds to a very large release of energy. The most striking example of the enormous energy which can be obtained in this way is the case of nuclear fission and its application in the atomic bomb and in nuclear fission reactors (*see* NUCLEUS).

Nature and Properties of the α-Rays.—Although the α-rays from active substances are of small penetrating power compared with the β- or γ-rays, they are responsible for most of the energy evolved by radioactive substances and contribute most of the ionization. Rutherford showed in 1903 that the α-rays are deflected in a powerful magnetic and electric field and consist of positively charged atoms of matter projected with high velocity. From the first it seemed probable that the α-particle was an atom of helium carrying two positive charges, and this was subsequently confirmed in a number of ways. The value of e/m—the ratio of the charge on the particle to its mass—and the velocity can be determined from observations on the deflection of the pencil of rays by a magnetic field and electric field. In this way Rutherford and Robinson in 1914 showed that the α-particle, whether from radon, radium A or C, gives a value of $e/m=4{,}820$ em units, agreeing within the limit of error with the electrochemical value of $e/m=4{,}822$, assuming that the mass of the helium atom is 4.004 and that it carries two unit positive charges. The magnitude of the charge carried by each particle was measured by Regener and Rutherford and Geiger, and found to be twice that carried by the electron. The velocity of the α-particles expelled from radium C′ (of range 7.06 cm.) was found to be 1.92×10^{9} cm. per sec., or about $\frac{1}{15}$ the velocity of light. From this result the velocity of expulsion of all α-particles can be calculated approximately from the relation found by Geiger, that $V^3=KR$, where V is the velocity of the particle and R its range in air. The evidence indicates that the α-particles from active products are in all cases atoms of helium.

In general, the α-emission from a given product consists of a single group of α-particles emitted with a definite velocity, which is characteristic of that product. In some cases, however, several

groups of α-particles, each group having a definite velocity, are emitted; the implications of this phenomenon will be discussed later. The velocity of emission of the α-particles is connected with the period of transformation of the element (*see* below).

The laws of absorption of the α-particle in matter were first worked out by W. H. Bragg and R. D. Kleeman. On account of its great energy of motion, the α-particle travels in nearly a straight line through matter, producing intense ionization along its path. The effects produced by the α-particle, whether measured by ionization, phosphorescence or photographic action, vanish suddenly after the α-particle has traversed a definite amount of matter. This means that particles of the same initial velocity have a well-defined length of path, or *range*. It is found that the ionization per centimetre of path caused by a narrow pencil of α-rays increases with the distance from the active matter, at first slowly, then more rapidly, near the end of the range. After passing through a maximum value the ionization falls off rapidly to zero, corresponding to the end of the range. If a uniform screen of matter is placed in the path of the pencil of rays the range is reduced by a definite amount proportional to the thickness of the screen. All the α-particles have their velocity reduced by the same amount in their passage through the screen. The ranges in air of the α-rays from the various radioelements have been measured and are usually expressed in terms of cm. of air traversed at 15° C. and 760 mm. pressure. The ranges for the different products vary between 2.6 cm. and 11.5 cm.

Bragg and Kleeman made observations of the stopping powers of gases and solids and these led to the empirical rule that the stopping power of an atom is proportional to the square root of its atomic weight. This simple rule has proved very useful in estimating the reduction in range of α-particles in traversing different kinds of matter. It was later supported on theoretical considerations.

The absorption of α-particles in matter results essentially from elastic collisions with the electrons. As the mass of the α-particle is about 7,000 times the mass of the electron, the energy lost in a single collision is an extremely small fraction of its total energy. Therefore a large number of collisions is necessary to stop the α-particle completely, and the range of all α-particles of the same initial velocity will be the same, except for small fluctuations. Moreover, since an impact with an electron can not deflect the α-particle appreciably, the particle will follow a straight path. In this way the remarkable definiteness of the range of the α-particle is explained. The collisions with an atomic nucleus, which may cause a large loss of energy and an abrupt change of direction, are too infrequent to affect the general picture. This description needs some qualification. The loss of energy of the α-particle is caused by a large but finite number of electron collisions or ionization processes, and these are subject to statistical fluctuations. The energy loss is therefore not quite the same for all the particles, and in consequence the range is not quite exactly defined but has an average value about which the ranges of the individual particles fluctuate. This effect is known as the straggling of the range. The mean fluctuation of the ranges around the average value is between one and two per cent. The average value of the range, known as the *mean range*, is now generally used to characterize a given emission of α-particles.

On account of its great energy of motion the effect caused by a single α-particle can be detected in a variety of ways. Sir William Crookes first noted that the α-rays produce scintillations when they fall on a screen of phosphorescent zinc sulphide. It is now known that each of these scintillations results from the impact of a single α-particle. The number of scintillations can be counted with the aid of a suitable microscope, and this method has proved of great utility in many investigations. Scintillations caused by α-rays are observed in certain diamonds, but they are usually not so bright as in zinc sulphide. S. Kinoshita has shown that a single α-particle produces a detectable effect on a photographic plate. When the α-rays fall on a plate nearly horizontally the track of the α-particle is clearly visible under a high-power microscope. This method has recently been developed to a useful means of investigation under appropriate conditions. By the expansion method developed by C. T. R. Wilson, the track of the α-particle through the gas is made visible by the condensation of the water on each of the ions produced. In a similar way the track of a β-particle can be easily shown. The photographs of these trails bring out in a striking and concrete way not only the individual existence of α- and β-particles, but the main effects produced in their passage through matter.

Rutherford and Geiger in 1908 devised an electrical method of detecting a single α-particle. The α-particle entered, through a small window, a metal tube containing a gas at a reduced pressure, and a strong electric field was applied between the wall of the tube and a central wire electrode. The ionization produced by the α-particle in its passage through the gas was magnified several thousand times by the movement of the ions in the electric field, so that the charge communicated to the central wire was large enough to be detected by means of an electrometer. A simple counter was devised by Geiger which responded to single β-particles as well as to single α-particles. This consisted of a fine needle point, or a small sphere at the end of a wire, placed axially in a metal cylinder. A strong electric field is maintained between the cylinder and the point; the gas in the cylinder may be at atmospheric or at reduced pressure. The point electrode is connected to a short-period electrometer and also grounded through a high resistance. When an α-particle enters the cylinder through a hole or window opposite the point a discharge occurs which causes a sudden variation in potential of the point, sufficient to be easily detected by the electrometer. The tube counter of Geiger and W. Müller differs from the point counter mainly in the shape of the electrodes. The cathode is cylindrical and the anode is a thin wire along the axis of the cylinder. The sensitive region extends over the whole space between the electrodes. This counter is more usually employed for the detection of β-particles or of γ-radiation. For this purpose, the conditions are generally chosen so that the multiplication is very high and the magnitude of the impulses produced becomes independent of the original ionization. It can however be used so that the magnitude of the impulse is proportional to the original ionization, when it is then possible to distinguish between the impulses caused by α-particles and those caused by β-particles. The most practical method of counting the impulses is to couple the counter circuit, by means of a small capacity, to a valve amplifier which operates a mechanical recorder such as a telephone callmeter.

In the counters just described the primary ionization of the particle is magnified by producing ionization by collision by means of a strong electric field. The most generally useful method for α-particles (and protons, etc.) is to use a valve amplifier in order to magnify the potential variation of the electrode of a simple ionization chamber. This method was first successfully applied by H. Greinacher, and developed to a high degree by C. E. Wynn-Williams. From four to six amplification stages may be used and the voltage amplification is of the order of 10^6 or more. The amplification is linear and therefore gives a measurement of the primary ionization. The α-particles can be counted in the presence of β- and γ-radiation, which however produce a disturbance resulting from the fluctuations in their ionization (*see* RADIOACTIVITY, ARTIFICIAL).

When the α-rays fall on a sheet of matter, a cloud of slow-speed electrons is emitted. These were first studied by J. J. Thomson and were called by him the delta (δ) rays. Most of the δ-rays have an energy corresponding to only a few volts but a few particles are present which have much higher speeds, some reaching to twice the velocity of the α-particle. These δ-rays are a secondary phenomenon and are liberated from the atoms of matter by the action of the α-particle. The δ-rays can be best studied by photographing the tracks of α-particles in a Wilson chamber containing a gas at low pressure. The swifter δ-particles are able themselves to ionize the gas and their tracks are easily visible. J. Chadwick and K. G. Emeleus and also P. Auger have shown that the number and velocity of the swifter δ-rays agree excellently with the view that they are produced by the collision of the α-particles with the electrons in the atom. The primary process of ionization by the α-particle is the removal of the electron and the second-

ary ionization is produced by the δ-particles. In general the primary ionization is about one-half of the total ionization observed.

The α-particle at the moment of its expulsion from a radioactive atom carries two charges and it was at first supposed that it retained this charge until very near the end of its range where the charge was neutralized by capture of two electrons. Later work, however, by G. H. Henderson and Rutherford showed that the α-particle changes its charge several thousand times in its passage through matter. When the α-rays pass through a sheet of matter in a good vacuum, the issuing rays consist of doubly-charged, singly-charged and neutral helium atoms. For high speeds, the doubly-charged particles predominate; at low speeds most of the particles are singly charged or neutral. It seems clear that the α-particle in its passage through matter occasionally captures an electron and that this may be removed in a subsequent collision. This process of capture and loss of electrons is repeated many thousand times before the α-particle is brought to rest.

Although most of the α-particles travel in nearly a rectilinear path through absorbing material there is in general a small scattering or deflection of the α-particles in passing through matter, amounting on the average to a few degrees. This scattering increases with the atomic weight of the absorber and with reduction of velocity of the α-particle. In addition to this small angle scattering, a small fraction of the α-particles is deflected by collisions with heavy atoms through angles greater than a right angle. This large angle scattering is in general caused by a close collision of an α-particle with a single atom of matter. A close study of the laws of single scattering of α-particles has been made by Geiger and E. Marsden. The observations on this large angle scattering first disclosed the nuclear structure of the atom and has given us most definite information on the laws of force inside the atom close to the nucleus and on the dimensions of atomic nuclei. (*See* NUCLEUS.) P. M. S. Blackett has obtained a number of expansion photographs showing close collisions of α-particles with the nuclei of light atoms like hydrogen, helium, nitrogen and oxygen. In general a forked track is obtained, one branch caused by the scattered α-particle and the other by the recoiling nucleus.

The Relation between Range of α-Rays and Period of Transformation.—It was early observed that there appeared to be a connection between the period of transformation of a product and the velocity of the α-particles emitted by it. The shorter the period of transformation, the swifter is the velocity of expulsion of the α-particle. This relation was brought out clearly by the measurements of Geiger and J. M. Nuttall, which show that if the logarithm of the range is plotted against the logarithm of λ, the constant of transformation, all the points for each radioactive series lie approximately on a straight line. The relation can be written

$$\log R = A \log \lambda + B$$

where A and B are constants, and the constant A is nearly the same for all three radioactive series. A similar relation exists between the logarithm of the transportation constant and the logarithm of the energy of the α-particle.

This relation, although only approximately fulfilled, was rightly regarded as of fundamental importance. One of the most striking successes of the theory of α-disintegration, advanced by G. Gamow and by R. W. Gurney and E. U. Condon in 1928, was to explain the meaning of this relation.

Theory of α-Disintegration.—The difficulty encountered in forming a theory of α-disintegration can be illustrated by the use of uranium. Scattering experiments, using the fast α-particles of thorium C′ (energy nearly 9 Mev) show that there is no appreciable departure from the Coulomb potential up to a distance of 3×10^{-12} cm. from the centre of the uranium nucleus. At smaller distances, to which the α-particle can not penetrate, there must be large deviations from the Coulomb potential, to account for the nearly stable binding of α particles in the nucleus. The general shape of the potential field between the nucleus and an α-particle is therefore as shown in fig. 5, where the dotted line represents the Coulomb potential $V(r)=2\frac{Ze^2}{r}$. On the other hand, the α-particles emitted spontaneously by uranium have an energy of about 4 Mev. As these particles must come from inside the nucleus, it is impossible to explain on classical mechanics how they can surmount a potential barrier which is at least twice as high as their energy. On quantum mechanics, however, there is the possibility of leakage through the barrier. An adequate description of the theory can only be given in terms of the Schroedinger equation for the time variation of the wave function of the α-particle, which enables a calculation to be made for the probability of the particle being found outside the nucleus after a certain time. A semiclassical description can be given by supposing that the α-particle inside the nucleus has a degree of excitation indicated by the height of the line AB, along which it vibrates, making collisions with the walls of the barrier. At each collision, the particle has a small but finite chance of penetrating the barrier and escaping. The greater the chance of escape, the fewer oscillations will be necessary for escape to occur and thus the shorter the period of transformation. This chance depends markedly on the height and thickness of the barrier, or, as the figure indicates, on the degree of excitation of the particle. Thus we see in a general way that a body which emits fast α-particles will have a short period and one

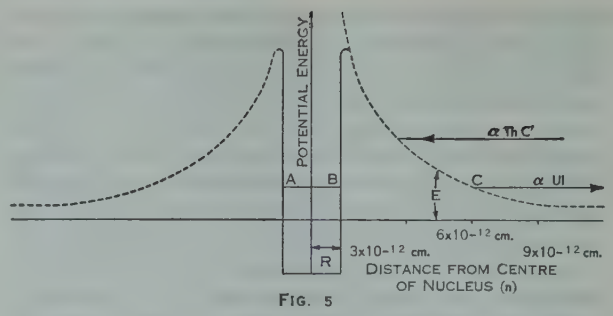


FIG. 5

which emits slow α-particles will have a long period. Detailed calculation leads in fact to a relation between the period of transformation and the energy of the α-particle which is similar to the Geiger-Nuttall law. Further, the calculation leads to values for the nuclear radii (R) of the radioactive atoms which are, for the same series, close to one another and in agreement with the order of magnitude of the nuclear radius as deduced in other ways.

Long Range α-Particles and Fine Structure Groups.—For many years all the α-particles emitted by a given radioactive element were believed to have exactly the same velocity. The first departures from this rule were found in the cases of thorium C′ and radium C′. In the former case, two weak groups of α-particles were found which have ranges of 9.7 cm. and 11.5 cm., considerably longer than the normal group of 8.6 cm. range. The "long-range" emission of radium C′ is more complicated, consisting of several groups of ranges between 7.7 cm. and 11.5 cm. In both cases, the intensities of the long-range groups are very weak, being about 10^{-4} to 10^{-6} or less of the main group. These long-range groups are believed to arise in the following way. The β-transformation of the C nucleus leaves the C′ nucleus in an excited state. There are then two possibilities, the nucleus may go to the normal state by emitting a γ-radiation, followed by the normal α-disintegration, or an α-particle only may be emitted, taking away the excess energy of the excited nucleus. The relative intensities of the two processes depend on the relative probabilities of γ-emission and of an α-particle of high energy. As the probability of γ-emission is large the second process will seldom occur, and will be observed at all only when the α-change has a short period. This explains why the long-range particles have been found only with radium C′ and thorium C′. On this explanation, the measurement of the energies of the long-range groups gives part of the excited-level system of these nuclei and the energy differences should correspond to γ-rays emitted in the transitions RaC-RaC′ and ThC-ThC′. This has been borne out by examination of the γ-ray spectra emitted in these transitions.

A more common complexity in the α-emission is known as "fine structure." This was first observed by S. Rosenblum who analyzed the α-groups by means of a magnetic spectrograph. Many products are now known, *e.g.*, ThC, An, AcC, AcX, RdAc, Ra, RaC, RaF, which emit a complex α-spectrum, consisting of a number of homogenous groups of about the same order of intensity. Thus thorium C has 5 groups, actinon 3 groups, radioactinium 11 groups. In these cases, the complexity of the α-emission arises from excitation of the product nucleus. If, *e.g.*, thorium C emits an α-particle of energy lower than the α-particle of the highest energy group, the thorium C″ nucleus, the result of the change, will be formed in an excited state. The energy difference between the groups measures the excitation energy of the thorium C″ nucleus. The various α-groups thus correspond to various energy levels of thorium C″. The thorium C″ nuclei will thus be formed in varying degrees of excitation, and there will follow transitions, with the emission of γ-radiation, to the ground state of thorium C″. Thus there must be a correspondence between the energy differences of the α-groups and the energies of the γ-rays emitted by thorium C″. This has been confirmed very satisfactorily.

The Properties of the β-Rays.—We have seen that the β-particles, which are emitted by a number of radioactive elements, consist of swift negative electrons spontaneously liberated in the transformation process. The energy of expulsions varies widely for different products, from values of some thousands electron volts up to a few million electron volts. The penetrating power of the rays varies correspondingly; *e.g.*, the β-rays of radium D are so easily absorbed by matter that they are difficult to detect, while those of radium C can pass through a few millimetres of aluminum before they are finally stopped. At first sight, the laws of absorption of β-particles by matter appear different from those observed with α-particles, although the process of energy loss is essentially the same. This is caused by the small value of the electron mass, about 7,000 times less than the mass of the α-particle, as a result of which the β-particles are easily scattered. While an α-particle can be deflected from its straight path only by collision with a nucleus a β-particle can transfer a large fraction of its energy and momentum to the electrons contained in the matter in its path. Consequently, the β-particles are frequently deflected from their course and pursue in general a tortuous path in their passage through

matter. Although we can still speak of a "range" in matter, this range is far from being so well-defined as that of the α-particle. Thus the study of the passage of β-particles through matter is much more complicated, both in theory and in experiment, than the same problem for α-particles. Although the energy of the β-particles is in general considerably less than the energy of the α-particles, the rate of loss of energy by ionization is much less, for the β-particle carries only one unit charge as against two for the α-particle and its velocity is much higher. An α-particle of 3,000,000 electron volts has a velocity of about 0.04c (c being the velocity of light) and produces about 4,000 ion pairs per millimetre of its path in air; whereas a β-particle of the same energy has a velocity of about 0.99c and produces only about 4 ion pairs per millimetre of path in air. Because of this small rate of energy loss the β-particle has a much greater range than an α-particle of the same energy. Thus, in our example, the α-particle would have a range in air of about 1.7 cm. while the β-particle would have a range of about 13 metres. The difference in behaviour between α-particles and β-particles is strikingly shown in experiments with the expansion chamber. In contrast to the short, straight and densely ionized tracks of the α-particles the tracks of the β-particles are long, show many gradual deflections and occasional "forks" resulting from a close collision with an electron, and are sparsely populated with ions. In addition to the loss of energy by ionization, there is a loss of energy by radiation caused by sudden deceleration of the β-particle on impact, an effect which is responsible for the emission of the continuous X-ray spectrum when cathode rays are stopped by a target. The production of γ-rays by β-rays in passing through matter was first observed by J. A. Gray.

A great difficulty in the study of the detailed properties of the β-particles is that the rays emitted by a radioactive product are not homogeneous but differ widely in velocity. This fact was not fully appreciated for some time. In the early days, it was found that the absorption of β-rays appeared to follow an exponential law and different groups of β-rays were characterized by a definite absorption coefficient. The exponential law is now known to be a fortuitous result of the initial spread in energy distribution, scattering, etc.; a group of homogeneous β-rays is not absorbed according to an exponential law. Absorption curves and absorption coefficients of β-rays in matter naturally have still some practical significance but it must be remembered that the results of absorption measurements depend markedly on the geometrical conditions of the experiments. When a homogeneous beam of β-rays is passed through a certain thickness of matter it emerges with a more or less wide spread in energy distribution, depending on the thickness of matter traversed, and the maximum of the energy distribution is displaced toward lower energies with increasing thickness of matter. The "straggling" in energy arises mainly from the fact that the paths of the particles are not straight, owing to scattering, but part is also caused (as in the case of α-particles) by statistical fluctuations in the number of impacts and in the energy lost in the electron collisions. The β-particles which emerge after traversing a layer of matter have had different lengths of path and suffered different energy losses. It is nevertheless possible to define and measure the range of the β-particle as a function of its energy. The results of experiments show that for the lower energies, up to about 200,000 electron volts, the range of the β-particle is proportional to the fourth power of the velocity, while for much higher energies the range is proportional to the energy.

The scattering of β-rays has been examined experimentally by many observers but the results are not concordant. This is partly because of the difficulty of realizing well-defined conditions and to the susceptibility to scattering of these particles. The scattering is indeed so marked that when a beam of β-rays falls on a thick sheet of matter a large fraction, as much as one-half in the case of heavy elements, may be irregularly reflected, *i.e.*, scattered through more than 90°.

The β-Ray Spectrum and the Disintegration Process.—It has already been stated that the β-particles arising from the disintegration of a single product are expelled over a wide range of velocity. When the β-rays from a product such as radium B or radium C are bent in a uniform magnetic field and fall on a photographic plate, a kind of magnetic spectrum is obtained. Superimposed on a continuous background resulting from particles of all velocities from zero up to a certain limit, a number of sharp lines are observed, each of which represents a definite group of β-rays which are emitted with the same velocity. These lines are generally referred to as the β-ray line spectrum and are characteristic of the radioactive product. Many careful measurements of the β-ray line spectra have been made, and they are now known accurately for most of the important radioactive substances. In some cases, the line spectrum is relatively simple while in others it is complex. The appearance of these lines in the spectrum is connected with the emission of γ-rays; they arise from the process known as *internal conversion*, the conversion by the photoelectric effect of a γ-ray emitted by the radioactive nucleus in the electronic structure of the atom (*see* below). These lines are thus secondary in origin and do not represent the primary emission of β-particles from the nucleus. The β-ray line spectra have been of great importance in the study of the γ-ray spectra of radioactive products.

Since most β-ray products also emit a strong γ-radiation the magnetic spectra in general show pronounced line spectra and for some time these were thought to be the disintegration particles. The fact that the number of particles in the lines was only a fraction of the total number of β-particles and that the primary β-emission had a continuous distribution of velocity was first recognized by Chadwick in the case of radium (B+C). Later experiments have shown that in all cases the disintegration electrons are ejected from the radioactive nucleus with a continuous distribution of velocities, and that the number of particles in this continuous spectrum corresponds, within the accuracy of experiment, to one particle for each disintegration. The form of the distribution has been measured for a number of products. The general result is that the distribution curves are similar, showing a definite maximum and then decreasing to zero at a well-defined upper limit of energy. The form of the curves in the region of very low energies is difficult to measure accurately, so that it is uncertain whether there is a definite lower limit of energy or whether the distribution extends to zero energy. On the other hand, the upper limit of the energy is well-defined and is characteristic of the radioactive product. Thus the upper limit of energy of the continuous spectrum of radium B is 0.65 Mev, of radium E, 1.17 Mev, and of radium C, 3.15 Mev. The value of this end point is an important constant, for on present theory it gives the total energy released in the β-disintegration. There is a relation between the maximum energy of the β-rays emitted by a product and its rate of disintegration, first pointed out by B. W. Sargent, but the relation is not so simple as the Geiger-Nuttall relation in the case of α-disintegration.

The distribution curve of the β-ray spectrum should be simplest in the case of a substance such as radium E, in which the resulting nucleus is formed in its ground state, as is shown by the absence of γ-radiation. In most cases, however, the β-transformation is more complex and the new nucleus can be formed in any one of a number of excited states; the transitions between these excited states to the ground state account for the γ-radiation which accompanies such β-transformations. In these cases, therefore, the energy distribution curve of the β-ray spectrum will be complex, consisting of a superposition of a number of continuous spectra, each one of which has a definite upper limit and corresponds to a β-transformation to a certain quantum level of the resulting nucleus. The successful analysis of a complex β-ray distribution into the simple or "partial" spectra would give information on the quantum states of the new nucleus, as in the case of the "fine-structure" of the α-emission. This is, owing to the broad distribution in the spectra, difficult to carry out in practice and in general little accurate information about quantum states has been derived from the primary β-ray spectrum.

The process of β-decay, in which the transformation from one nucleus to another appears to take place with a release of energy varying between wide limits, is in such strong contrast to the process of α-decay, and indeed of all other nuclear phenomena, that for some time the facts were not generally accepted. It was suggested, *e.g.*, that the β-particles are all liberated initially with identical energies and that the continuous spectrum results from varied losses of energy suffered by the different particles in escaping from the atom. This supposition was disproved by direct experiment, in which the average energy released per disintegration of radium E was measured by means of a calorimeter. The experiments gave an average energy of 0.34 Mev, in close agreement with the average value deduced from the observed distribution curve, and far from the upper limit of 1.17 Mev. There can therefore be no doubt that the β-particles are emitted from the nucleus with varied energies. On the other hand, all phenomena connected with α- and γ-ray spectra show that the radioactive nuclei have well-defined quantum levels and that the energy of the initial nucleus and the energy of the product nucleus have well-defined values. In order to retain the conservation of energy in the process of β-decay—and to abandon it is a counsel of despair—it is necessary to assume that part of the energy of disintegration is emitted in the form of a new and undetected type of radiation. Pauli suggested that this radiation may consist of particles bearing no electric charge and of small, possibly zero, mass. Such particles, called *neutrinos*, would have practically no interaction with matter and thus could not be detected directly. The β-decay process would then consist of the simultaneous emission of an electron and a neutrino, which share the constant total energy of the disintegration, distributed between them in a continuous way. The maximum energy of the β-particle would occur when the neutrino is emitted with zero velocity; the total energy in the disintegration process is thus equal to the maximum energy of the β-rays plus the self-energy of the electron mc^2, assuming that the neutrino mass is zero. In all cases where a test can be made, this assumption leads to consistent results.

In addition to helping to conserve energy in the β-decay process, the assumption of a neutrino removes other difficulties, for experimental evidence shows that the nucleus produced in a β-decay process has the same spin and the same statistics as the initial nucleus, in spite of the emission of an electron possessing a spin of one-half and Fermi-Dirac statistics. The correct relations regarding spin and statistics are restored if a spin of one-half and Fermi-Dirac statistics is ascribed to the neutrino. All attempts to observe effects resulting from the interaction of the neutrino with matter have failed, but such a result is only to be expected from the properties which the neutrino must be assumed to possess. Some expansion chamber experiments in which the energy and momentum of the emitted β-particle and of the associated recoil-

ing nucleus have been measured have, however, given some indications that momentum is not conserved if only these two particles are involved in the disintegration. These experiments thus give some support to the hypothesis of the neutrino.

A theory of the β-disintegration process was constructed by Fermi on the basis of the neutrino hypothesis. Fermi proposed that β-disintegration corresponds to the transformation, inside the nucleus, of a neutron to a proton, with the simultaneous emission of an electron and a neutrino. In this way he was able to explain the general shape of the continuous spectrum of primary β-rays, and also to deduce a relation between the mean life of a substance and the maximum momentum of its β-particles, analogous to the rules found empirically by Sargent. It is not surprising that the deductions from the theory show some discrepancies with experimental results, for the theoretical basis of some of the arguments is incomplete, depending as it does on an intimate understanding of the nature of the relation between the proton and the neutron. The theory is rather to be regarded as the first, although an important, step toward the description and explanation of β-disintegration on the basis of quantum mechanics.

The Properties of the γ-Rays.—The γ-rays from radioactive substances are electromagnetic radiations. A γ-radiation may be characterized by its wave length, generally expressed in X-units (1 X-unit $= 10^{-11}$cm.), by its frequency ν, or more often by the energy of the quantum $h\nu$, generally stated in electron volts. The γ-radiation from any one product consists of one or more spectrum lines which may differ widely in wave length and in intensity. The spectral region occupied by the γ-radiations extends from the soft X-ray region of some thousands of electron volts in quantum energy to the high-frequency region of a few millions of electron volts.

The absorption of γ-rays by matter is analogous to the absorption of X-rays, but owing to the higher frequencies of the γ-rays some effects assume a greater importance than in the case of X-rays. The absorption follows an exponential law with thickness of matter traversed; thus the ionization in an electroscope falls off according to the equation $I/I_0 = e^{-\mu d}$, where d is the thickness of matter traversed and μ the coefficient of absorption. The absorption coefficient for different kinds of matter is approximately proportional to the density, indicating that absorption depends on the mass of matter traversed. The absorption curve, more especially in the case of high energy γ-rays, depends to some extent on the geometrical conditions, the results being more nearly characteristic of the radiation and the absorbing matter the more the effects of scattered radiation are excluded from the measurements.

The absorption of γ-rays in matter is mainly caused by interaction with the electrons. There are three different processes—scattering, photoelectric absorption and creation of positive and negative electron pairs; the relative importance of these three processes depends upon the frequency of the radiation and the atomic number of the absorbing element. The experimental investigation of these types of interaction of γ-rays with matter is thus complicated by the difficulty of separating their effects.

In the classical theory of scattering a free electron is set in vibration by the electric field of the incident radiation, emitting spherical waves of the same frequency as the incident waves. Thus on the classical theory the scattered radiation has the same frequency as the incident radiation. It was early noted by J. A. Gray that scattered γ-radiation was more easily absorbed than the incident γ-radiation, indicating a change in frequency, but these experiments did not attract much attention. The explanation of the change of frequency on scattering, and the calculation of its magnitude, was given by A. H. Compton, together with experimental proof. Compton's argument was that the process of scattering must be regarded, on the quantum theory, as a collision between a photon, or quantum of radiation, of energy $h\nu$ and an electron. In general, the electron will be ejected from the atom and the photon will be deflected from its original direction. Since the photon transfers momentum and energy to the electron, the scattered quantum will have a smaller energy than the incident quantum. Scattering will therefore be accompanied by a change of frequency (the Compton effect). However, if the electron is very tightly bound in the atom, the process may be similar to the classical process of scattering, and there will be scattered radiation of unmodified frequency. Such scattering is responsible for the interference of X-rays and γ-rays in crystals, which could not occur if the scattered radiation were not coherent. This unmodified scattering becomes less important with increasing energy of the photon; with high energy γ-rays it can only be detected with difficulty.

The Compton effect is of great importance in the case of high-frequency radiations, such as compose in general the γ-rays emitted by radioactive substances, for it means that the radiation becomes degraded as it passes through matter, acquiring in a single scattering process a wave length of perhaps several X-units. The scattering theory has been verified experimentally by observation of the change of frequency and also of the simultaneous production of the scattered quantum and the recoil electron. A detailed quantum theory of scattering has been given by O. Klein and Y. Nishina on the basis of P. A. M. Dirac's relativistic theory of the electron.

Absorption of γ-rays by the photoelectric effect occurs when the whole energy $h\nu$ of the quantum is transferred to an electron in one or other of the K, L, M, etc., levels of an atom. The photoelectron will be ejected with a kinetic energy $E = h\nu - W_i$ where W_i is the energy required to ionize the atom in the corresponding quantum level. In this case, the quantum of radiation is completely absorbed, and the residual atom takes up the momentum necessary for the conservation of momentum and energy.

For light elements and for γ-rays of energy of the order of 1 Mev the absorption results almost entirely from Compton scattering. For heavy elements and radiation of low energy, the absorption is mainly caused by the photoelectric effect. In the intermediate region, the two processes are comparable in their effects. The experiments of J. A. Gray and G. T. P. Tarrant, C. Y. Chao and others showed that in heavy elements the absorption of γ-rays of high energy is not entirely accounted for by Compton scattering, coherent scattering by bound electrons, and by the photoelectric effect, but that a further absorption process must take place. This was later explained to be caused by the creation of positron-electron pairs, a quantum-mechanical process which has no classical analogy.

The explanation of this process is derived from Dirac's relativistic theory of the electron and its consequence of negative energy states as well as of positive energy states. A quantum of energy greater than $2\ mc^2$, where mc^2 is the rest energy of an electron, can raise an electron from a state of negative energy to a state of positive energy. This will manifest itself in the creation of a pair of particles, a negative electron corresponding to the state of positive energy and a positive electron corresponding to the "hole" in the negative energy state. This process is analogous to the photoelectric effect. It can not occur in empty space for, as the quantum is wholly absorbed, energy and momentum can not be conserved; it occurs in the electric field near the nucleus and the nucleus takes up the extra momentum. The probability of pair production increases with increasing quantum energy of the radiation and is proportional to the square of the nuclear charge, Z, of the absorbing element. As the Compton scattering is proportional to the number of electrons, Z, and decreases with increasing energy, the total absorption coefficient should show a minimum for a certain quantum energy, which will be higher for the lighter elements than for the heavier, and then increase again with increasing quantum energy. For lead, the minimum absorption coefficient should occur for γ-rays of about 3 Mev, for aluminum, for γ-rays of about 20 Mev.

The γ-Ray Spectra.—The spectral distribution of the γ-rays has been examined in a few cases by means of diffraction in crystals. The first work of this kind was done by Rutherford and E. N. da C. Andrade in 1914, who studied the reflection from a thin crystal of rock salt of the γ-radiations emitted from a fine glass tube filled with radon. A complicated spectrum of sharp lines was observed corresponding to some of the γ-rays emitted by radium B and radium C. Later, similar experiments were carried out by M. Frilley and by J. Thibaud.

The crystal diffraction method has the advantage of easy and direct interpretation but it has disadvantages which seriously limit its use. The angle of reflection of high-frequency radiation is only a few minutes of arc, so that the precision obtained is not great; very active sources are required, and even with these only the strongest γ-ray lines have been photographed.

Nearly all our information on γ-ray spectra has been derived by an entirely different method depending on the photoelectric effect. A γ-ray in escaping from the radioactive atom occasionally interacts, with one of the electrons in the shells of the atom in which it originates, giving rise to a secondary β-ray. This process is known as *internal conversion*. Considering a large number of disintegrating atoms there will be a certain probability that a particular γ-ray will be converted in the K, L, M, etc., levels, and consequently the secondary β-ray emission will consist of a number of groups of energy $h\nu - W_K$, $h\nu - W_L$, $h\nu - W_M$, etc. Since the energy of the β-ray can be deduced from its deflection in a magnetic field, and W_K, W_L, etc., are known from X-ray data the frequency ν of the radiation can be directly determined. In general, the γ-ray spectrum of a radioactive substance consists of a number of lines, each of which may give rise to one or more groups of β-rays. If the γ-ray is intense enough to give several β-ray lines caused by conversion in the various electron shells, the interpretation is clear; but when the γ-ray is weak it may not be possible to observe more than one β-ray line, and interpretation becomes more difficult.

This method has been extensively developed by C. D. Ellis, L. Meitner, Thibaud and others, and the γ-ray spectra of many of the radioactive elements have been studied. In general, the frequencies of the γ-rays, especially of the strong lines, are now known with fair accuracy; the intensities, on the other hand, are in most cases known only roughly. The β-rays resulting from internal conversion appear always to consist of homogeneous groups, indicating that the γ-ray spectra consist of highly monochromatic lines. No experiment has yet revealed a measurable width of the γ-ray lines, and their width is at present estimated purely on theoretical reasoning.

In measuring the energy of the γ-rays by this method it was a question of some importance to decide whether the binding energies W_K, W_L, etc., of the electron levels of the initial nucleus or those of the product nucleus should be substituted in the photoelectric equation, *i.e.*, whether the γ-rays are emitted *before* or *after* the expulsion of the disintegration particle from the nucleus. This question

was investigated by a number of observers by different methods, leading to a clear proof that in all cases, whether of α- or β-disintegration, the γ-ray always follows the emission of the disintegration particle. For example, the γ-rays which are ascribed to the disintegration of radium B of nuclear charge 82 actually arise from the nucleus of charge 83 resulting from the expulsion of a β-particle from radium B and are converted in the electronic levels of an atom of charge 83. This conclusion accords with the modern conception of the emission of γ-radiation, which is supposed to be caused by the excitation of the product nucleus and the subsequent transitions to the ground state. The general evidence indicates that the γ-ray spectra can be interpreted by assuming a system of energy levels in the nucleus, analogous to the well-known system of levels in the electronic system of an atom which have been postulated for the explanation of optical and X-ray spectra. In contrast to the case of the atom, where emission of radiation is caused by electronic transitions, there is every reason to believe that the emission of radiation from the nucleus is caused by the motion of heavy particles—protons, neutrons, α-particles. First, electrons are believed not to exist in the nucleus; and second, if the γ-emission were caused by an electron, the γ-ray lines would not possess the high degree of homogeneity which is actually observed.

In principle it is possible to devise a system of energy levels which will describe the γ-ray emission and so to arrive at the quantum levels of the radioactive nucleus. In most cases the experimental data on the energies and especially on the intensities of the γ-ray lines are still too meagre and too inaccurate to give an unambiguous solution of the problem. Generally, the level system can only be partially and somewhat tentatively established. In some cases, however, notably those in which additional information about the level system is available from α-ray groups, the solution is more satisfactory.

The disintegration process of a nucleus X which emits long-range α-particles and changes to a nucleus Y can be represented diagrammatically by fig. 6. In the potential "well" of X, A is the ground state from which the normal α-particles are emitted, with an energy corresponding to the difference between A and the ground state B of the nucleus Y. Levels A_1, A_2, etc., are the excited levels from which the various groups of long-range α-particles are emitted, with energies corresponding to the transitions (2), (3), etc., to the ground state B. The spectrum of the γ-radiation emitted by the nucleus X should be accounted for by transitions in the level system A, A_1, A_2, etc. An appropriate example of this case is that of radium C′, for which the long-range α-groups have been closely examined. It has been found possible to account for many of the γ-ray lines by transitions between the levels deduced from the study of the long-range α-particles.

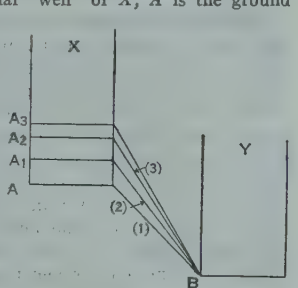


FIG. 6

If the nucleus X emits α-particles with a "fine-structure" the emission of the most energetic group of α-particles will correspond to the transition (1) in fig. 7, from the ground state A to the ground state B of the product nucleus, and the other groups will correspond to transitions (2), (3), etc., to the excited states B_1, B_2, etc. A good example of this process is the case of thorium C→thorium C″. The fine-structure groups of thorium C have been measured accurately, so that the level system of thorium C″ should be well established, and the γ-ray spectrum of thorium C″ is also well known. Comparison shows that all the lines of the γ-ray spectrum can be explained, both in energy and in intensity, by transitions in the level system deduced from the fine-structure.

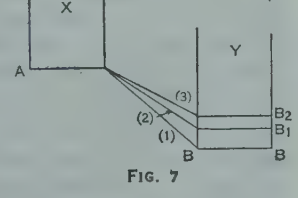


FIG. 7

If the nucleus X decays by emission of a β-particle there will in general occur transitions (2), (3), etc., to excited states of the nucleus Y. In this case, it is difficult to separate the different partial spectra, owing to the continuous energy distribution of the β-rays in each, and the consequent overlapping. Only in rather simple cases can any accurate information be obtained about the energy levels B_1, B_2, etc. In β-ray disintegrations, one has to rely mainly, if not entirely, on the information from the γ-ray spectrum to construct the level system of the product nucleus. It may be noted that the emission of a β-particle to an excited state B_1, etc., should be associated with the emission of a γ-ray in the γ-emission of nucleus Y. Since the γ-ray is, as a rule, emitted almost instantaneously these two processes are practically simultaneous. The observation of "coincidences" between the emission of a β-particle and of a γ-ray can thus give considerable help in the elucidation of the level system.

Radioactivity of Ordinary Matter.—All matter shows a very weak radioactivity, which in most cases is caused by the presence of extremely small amounts of the well-known radioactive elements. Thus, in general, one gram of a common metal will contain an impurity of the radioactive elements equivalent in activity to about 10^{-14} or 10^{-15} gram of radium. Four cases had, however, been definitely established in which the activity is not caused by a contamination of the known radioactive elements but had been proved to be characteristic of the element itself. These four are the following elements:—potassium, rubidium, samarium and lutecium (cassiopeium).

The activities of potassium and rubidium were discovered in the early days of radioactivity, while those of samarium and lutecium were found only in recent years. The activity of all these elements is very weak.

Potassium emits a β-radiation of average penetrating power, and a small amount of penetrating γ-radiation. By a separation of the isotopes of potassium it has been shown that the β-activity is caused by the isotope of mass 40, present in ordinary potassium to the extent of about 1 part in 8,000. The half-value period of the transformation is 1.9×10^9 years and the resulting product is calcium of mass 40. Some evidence has been obtained which suggests that potassium 40 undergoes decay by another process also, that of electron capture. In this case, the result of the transformation would be argon of mass 40; and the transformation period will be less than the figure just quoted.

Rubidium emits a rather soft β-radiation, but its amount is, weight for weight, greater than that of potassium. The active isotope is that of mass 87, which has an abundance of 27% in ordinary rubidium. The period of transformation is 5×10^{10} years; the resulting product is strontium of mass 87. Strontium has been extracted from a quantity of lithium mica which contained from 2% to 3% of rubidium. A mass-spectrographic examination of this strontium showed that it consisted almost wholly (99.7%) of strontium 87, whereas ordinary strontium contains only 7% of this isotope.

Samarium is the only element outside the three radioactive series which has been found to emit α-particles. These have a mean range of 1.13 cm. in air at 15° C. and 760 mm. pressure, and are thus much shorter than any emitted in the known series. It has been shown by separation of the isotopes, depositing them directly onto a photographic plate, that the isotope of mass 148 emits the α-rays. Its period is 1.4×10^{11} years.

Lutecium (cassiopeium) emits a very soft β-radiation. It is probable that it is the isotope of mass 176 which is responsible, and on this assumption the half-value period of transformation is about 7.3×10^{10} years. These results are summarized in the following table:

Element	Atomic No. Z	Mass No. of Isotope, A	T	Type of Change
Potassium	19	40	1.9×10^9 years	β
Rubidium	37	87	5×10^{10} years	β
Samarium	62	148	1.4×10^{11} years	α(1.13 cm.)
Lutecium	71	176(?)	*c.* 7.3×10^{10} years	β

In addition to these well-established cases, there is some indication that certain other elements may be unstable. According to theory of the stability of atomic nuclei, current in 1947, two neighbouring isobars, *i.e.*, two nuclei with the same mass number and with nuclear charges different by one unit, should not both be stable, but the nucleus of higher energy should undergo radioactive change and transform into the other. Such pairs are A^{40} and K^{40}, K^{40} and Ca^{40}, Rb^{87} and Sr^{87}, Lu^{176} and Hf^{176}, and as we have seen one element of each of these pairs has been shown definitely to be radioactive. There are other pairs of neighbouring isobars, however, in which both members of the pair are apparently stable, viz. Cd^{113} and In^{113}, In^{115} and Sn^{115}, Sb^{123} and Te^{123}, Re^{187} and Os^{187}. Although these elements have been examined carefully, only in one case has evidence of transformation been obtained. This is the case of osmium, where it appears that osmium probably transforms by K-electron capture, followed by the emission of K-radiation from the resulting rhenium atom. The period of transformation suggested by the experiments is about 3×10^8 years but this value may be in error by a large factor.

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RADIO COMPASS, a radio receiving set which permits determination of the line of travel of waves as received from transmitting stations. *See* WIRELESS TELEGRAPHY; AERIAL NAVIGATION; NAVIGATION.

RADIOLOGY. Radiology is that branch of medicine which deals with the employment of X-rays as an aid in the diagnosis of

disease and the use of X-rays, gamma-rays and other forms of ionizing radiation in the treatment of disease. (For details of the physical nature, method of production and technical and industrial applications of the various components of the electromagnetic spectrum, *see* RADIATION, RAYS; RADIOACTIVITY, ARTIFICIAL; RADIOACTIVITY, NATURAL; and X-RAYS, NATURE OF.)

DIAGNOSTIC RADIOLOGY

Quality and Intensity of Radiation Employed.—In some of the work for which X-rays are used, the quality or penetrating ability of the radiation is expressed in wave length, in frequency or in terms of its absorbability in filters of standard composition and thickness; and its intensity is designated in ionization units, such as the roentgen. In X-ray diagnosis, however, it is the practice to indicate radiation quality and intensity by stating the voltage and current applied to the tube, the current being expressed in milliamperes, abbreviated ma. (1 ma. = 0.001 amp.), and the voltage in peak kilovolts, abbreviated kv. Current is measured by means of a milliammeter inserted between the two halves of the secondary winding of the X-ray transformer at a point where the potential is close to zero; and tube voltage by means of a kilovoltmeter wired across the primary of the X-ray transformer.

Certain aspects of alternating currents and of pulsating unidirectional currents will be reviewed at this point. When one plots on a time scale the instantaneous voltage of the current produced by a single-phase, 60-cycle, alternating-current generator, he obtains a sine curve. Rising from zero, the voltage reaches full potential during the first $\frac{1}{240}$ sec., returns to zero by $\frac{1}{120}$ sec., falls to full negative value by $\frac{1}{80}$ sec. and returns to zero by $\frac{1}{60}$ sec., repeating the pattern indefinitely. That portion of the curve lying between the first and third zero points is called 1 cycle, and it is the repetition of this cycle 60 times in each second that gives 60-cycle current its name. Obviously the designation of the voltage of such a current requires reference to the factor of time, and for such applications as heating, lighting and power the "root mean square" value is employed. This is abbreviated R.M.S. and means the square root of the mean of the instantaneous voltages throughout the entire cycle.

A time-voltage plot of the potential applied to the tube of a self-rectified X-ray machine consists of a distorted sine curve in which the peak of the half-cycle that is used is lower than that of the half-cycle that is suppressed; and in the case of full-wave rectification the plot becomes a series of more or less distorted half-cycles, all having the same electrical sign.

In pure sine wave alternating current, R.M.S. voltage may be computed from maximum instantaneous voltage or vice versa by substitution in the equation

$$\text{R.M.S.V} = \frac{\text{MIV}}{\sqrt{2}} \quad ,$$

but in pulsating unidirectional currents this simple relationship breaks down. The R.M.S. values for such nonsinusoidal currents could be determined by suitably designed meters or by complete analysis of the instantaneous voltages throughout the curve, but this is not commonly done because in the production of X-rays it is the maximum instantaneous voltage of the current passing through the tube that is of particular importance. This voltage is termed the peak voltage and since in practice it amounts to several thousands of volts it is commonly expressed in kilovolts (1,000 v. = 1 kv.). In most X-ray generators the so-called kilovoltmeter is merely an ordinary A.C. voltmeter wired across the primary winding of the high-tension transformer but calibrated in peak kilovolts by means of direct sphere gap measurements of tube voltage made by the manufacturer during the factory calibration of the machine.

For fluoroscopy and the making of X-ray films, tube current may be as low as 3 ma. or as high as 500 ma. or even higher, and voltage usually ranges from 45 kv. to 90 kv. or even up to 130 kv. The magnitude of the voltage applied to an X-ray tube has two important effects on the radiation that is produced. It determines the wave-length composition of the beam and therefore its penetrating ability, and in addition affects the intensity of all beam components exponentially. For example, a tube voltage of 45 kv. will produce a certain amount of rather soft radiation having a maximum shortness of approximately 0.274 angstroms (A) (0.274×10^{-8} cm.), a type of radiation so feebly penetrating that it is unsuitable for the fluoroscopy or filming of heavy body parts. Doubling the voltage (to 90 kv.) brings the maximum shortness of the beam down to 0.137 A, thus providing penetration adequate for the thickest anatomical parts, and in addition this voltage change quadruples the intensity of all the components of the beam.

Contrary to a widely held misconception, there is no specific relationship between the part to be examined and the voltage, current and exposure time that should be employed. As far as the photographic effect is concerned, these factors—voltage, current and exposure time—may be juggled almost at will, provided only that the time intensity product of the radiation reaching the film approaches a constant that has been determined empirically as adequate for recording the tissue densities of the body part that is being examined. The experienced radiologist or X-ray technician uses voltages of approximately 60 kv. and currents of something like 25 ma. for thin body parts that can be well immobilized, thus keeping the exposure time within the range where minor time switch errors are of negligible importance and allowing the use of fine-focus tubes; but when the work to be done requires that the exposure time be as short as possible, he sets the time switch for $\frac{1}{60}$ sec. or sometimes even $\frac{1}{120}$ sec., sets the current at the maximum allowable for the tube (for example, 500 ma.) and then adapts to variation in the thickness and density of body parts by varying kv.

X-Ray Generators.—In their simplest form the X-ray generators used in diagnosis consist of a hot cathode X-ray tube, a controllable means of heating the cathode, a source of alternating current and a means of regulating the voltage of that current. Circuits of this sort are known as self-rectified because in them the X-ray tube itself acts as a rectifier, passing one half-cycle and suppressing the other half-cycle of the raw alternating current that is supplied by the transformer. Thousands of sets of this design are in daily use throughout the world, functioning as dental X-ray machines, portable and bedside X-ray machines and in small fluoroscopes. They are adequate where the service is intermittent and the loads range from 3 ma. to 10 ma. at potentials from 40 kv. to 75 kv., but for heavy work full-wave rectification is preferable.

In theory, full-wave rectified generators differ from the self-rectified sets described above merely by the insertion of four kenotrons between the high-voltage terminals of the transformer and the terminals of the X-ray tube. In practice, however, they are much more complex, including voltage stabilizers for the filaments of valve tubes and X-ray tube, voltage regulators for the primary windings of the high-voltage transformer and the X-ray filament transformer, devices for the automatic selection and limitation of tube voltage and current, circuits for energizing the rotors of rotating anode tubes, meters, fuses, circuit breakers and some means for the precise timing of both short and long exposures. In addition, they allow employment of higher voltages and larger tube currents. All modern generators are completely insulated or "shockproof," regardless of whether they are of the self-rectified or the valve-tube-rectified type.

X-Ray Tubes.—The tubes used in X-ray diagnosis consist of a well-exhausted glass-enveloped diode surrounded by a metallic housing that is lined with lead, except at a small port through which the useful beam of X-rays emerges. The space between glass insert and housing is filled with insulating oil. In the simplest and smallest sets the tube housing is integral with the transformer housing, but in larger machines the two usually are separate, tube and transformer being connected by means of flexible, shielded, insulating cables. In these modern descendants of William David Coolidge's hot cathode tube, the cathode stream is focused as a ribbon on a steeply inclined target so that the heat of impact will be distributed as widely as possible and yet the optically effective source of the rays will approach a point. Frequently two filaments are provided—one focusing the electrons sharply for use when great detail is required and small currents

are allowable, the other distributing the electrons over a larger target area for use when heavier currents must be employed. Targets are of two general types—those that are stationary and those that rotate or spin during operation. In the stationary anode tube, the target is of swaged tungsten embedded in a massive copper anode which extends out through the glass envelope to conduct the heat of electron bombardment into the insulating oil that surrounds the tube. Sometimes there is a pump or impeller to circulate the oil and usually there is a blower to expedite removal of heat from the housing.

Rotating anodes turn on precision bearings that are mounted within the exhausted glass envelope and therefore must be devoid of ordinary lubricants which would ruin the vacuum. The stator lies outside the envelope, its lines of force passing through the glass to operate the rotor which is attached to the anode stem. Sometimes the anode disk is of massive copper with an embedded belt of tungsten to receive the electron bombardment, but more commonly it is of solid tungsten capable of withstanding a cherry-red heat during heavy loading. For many applications rotating anode tubes are extremely satisfactory, but they have the serious limitations of dissipating target heat almost exclusively by radiation through the glass envelope and lacking the direct conduction through copper that is so effective in the case of stationary anode tubes.

Fluoroscopy.—A fluoroscope is an apparatus for the direct observation of body tissues by means of X-rays. It consists of a fluoroscopic screen supported in front of the port of an X-ray tube so that a patient may be interposed between the screen and the source of the radiation. A shutter usually is provided to control the area of the beam of radiation emitted by the tube, and a sheet of plywood or other strong but radiolucent material is interposed between tube and patient to provide a surface on which he lies when the instrument is tilted from the vertical into the horizontal position.

Many crystalline substances will glow when exposed to X-rays. Among the best for clinical fluoroscopy is zinc cadmium sulphide mixed with traces of other materials. A fluoroscopic screen consists of a piece of cardboard coated with a layer of such fluorescent salts and faced with a sheet of thick lead-bearing plate glass that is highly opaque to X-rays but almost perfectly transparent to the greenish light given off by the fluorescing crystals.

Fluoroscopy has a great advantage over filming in that it is able to record motion, but there are many offsetting disadvantages, the most important of which is the inevitable radiation hazard to operator and patient. In addition, fluoroscopy lacks objectivity because it leaves no permanent record and the image on the screen is so faint that to see it the room must be well darkened and the eyes of the fluoroscopist fully dark-adapted. The dark-adapted eye employs largely the rod type of vision which is suitable only for rather coarse "seeing." Thus, many of the finer anatomical details that would be seen well by the cone vision used in examining brightly transilluminated X-ray films cannot be seen at all on the fluoroscope. Formerly fluoroscopy was widely employed to detect fractures of the extremities and to aid in their reduction, but it was recognized that this practice is dangerous to patient and physician, as well as being diagnostically inferior to filming. The most important remaining clinical use of fluoroscopy is in the examination of the alimentary tract and the spinal cord, where it is used in conjunction with filming.

Films, Screens and Cassettes.—X-ray films consist of an acetate cellulose base coated on both sides with an emulsion of silver halide and gelatin. It is possible to prepare emulsions that are particularly sensitive to X-rays, but since most X-ray films are used in conjunction with calcium tungstate intensifying screens, the emulsions are given maximum sensitivity to the fluorescence of calcium tungstate rather than to X-rays themselves.

For the examination of certain parts—such as the teeth, fingers and toes—plain film without screens is ordinarily used, and in such applications it suffices to wrap the film or otherwise enclose it in a covering such as black paper or cardboard which is opaque to visible light but not to X-rays. For the filming of heavier parts, however, the exposure time can be reduced and the contrast in the image enhanced if films pressed between two intensifying screens are used instead of plain films. These screens must be in intimate contact with the emulsions if sharp detail is to be recorded. Such contact is provided by rigid lightproof containers known as cassettes. The fronts of cassettes are made of bakelite or magnesium to exclude light but admit X-rays, and when phototiming is employed the backs must also be reasonably radiotranslucent. The screen attached to the inside of the cassette front is purposely thin because it must transmit most of the radiation, but the rear screen is thick, absorbs more radiation and fluoresces more actively. In the making of a film—for example, of the chest—the patient stands facing a 14-in. × 17-in. duplitized X-ray film (double emulsion) contained in a double-screen cassette of the sort described above, the X-ray tube being arranged so that its beam of radiation passes through the patient's back in a direction perpendicular to the surface of the film. The X-rays induce a moderately brilliant fluorescent image of the lungs, ribs, heart, etc., on the front screen, produce a slight photographic effect directly on the front and rear layers of film emulsion, and finally induce a brilliant fluorescent image on the rear screen. The light from the two fluorescent images photographs itself onto the emulsion along with the two direct X-ray images, and in the completed film all four images, being superimposed, appear as one.

Primary and Scattered Radiation.—X-rays arise on the target of an X-ray tube at the point where it is bombarded by electrons emitted by the cathode. In fine-focus tubes the effective X-ray source may have a diameter as small as 1.0 mm. and in coarse-focus tubes as large as 4.5 mm. All else being equal, X-ray images are sharpest in detail when the radiation source approaches a point and become blurred when the source is large. In the discussion that follows, we shall assume, for convenience, a point source of radiation.

From their point of origin X-rays are propagated in straight lines in all directions over a solid angle of 4π, but most of them are absorbed in the lead lining of the housing and the cone of useful radiation that emerges through the port has an apex angle of only aproximately 15°. Within the ordinary meaning of the terms, X-rays cannot be reflected or refracted by the substances they encounter on their straight-line course to the X-ray film, but some of them do become scattered. For small, thin parts, scattering is practically negligible, but for heavy parts, such as the skull and trunk of an adult, the radiation that is scattered in the patient's body fogs the image formed by the straight-line or primary radiation to such a degree that finer details become indistinguishable.

Prior to 1917 good X-ray plates of the skull, spine, hip, etc., required that the primary beam be narrowed to a very small diameter to reduce scattering, and 14-in. × 17-in. plates of the entire pelvis of a heavy subject were so badly fogged by scattered radiation as to be of little clinical usefulness (they were glass plates in those days rather than films). However, as early as 1912 Gustav Bucky in Germany laid the groundwork for overcoming this difficulty, and by the early 1920s there became commercially available, first in the U.S. and later in Europe, moving grids designed by the U.S. radiologist Hollis Potter. These instruments, known as Potter-Bucky grids or, less properly, as Potter-Bucky diaphragms, became an indispensable part of the equipment of all diagnostic radiologists. Such grids, consisting of an assembly of lead strips interspaced with strips of wood, plastic or other radiotranslucent material, are interposed between patient and film and are kept in motion while the exposure is being made. The lead strips are aligned as radii of a segment of a theoretical cylinder that has a diameter equal to twice the target-film distance. A small portion of the primary or unscattered radiation that emerges from the patient's body impinges squarely on the edges of the lead strips where it is absorbed, but most of it passes through the interstices between the strips and thus to the film. The scattered radiation, on the other hand, being no longer aligned with the translucent interstices, impinges for the most part on the sides of the lead strips, where it is absorbed.

In Bucky's original stationary grids, the metallic members were thick and widely spaced, thereby causing disturbing patterns on the film, and Potter's contribution was to conceive and build grids

that could be moved during exposure, thus obliterating the pattern of their grid members but not interfering with their ability to absorb scattered radiation. Modern moving grids are flat rather than curved; they are built to extremely precise dimensional tolerances, have greatly improved ability to absorb scattered radiation and reciprocate throughout the exposure instead of starting before the exposure begins and continuing to move in the same direction until the exposure has been completed. Stationary grids were improved even more. In their original form they were virtually useless except as precursors to a great idea, but the work of the Swedish radiologist Eric Lysholm revived interest in them. Excellent European and U.S. units became available, some composed of parallel strips, others having two systems of parallel strips aligned at right angles to one another to form crisscross or honeycomb grids. Grids of this latter type came to be used widely for bedside raying, raying in the operating room, for angiography and for spot filming of the stomach and intestines.

Unlike the moving grids, the stationary ones inevitably leave their own images on films along with the images of the body parts that are being examined. In modern stationary grids, however, these superimposed patterns are regular and faint, detracting little from appearance and nothing from clinical usefulness.

Timing the Exposure.—When the intensity of the X-ray beam is low and the exposure time of the order of 10 sec., errors of plus or minus a few tenths of a second are negligible and the simplest of spring-driven time switches are adequate to time the exposure; but for tube currents of from 100 ma. to 500 ma. and exposure times of the order of $\frac{1}{60}$ sec., precise timing becomes important and difficult, much of the difficulty being inherent in the pulsating nature of the current applied to the X-ray tube. When 60-cycle current is employed, X-rays are emitted by the target not continuously but in brief bursts starting from zero, rising to full intensity and then returning to zero every $\frac{1}{120}$ sec. (each half-cycle). Brief exposures therefore must be measured out in half-cycles and it is important that the exposures be initiated and terminated approximately at zero points on the voltage wave. In other words, the timing device and the contactor must be phased with the generator. Such phasing formerly was accomplished reasonably well even with heavy conventional magnetic contactors, but it was rendered vastly easier and more precise by the substitution of the electron discharge in heavy-duty thyratrons for mechanically operated metal-to-metal contacts.

Phototiming.—In the early 1940s it became possible to time X-ray exposures automatically by means of multiplier phototubes. Phototiming, as it is called, gradually was made available in commercial X-ray machines. In general radiography the phototube and a fluorescent screen are mounted in a box that is impervious to light but has a top that is transparent to X-rays. This box, known as a detector, is located beneath the Potter-Bucky grid where it receives radiation that has passed through the patient's body, the film and the cassette. The detector is calibrated empirically so that when the film has received an amount of exposure that will assure an optimum image, the phototube will have received sufficient fluorescent light to cause it to trigger an electronic switch and thus terminate the X-ray exposure. In photofluorography (described below) the phototube is mounted in the camera head and, like the lens, "observes" the fluorescent screen. In the case of the filming fluoroscope, which is so important in the examination of the gastrointestinal tract, the phototube scans an image produced on the fluoroscopic screen by radiation that has passed through the patient's body and through the back of the film cassette.

Processing X-Ray Films.—When the technician who exposes an X-ray film also develops it, the composition and temperature of the developer and the length of development need not be regulated precisely because modern films have wide latitude and the experienced worker learns to shorten or prolong development until inspection before a safelight indicates that an acceptable image has been obtained. Where the volume of work requires division of labour, however, the situation is different. One set of workers exposes the films to carefully measured amounts of radiation and another group working in darkrooms develops them in solutions of standard strength and temperature for standard periods of time. After World War II, larger hospitals and clinics turned to automatic film-processing machines, and even in smaller laboratories the simpler hand-operated processing tanks usually included constant-temperature baths. The common practice is to standardize exposures so that development for from four to five minutes at temperatures of from 65° F. to 67° F. in standard-strength developer will yield films of optimum density. For special examinations, such as those conducted in the operating room in conjunction with surgery, the solutions may be made rather warm in order that developing time may be shortened, the saving in time being considered more important than the inevitable reduction in the quality of the image.

The Land method of rapid film processing was adapted for certain phases of military radiography. The "film" is enclosed in a special envelope that contains capsules or "pods" of processing chemicals. After exposure to X-rays the film-chemical assembly is passed through a special wringer box and a few seconds later is developed, fixed, dried and ready for inspection by the radiologist.

Photofluorography.—From the earliest days of radiology, attempts were made to make permanent records of fluoroscopic images by photographing them, but until the late 1930s the manoeuvre saw little practical application. The advantage of photofluorography lay in its ability to employ small, inexpensive and easily processed photographic roll film instead of large, costly, individual sheets of X-ray film, its disadvantage in the fact that fluoroscopic images were faint and the camera lenses available for recording them slow. As far as the chest is concerned, the disadvantages finally were overcome by developing faster film emulsions, faster screens and refractor lenses large enough to cover a 64-mm. by 70-mm. area on roll film and yet having a speed of F/1.5. Millions of members of military and civilian populations were subjected to small-film chest surveys, but though such photofluorography of the chest is of genuine importance as a public health measure it is not a rival of the older methods as a means for the detailed study of pulmonary diseases.

The substitution of large-aperture reflector lens systems for the F/1.5 refractors made it possible to extend microfilm surveys to the alimentary tract where the fluoroscopic image is much fainter than in the case of the chest, but the importance of such surveys to the individual and to the public health was still doubtful in the early 1950s.

X-Ray Motion Pictures.—Within a year following Wilhelm Konrad Röntgen's announcement of the discovery of X-rays, attempts were made to produce X-ray motion pictures. Scores of publications on the subject appeared thereafter in the public and scientific press. More than half a century later, however, no really practical method had been developed. In the so-called direct method a motion-picture positive is made from a sequence of individual X-ray negatives, and in the indirect method the positive is printed from a motion-picture negative of the fluoroscopic screen. Both methods have limited applications in experimental medicine but both have the fault of requiring too much X-ray exposure to the tissues that are being examined.

Electronic Amplification of the Fluoroscopic Image.—The conventional fluoroscopic image of the abdominal organs of an average adult has a brightness only about $\frac{1}{30,000}$ as great as that of a page of newsprint viewed by the light of an ordinary reading lamp. Even this amount of fluoroscopic brilliance assumes the use of the most sensitive of modern fluoroscopic screens, a tube voltage of 90 kv. and a tube current of 3 ma. Even small increases in the amount of the X-rays employed would involve health hazards that would be out of keeping with the resulting gain in brilliance.

W. Edward Chamberlain and George C. Henny in 1947 discussed the theory of enhancing image brightness by electron acceleration. John W. Coltman produced an image tube with some clinical applications. R. H. Morgan had promising results using television techniques and R. J. Moon worked on a method of amplifying the fluoroscopic image by means of a scanning X-ray tube.

Dental Radiography.—Intraoral films were early employed

for detecting abscesses in the bone about the apexes of the teeth, for locating unerupted or impacted teeth and for discovering retained broken tooth roots. Their field of usefulness was enlarged until they came to play an important part even in the periodic examination and cleaning of the teeth. Small cavities at abutting surfaces, poorly fitting fillings and inlays, recession of the bone from the necks of the teeth and, most important of all, subgingival deposits of salivary calculus—such lesions as these are easily detectable in X-ray films though they may escape all but the most skilful and searching direct inspection.

Radiography of Bones.—For the first few years following Röntgen's discovery, it seemed that X-rays might be used in medicine chiefly as an aid in the diagnosis and reduction of fractures, but subsequently almost all the tissues of the body came within the scope of radiography. In the case of bones, X-ray films are used not only for the detection of injuries but also for demonstrating the presence of tumours, infections and almost every other form of skeletal disease. In normal bone the cortex shows in X-ray films as a dense amorphous shell and the spongy portion as a honeycombed structure made up of the shadows of the coarse primary trabeculae, on which are superimposed the shadows of the fine secondary trabeculae. The disuse of living bone causes a generalized loss of density known as osteoporosis, but when portions of bone are killed by disease or injury before osteoporosis has occurred, they retain their original density for long periods of time. Some tumours and infections cause localized destruction of bone and others cause the bone to become denser than normal (sclerosis). Certain parts of normal living bone, such as marrow, periosteum and articular cartilage, though not themselves discernible by X-rays, may when diseased produce subtle changes in visible bone adjacent to them, thus leading to their own detection. Rickets, scurvy, syphilis, tuberculosis, Paget's disease, benign and malignant tumours and many other skeletal diseases produce changes in the X-ray appearance of bones that are almost always easy to see and frequently so characteristic as to warrant a specific diagnosis.

Stereoscopic X-Ray Films.—Three-dimensional vision is helpful in the radiography of any part of the body and almost essential in X-ray examinations of the skull and trunk. Two films that are required are made with the film and body part in identical spatial relationship for each but with the X-ray tube shifted slightly between the two exposures. The amount of the shift is determined by the relationship between the distance from the film to the target of the X-ray tube at the time the exposure is made and the optical distance from the film to the eyes of the observer at the time the two films are examined. If these two distances are identical the tube shift should be 66 mm., which is the average interpupillary distance, but if the more common situation obtains and target-film distance is greater than film-eye distance, then the tube shift must be increased proportionally.

Even without the aid of instruments some workers become able to view one of the films with one eye, the other with the other eye and then fuse these two slightly dissimilar, real, flat images into a single, virtual, three-dimensional image. It is more convenient, however, and for some persons actually essential to employ a special viewing apparatus known as an X-ray stereoscope.

Chest and Heart.—Although internists and surgeons must lean heavily on the findings of the radiologist for the detection and managing of such pulmonary diseases as tuberculosis, pneumonia and cancer, they must weigh all the evidence in making the final diagnosis and not depend on X-rays alone. Active fibrocaseous tuberculosis usually produces rather characteristic dense splotches in one or both of the lung apexes, but at certain stages in their course some of the pneumonias show almost identical X-ray patterns. Malignant tumours arising in the bronchi usually reveal themselves promptly by causing bronchial obstruction with resulting rather typical areas of atelectasis. Foreign bodies accidentally introduced into the trachea or bronchi frequently are dense enough to show directly in X-ray films but when radiotranslucent may be detectable with the aid of opaque mediums or by virtue of changes they produce in the air patterns of the lung. When the diagnosis of pulmonary tuberculosis has been established, repetition of the X-ray examination is important for observing the results of treatment, but here too it is only by combining information obtained by numerous means that the physician can be sure a particular lesion is healed or that another is still active.

Radiology plays only a minor role in the diagnosis and management of heart disease, but it plays that role well. It is the best means of determining the size and shape of the heart and provides dramatic proof of the presence or absence of aortic aneurysm. Cardiologists faced with the seemingly hopeless task of predicting the likelihood or unlikelihood of coronary disease in subjects who have not yet had an attack would welcome radiologic information as to the presence or absence of calcification in the coronary vessels. In the cadaver it is an easy matter to make stereoscopic films that will show such calcified vessels in great detail, and even in the vigorously moving living heart the radiologist can by employing heavy currents and very brief exposures make acceptable single films. Three-dimensional portrayal is needed, however, to distinguish calcification in the coronary vessels from that in hilum glands, ribs, costal cartilages and other structures, and at mid-20th century methods for obtaining it were still lacking.

Contrast Mediums.—The lungs show in X-ray films and in fluoroscopic images by virtue of the sharp difference between the X-ray absorbing power of the air that distends them and that of the pulmonary tissue itself. This difference in absorbing power is called "contrast." The heart, being composed largely of muscle and blood, contrasts strongly with the air-filled lungs adjacent to it but scarcely at all with the liver beneath. The uterus, also composed of muscle, normally does not contrast with the structures surrounding it because usually they too have about the same density of muscle. Bones are distinguished from surrounding muscle and the various parts of bone from one another by virtue of the calcium phosphate they contain. The deposition of radiopaque salts makes it possible to see most of the stones that may be formed in the kidney and urinary bladder and some of those that occur in the gall-bladder.

To a great extent, however, the clinical usefulness of the X-ray examination depends on the employment of artificial contrast mediums. The most extensively used opaque medium is barium sulphate. Stirred into water and flavoured with a little chocolate syrup, this insoluble heavy metal salt is employed for examination of the oesophagus and stomach, and mixed with powdered acacia and water it becomes a barium enema for the examination of the rectum, colon and terminal ileum. For the examination of the gall-bladder the halogenated phthalein introduced by Evarts A. Graham gave way to β-(4-hydroxy-3,5-diiodophenyl)-α-phenylpropionic acid (Priodax) or another similar but more highly iodized organic compound, Telepaque.

X-ray visualization of the bronchi better than that obtained merely by the contrast of contained air is made possible by the introduction into the bronchial tree of unsaturated vegetable oil partially saturated with iodine (Lipiodol). An emulsion of ethyl iodophenylundecylate (Pantopaque) was offered as a substitute for Lipiodol in bronchography and largely supplanted it in the examination of the spinal canal (myelography).

Among several iodized organic compounds available as contrast mediums for the urinary tract and blood vessels, iodopyracet compound (Diodrast) was in widest use in the United States during the early 1950s. The colloidal suspension of thorium dioxide (Thorotrast) had fallen into disrepute. Thorotrast may be injected into the blood stream with little or no immediately unfavourable reaction, is extremely opaque to X-rays and is perhaps the only medium that can be expected to accomplish X-ray visualization of the spleen and liver, but these important advantages are negated by potential long-range dangers inherent in the particulate nature of the material and the fact that it is slightly radioactive.

Skull, Brain and Spinal Cord.—The X-ray criteria employed for diagnosing injuries and diseases of bone are most dependable in regions where cortex is thick and well differentiated from spongiosa, as in the long bones of the extremities. Cortex is well developed in the vault of the skull, and fractures, neoplasm, in-

fection, etc., there are usually reasonably evident. In the face bones where the cortex may be as thin as paper, however, such lesions may be almost invisible.

Because of the air that they contain, the normal mastoids and the sinuses (frontal, ethmoid, maxillary, sphenoid) show as black shadows sharply silhouetted against bone, and if fluid or benign or malignant tumours are present they too will stand out in contrast with the air. Certain tumours of the pituitary gland cause the sella turcica to enlarge in a characteristic fashion, and in young children a long-continued increase in the intracranial pressure may be inferred from a resulting "bursting of the seams" of the skull, or diastasis of the sutures as it is called.

The brain itself is radiotranslucent except for several normal and occasional pathological patches of calcification, and so it is necessary to employ contrast mediums when the brain is to be examined, the medium of choice being oxygen or air. When such gases are introduced into the subarachnoid space, the procedure is termed encephalography, and when they are injected directly into the hollow chambers or ventricles at the centre of the brain it is called ventriculography. In either case, the X-ray examination is done with stereoscopic films rather than fluoroscopy, and the object is to study the internal and external contours of the brain by virtue of the gas that is in contact with them.

Opaque mediums are much more effective than gas for examining the spinal cord and the canal in which it lies, a procedure known as myelography. In the United States, Pantopaque is the medium most commonly employed for myelography, but water-soluble organic compounds such as Diodrast are sometimes used, particularly in Europe. Under fluoroscopic control, the contrast material in the subarachnoid space is manoeuvred into all parts of the spinal canal from the tip of the caudal sac in the lumbosacral region up to (but not into) the cisterna at the base of the brain. The films that are made at all levels and in several positions show the cord itself as a translucent or negative shadow and the surrounding subdural space as a dense shadow by virtue of the Pantopaque it contains.

Protruding knobs of intervertebral cartilage, spikes or ridges of arthritic osteophytes, tumours of bone, cord or meninges are among the abnormalities that may be detected by myelography; but normal variation is great and differentiation difficult even when the examination is conducted by teams of specially trained neurosurgeons and radiologists.

Gall-Bladder and Bile Ducts.—In 1923 E. A. Graham introduced a method for the X-ray examination of the gall-bladder which came into universal use, known as cholecystography. An iodized organic compound (Priodax or Telepaque at mid-20th century), after being given by mouth in tablet form, is absorbed from the alimentary tract into the blood and then removed from the blood stream by the liver and combined with the bile. A normal gall-bladder, receiving through its cystic duct watery, weakly iodized bile, concentrates it until eventually it becomes thick and its iodine content high. In X-ray films made 10 to 15 hours following administration of Telepaque, the normal gall-bladder casts a dense shadow and any cholesterol stones present stand out as negative shadows against the iodized bile. If the gall-bladder is seriously diseased or its cystic duct is occluded, bile will fail to reach the gall-bladder or, reaching there, will fail of concentration, either of these events resulting in nonvisualization.

Cholangiography, which is the examination of the bile ducts, usually is conducted in conjunction with surgery to assure that stones or a tumour obstructing the ducts have not been overlooked. Diodrast is the contrast medium usually employed, the injection being either through a T tube tied into one of the bile ducts or by means of a hypodermic needle introduced through the wall of a duct or of the gall-bladder itself.

Urinary Tract.—Pyelograms are X-ray films of the urinary tract made following the introduction of an opaque medium, usually Diodrast. In the retrograde method, Diodrast is injected through ureteral catheters introduced with the aid of a cystoscope. In the excretion or intravenous method, Diodrast is injected intravenously followed by filming at intervals of from 5 to 15 minutes.

Most tumours lying in the fleshy part of the kidney outside its collecting system compress, stretch and otherwise distort the calyces and pelves. Tuberculous abscesses are prone to break through into the calyces, allowing the opaque medium to extravasate into disease tissue, and the infrequent kidney stones that are radiotranslucent may be rendered visible by Diodrast in the same way that Telepaque visualizes cholesterol gallstones. Cystograms are films of the urinary bladder made after the direct or excretory filling of that organ with Diodrast. Bladder tumours, diverticula and urethral obstruction by chronic prostatic enlargement produce rather characteristic alterations in the appearance of the cystogram.

Use of Radiology in Gynaecology and Obstetrics.—Sterility of the human female may result from various causes, one of which is occlusion of the fallopian tubes. The best means of demonstrating such occlusion is to make X-ray films following the injection of iodized oil into the uterus. In the normal subject, the oil passes out through both fallopian tubes to spill into the peritoneal cavities where, 24 hours later, it becomes smeared over the serous surfaces of loops of bowel and appears by X-ray as a slightly opaque, crumpled veil. When no connection exists between the uterine cavity and the peritoneal cavity, the peritoneal spread of the oil does not occur, and when occlusion is due to saclike adhesions about the outer ends of the fallopian tubes, the oil breaks up into droplets and is retained in the watery fluid that fills the sacs (hydrosalpinx). While the purpose of the injection is diagnostic, it is believed that it may sometimes be therapeutic as well, breaking up adhesions if they are not too tough and developing communication where none existed before.

When a pregnant woman is known to have an obstetrically adequate pelvis and a presumably normal foetus, pelvic X-ray examination seldom is called for, but if circumstances require quantitative knowledge as to the dimensions of the birth passages, the X-ray examination is by far the best means of measuring them.

Since X-rays diverge from their point of origin, the X-ray images of anatomical parts that are parallel with the plane of the film are always somewhat larger than the parts themselves; and if the parts are oblique to the film, that too causes distortion of the image. With the aid of a little special equipment and the application of a little simple geometry it is possible to compensate for distortion and translate measurements of film images into the actual dimensions of the maternal or foetal parts they portray, the procedure being known as pelvimetry or foetometry.

Blood Vessels.—For many decades opaque injections of heavy metal salts were used for making X-ray films of the blood vessels of anatomical specimens, and later angiography of the living subject became of serious clinical importance. Diodrast is the medium commonly employed. When the vessels to be injected are those of the brain, most workers prefer to use the material in 30% concentration, but for the chambers of the heart and the great vessels leading from them concentrations as great as 70% are necessary. Several films must be made in rapid succession, each exposure being brief, the first in the series phased carefully with the beginning of the injection. For angiography most radiologists employ wide rolls of X-ray film motor-driven past a radiolucent window in a device patterned after aeroplane mapping cameras but, of course, having no lens. Other workers prefer series of cut film in either standard or special cassettes, and photofluorography has been employed experimentally. Motion pictures of the electronically amplified fluoroscopic screen constitute the ideal but at mid-century still unattainable medium for angiography.

Angiograms are used for the investigation of certain brain tumours, to identify obstructions and abnormal communications involving vessels of the extremities and, above all else, for the study of the abnormal anatomy of the great vessels in patients with congenital heart disease for whom cardiac or vascular surgery is contemplated.

Stomach and Intestine.—X-ray examination has become an important, almost indispensable, agent in the diagnosing of peptic ulcer, benign and malignant tumours of the oesophagus, stomach and bowel, diverticulosis and diverticulitis, ulcerative colitis, regional ileitis and several other diseases. Barium sulphate is the

medium almost invariably employed. Formerly it was the fluoroscopic examination that made the diagnosis, with films occupying a position of secondary importance, but many modern radiologists came to look upon fluoroscopy largely as a means of obtaining small, so-called "spot" films of various parts of the tract. In spot filming, the fluoroscopist manipulates a small segment of the alimentary tract into position beneath the fluoroscopic screen and adjusts the amount of barium that it contains and the pressure applied to it until he has an optimum view. A film is now brought into position between the patient and the fluoroscopic screen and, when the X-ray machine setting has been changed from the continuous small current adequate for fluoroscopy to the high voltage and large currents needed for rapid filming, the exposure is initiated with a foot switch and terminated automatically with a phototube. Peptic ulcers usually deform the outline of the stomach or duodenal bulb and, in addition, frequently excavate craters which, when filled with barium, are highly diagnostic. Cancers appear as soft tissue masses protruding into the lumen of the stomach or bowel and distorting the appearance of the gastric or intestinal mucosa.

THERAPEUTIC RADIOLOGY

One of the most remarkable attributes of the X-rays that Röntgen discovered in 1895 was the seemingly innocuous way in which they penetrated human tissue without causing pain, a feeling of heat or any other immediate sensation; but it did not take long to learn that in spite of the absence of immediate effect, large doses led presently to redness of the skin, blistering and ulceration. Even small doses, it was found, if repeated often enough were followed by serious skin lesions that showed up only after a considerable lapse of time. Of course, an agent so capable of damaging normal tissue was bound to be employed therapeutically on the theory that some means might be found to direct its damaging effects specifically against diseased parts.

By the early 1950s a little had been learned about the fundamental nature of the biological action of radiation, and research on this subject had been accelerated; but usefulness had not waited on a complete understanding. Radiation therapy became one of medicine's few means of restraining and in some cases curing cancer.

Those who practise it must be able to measure the dose and map its distribution in the body with great precision, but they must accept the fact that frequently the cancers at which it is aimed can be delimited only approximately. It is a professional requirement that they keep always in mind quantitative information as to the optimum dosage and technique for each of scores of types of neoplasms without forgetting that such information is empirical and that individual response may be at sharp variance with the rule. They must be optimists without becoming complacent; strive for major victories but be content sometimes with small gains; advance their specialty as a science but apply it as an art.

The radiations they employ include X-rays ranging in voltage from about 5 kv. to more than 4,000 kv., radium, artificial radioisotopes, electrons, neutrons and other high-speed particles. Important differences in the physical distribution of the dose determine which of these should be used for a particular application, but biologically speaking it is the similarities rather than the differences that are most obvious throughout the entire range from the low-voltage X-rays used in contact therapy to the high-speed particles of the largest cyclotrons.

Historically and for several other reasons a discussion of radium and low- and medium-voltage X-ray therapy lends itself particularly well to an exposition of principles that apply throughout the entire radiation range. It is for this reason alone that radium and X-rays of low and medium voltage are emphasized below. This distribution of emphasis should not be misinterpreted as indicating that multimillion-volt X-rays, radioisotopes and high-speed particles are clinically unimportant.

Progress after Röntgen.—The ideas of Heinrich Geissler, J. W. Hittorf, Sir William Crookes and P. E. A. Lenard were important immediate antecedents to those of Röntgen, and in the years after 1895 the stream of those ideas was swelled by innumerable tributaries. Italians such as Enrico Fermi supplied key ideas in nuclear physics. Frenchmen such as the Curies, H. Coutard, A. Lacassagne and C. Regaud discovered radium and established the importance of the time factor as a modifier of the reaction of tissue to radiation.

German physicists made important contributions, and German physicians such as H. Holthusen studied large masses of clinical material to establish much empirical knowledge. Scandinavians typified by G. Forssell and R. Sievert refined and advanced dosimetry and made large-scale clinical application of facts established in the laboratory.

British contributions were of two sorts. In the closing decades of the 19th century and the opening decades of the 20th such physicists as J. J. Thompson, C. T. R. Wilson, H. G. J. Moseley and the two Braggs led in the development of X-ray physics, and later such physicians as Ralston Paterson and David Smithers and such radiation physicists as W. V. Mayneord, W. J. Meredith and H. M. Parker increased the precision with which radiation beams may be regulated and directed and advanced knowledge as to the response of normal and diseased tissues to such beams.

In the U.S., W. D. Coolidge conceived and produced X-ray tubes superior to anything available before, and Arthur Compton and his students, employing X-rays to study the nature of matter, discovered in the process new and important facts about the X-rays themselves.

Ernest Lawrence's pioneering cyclotron typified a whole group of instruments developed for accelerating particles of various sorts, and the large-scale biological experiments on ionizing radiation that were carried on during World War II under John Lawrence in California and under Robert Stone in Chicago served as patterns for many later similar activities.

During the war years it was necessary to direct most of such effort at the military aspects of radiation, but with the lifting of restrictions on materials and information the clinical aspects received the attention of increasing numbers of U.S. physicists, biologists and physicians.

MEASURING THE DOSE

The dose employed in X-ray therapy cannot be defined merely by stating the voltage and current at which the X-ray tube is operated. Numerous other factors are involved, including diameter and filtration of the X-ray beam, target-skin distance and the size and location of the lesion being irradiated. The need of dependable dosage guides was recognized more or less clearly from the outset but their development proved difficult. Tried and found wanting were the measurement of the heat produced by the absorption of X-rays; the intensity of fluorescence; colour changes in several different combinations of chemicals; the blackening of silver bromide paper; the liberation of iodine from a solution of iodoform in chloroform and an increase in the electrical conductivity of selenium under the action of X-rays.

Ionization Methods.—Röntgen's original papers described the ability of X-rays to ionize air and in 1896 J. J. Thompson independently discovered the effect and suggested its use by physicists as a means of measuring X-ray intensity. P. Villard in 1908 advocated ionization for measuring the clinical dose but his idea was not practical at that time because the large, delicate ionization chambers that were serving physicists so well were not suitable for clinical work and no others were available. Gradually, however, small, rugged chambers were developed, and in 1928 at the second International Congress of Radiology in Stockholm, Swed., there was adopted the "r" or roentgen unit, which became the standard throughout the world.

The Roentgen Unit.—The roentgen unit was defined in Stockholm as follows:

> The unit of dose is that quantity of roentgen radiation which, when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produces in 1 cc. of atmospheric air at 0° C. and 760 mm. mercury pressure such a degree of conductivity that one electrostatic unit of charge is measured under saturation conditions.

This definition sufficed as long as the X-rays to be measured were produced at voltages up to 200 kv., but as r meters began

to be employed in the 1,000-kv. range and for the gamma-rays of radium, the following definition was substituted:

> The roentgen shall be the quantity of X or gamma radiation such that the associated corpuscular emission per 0.001293 grams of air produces, in air, ions carrying 1 esu of quantity of electricity of either sign. (The mass of 1 cu. cm. of dry atmospheric air at 0° C. and 760 mm. of mercury pressure is 0.001293 gm.)

Roentgen (r) Meters.—The condenser-type r meters in general use in the United States consist of two parts, a chamber-condenser unit and a charging-measuring unit. Three sizes of chamber usually are supplied—a large one that measures up to 25 r, an intermediate size measuring up to 100 r and a small chamber for measurements up to 250 r. The electrometer that measures the charge has three corresponding scales calibrated from 0 on the left to 25 r, 100 r or 250 r, respectively, on the right.

Chamber-Condenser Unit.—In the 100-r unit the chamber itself is a small plastic thimble that contains one cubic centimetre of air at room temperature and pressure. The inside of the wall of the chamber, which has been rendered conducting by a thin coating of carbon, constitutes one electrode and is connected to the metal sheathing that forms one of the plates of a 60-micro-microfarad condenser. The second electrode is a carbon-coated plastic rod mounted in a block of high-impedance material with its tip protruding into the air in the chamber, its base in electrical contact with the insulated plate of the condenser. Care is taken to exclude air from all parts of the system except the space inside the chamber itself.

Charging and Measuring Unit.—The charging and measuring unit consists of a hand-driven plastic disk that generates a static charge by rubbing against a leather pad, plus a quartz fibre electroscope that is calibrated in roentgen units. In using the instrument, the condenser is plugged into the charging unit and the charging wheel is rotated until the fibre stands at 0. The charged condenser is then disconnected from the electrometer and placed for a measured period of time with its chamber in the beam of the X-ray that is to be measured. The X-rays ionize the air in the chamber, causing it to become an electrical conductor, and this in turn allows the charge on the central plate of the condenser to leak to the wall of the chamber and thence to the outer plate of the condenser. When the partially discharged condenser is reconnected to the electrometer, the fibre has moved from the fully charged 0 position on the left toward the discharged 100-r position on the right, the precise amount of loss of charge being read directly in roentgens without computations of any sort.

Roentgen meters of this sort are secondary standards requiring initial checking against large standard chambers and occasional subsequent rechecking, but when they are carefully built and properly calibrated their accuracy is well within the limits necessary for radiation therapy. The required dose varies widely from as little as 1,200 r in some lymphomas to as much as 5,000 r in most laryngeal carcinomas.

LOW-VOLTAGE X-RAYS—5 KV. TO 100 KV.

Until the close of World War I most clinical X-ray apparatus could not be operated at voltages in excess of 100 kv. and, while this was more than enough for diagnosis, it limited therapeutic applications to lesions lying at or close to the surface of the body. Regardless of the inciting voltage, the raw beam as it leaves the X-ray tube contains amounts of long wave-length radiation that are enormously greater than the amounts of short wave-length rays. Because the long-wave rays are easily absorbed, they are said to be "soft," while the short penetrating rays are said to be "hard."

If raw radiation from a tube operated at 100 kv. is allowed to fall on a patient's skin, the soft radiation will be strongly absorbed in the superficial layers, so that an exposure time long enough to result in serious skin damage delivers only small amounts of relatively hard radiation to tissues lying a few centimetres beneath the surface.

Filtration through three millimetres of aluminum will harden such a beam so that it may be possible to deliver 20% of the surface dose to tissues five centimetres beneath the surface, but it is impractical to deliver doses of therapeutic magnitude to tissues ten centimetres deep unless the voltage at the X-ray tube is raised well above 100 kv.

Formerly the degree of reddening of the skin was used as an indication of the dose, but this so-called erythema dose had serious limitations and was abandoned in favour of actual tissue doses expressed in roentgens. Along with the conception of erythema dose went also an undiscriminating attitude toward the employment of radiation for almost any of the cutaneous diseases. Radiation has its place in dermatology but it is dangerous as well as useful and its employment must be restricted to physicians who are specially trained in its use. Under competent supervision, low-voltage X-rays are indicated in the treatment of such conditions as small- to moderate-size skin carcinomas, large keratoses, obstinate circumscribed neurodermatitis, plantar warts, superficial hemangiomas, scalp ringworm, cutaneous lymphomas and Kaposi's sarcomas, but in skin lesions where drugs and other agents will suffice they should be employed rather than X-rays.

Contact Therapy.—Much of the very soft radiation produced at any operating voltage is absorbed in the glass wall of the X-ray tube and when voltages are reduced below 30 kv. almost none of the rays are hard enough to pass through the glass. For some of the vascular birthmarks, keloids, skin cancers and certain other skin lesions, it is desirable to be able to irradiate superficial tissues heavily with only a minimum dose to deeper structures. This is made possible by special X-ray tubes in which the port for the emergence of the radiation is a thin sheet of beryllium rather than glass. Such tubes are operated at voltages of the order of five peak kilovolts and the circuits are arranged so that it is safe to press the port against the skin of the patient. These three factors —closeness of the target to the skin, low operating voltage and minimum beam filtration—operate to minimize the depth dose and maximize the dose at the surface.

RADIUM

Opinion as to the clinical importance of radium fluctuated widely after the discovery of this element was announced by the Curies in 1898. Administered internally, it is a slow but lethal poison devoid of any therapeutic value; but confined in airtight needles or capsules, sheathed with a filtering layer of one-half millimetre or more of platinum, it constitutes a gamma-ray emitter of established clinical importance. Radium needles or capsules having only thin layers of brass or Monel metal as filters emit large quantities of electrons or beta-rays and are of only limited clinical value.

The hardest gamma rays of radium have a hardness or penetrating power approximately equivalent to the hardest of the X-rays produced at 3,000 kv.; but paradoxically the important medical role of radium is to deliver large ionizing doses to superficial tissues while minimizing the effect at a depth. The explanation lies in the geometry of the situation. Gamma-rays like X-rays diverge from their point source of origin in a solid angle of 4π, so their intensity falls off as the square of the distance from that point of origin. Radium usually is employed in rods of appreciable diameter and length which act as multitudes of point sources re-enforcing one another, but to simplify the explanation that follows, it will be assumed that the radium has been concentrated in a single minute sphere. Since it is possible to bring the source of the gamma-rays into almost full contact with surface tissue it follows that tissues one centimetre distant from that source will receive only about 1% of the dose that is delivered at the surface, and tissues five centimetres distant only about 4% of the dose delivered at one centimetre. (These values ignore losses by absorption and gains by scattering, though both must be taken into consideration in actual practice.)

In a few instances several grams of radium have been concentrated in heavily shielded containers that can be backed off five to ten centimetres from the surface of the patient's body. Such gamma-ray beams filtered through one millimetre of platinum deliver depth doses distinctly better than those obtained with radium at the surface or inserted into the body but are inferior in this respect to well-filtered 250-kv. X-rays from tubes stationed 80 cm., 60 cm. or even 50 cm. away from the surface of the body.

These so-called telecurie radium applicators would lose all justification with the availability of megacurie radiocobalt applicators, but heavily filtered interstitial and intracavitary radium employed sometimes alone and sometimes in conjunction with X-rays meanwhile continued to be important.

ARTIFICIAL RADIOISOTOPES

In addition to the series of naturally occurring radioisotopes of uranium known collectively as radium which emit gamma-radiation and have an aggregate half life of 1,590 years, there are available as products of cyclotrons and nuclear reacting piles a great number of artificial radioisotopes of many different elements. In some of these the radiation intensity decays to half its initial value in fractions of microseconds while others have half lives longer than that of radium. A few of these isotopes had been investigated clinically by the early 1950s but most of such work remained to be done. P^{32} administered intravenously as a sodium phosphate in doses of one to two millicuries a week for four to eight weeks is employed for the treatment of chronic leukemia. I^{131} administered orally as a solution of sodium iodide in doses of six to eight millicuries, repeated if necessary at trimonthly intervals, is used to reduce excessive activity of the thyroid gland, and occasionally cancer of the thyroid responds favourably to much larger doses. By mid-century there was great interest in the clinical possibilities of Co^{60}. Megacurie cobalt applicators under construction were expected to possess many of the virtues that were lacking and to avoid most of the faults that were inescapable in telecurie radium applicators. The charge of radioactive Co^{60}, though weighing only 12 g. and comprising a rod only 0.7 cm. in diameter and 3 cm. in length, will produce gamma-rays of 1.13 and 1.32 Mev with a source intensity more than 200 times that of the same weight of pure radium or 260 times that of radium chloride. It is true that the decay of intensity by one-half within five and three-tenths years will require occasional substitution of new cobalt and the consideration of decay time in computing the output of the applicator, but at most these should prove to be only minor inconveniences.

To shield against unwanted gamma-radiation and to regulate the dimensions of the port, the container itself and the port diaphragms will be constructed of uranium 13 cm. thick, but the removal of all beta-radiation from the beam will require merely a thin aluminum filter. With such a cobalt source stationed 80 cm. distant from the skin, it is expected that the surface dose to a 5 cm. by 5 cm. area will be approximately 35 r per minute and the dose 10 cm. beneath the surface 18.2 r per minute.

MEDIUM-VOLTAGE X-RAYS—100 TO 400 KV.

By 1915, German scientists had added three concepts and a group of associated techniques which became basic to the radiation therapy of deep-lying lesions. These concepts were: the role of voltage, filtration and the geometry of patient and X-ray beam in determining the dose delivered to deep-lying tissues. The techniques were Walter Friedrich's thimble chamber for measuring the dose in air, body cavities, wax, water, etc., and Friedrich Dessauer's 200-kv. X-ray generators, isodose charts, and the employment of wax, water bags and similar material to reduce the patient's body to a straight-sided geometric form to which his isodose charts could be applied. In the next three decades, knowledge and experience advanced enormously; but Dessauer's paper, presented in 1921 to the American Roentgen Ray society, lacked little that is really fundamental to an understanding of medium-voltage X-ray therapy as it was practised 30 or more years later.

Increasing the voltage to 200 kv. made it possible to treat deep-seated lesions, most of which had been inaccessible before; but raising it another 50 kv., though desirable, did not prove to be essential. Increasing the voltage still further to 400 kv. brings additional advantages, but most workers agree that they are more than offset by decreased flexibility and considerably greater cost. Experimental work during the early 1950s was designed to show that generators in the 2,000- to 4,000-kv. range would yield clinical advantages commensurate with their great cost. Meanwhile, the most important tool of the X-ray therapist continued to be the generator in the 200- to 250-kv. range.

RADIATION PHYSICS

The work of calibrating X-ray machines, mapping the doses of the radiation that is purposely delivered to the tissues of a patient's body and protecting patients and radiation workers from unwanted radiation became a subspecialty within the specialty of radiation therapy. Modern treatment centres require the full-time services of considerable numbers of graduate physicists specially trained in this branch of physics. Much oversimplified, dose mapping may be summarized as follows:

The intensity and hardness of the X-ray beam are adjusted by varying the operating voltage and current and the nature and amount of interposed filter. For example, one combination will be found which yields a beam that will have its intensity reduced to one-half by the addition of a testing filter of one millimetre of copper. Such a beam is designated as having a hardness of 1 millimetre of copper half value layer (mm.cu.hvl.). Another combination will yield a hardness of 1.5 mm.cu.hvl., and a third a hardness of, for example, 3.0 mm.cu.hvl.

These calibrations depend on r meter measurements of the beam with and without the added test filters, and from time to time the physicist checks them with his meter, but for the day-to-day work beam hardness is adjusted merely by selecting the interposed filter, voltage and current indicated on the calibration charts.

Other tables are prepared showing the dose in r per minute measured at points located, for example, 50 cm. and 80 cm. from the target of the tube.

From r measurements made with the thimble chamber at the surface and inserted into phantoms of wax, water or similar absorbing and scattering material, tables and isodose charts are prepared to show the doses that will be delivered at various points beneath the surface for given beam hardness, tube-skin distance, beam diameter and minute surface intensity.

It is the responsibility of the clinical radiologist to judge as closely as possible the size and location of the lesion, the amount and delivery rate of radiation most likely to be effective, and the tolerance of neighbouring uninvolved tissues. When this has been done his physicist determines the hardness intensity, geometry and aiming of the single or multiple beams best suited to place the radiation in the amounts and at the points stipulated, following which the technician administers the treatment as directed.

The usefulness of the physician-radiologist is enlarged greatly by such assistance from his physicists and technicians, but his own contribution to the work of the team requires that he be competent in their fields as well as his own; and legally as well as morally he must be responsible for the whole.

CLINICAL ASPECTS

The tissues of the body are unaffected by radiation that merely passes through them; it is only absorbed radiation that produces an effect. When there is an effect it is invariably cell injury, and the direct agency in this injury appears to be the ionization invariably associated with absorption.

The relationship between the degree of ionization and the nature and magnitude of the biological response is constant throughout the low- and medium-voltage range. In the multimillion-volt range, direct comparison is difficult because measuring instruments regularly employed for lower-voltage radiation are no longer fully dependable and the type of ionization itself changes slightly. It seems probable, however, that with the change in type of ionization there is an advantageous alteration in the ratio between the intensity of ionization and the magnitude of cell response.

Opinions differ as to whether radiation should be used to treat non-malignant conditions such as arthritis, infections, etc., but its value in cancer is established beyond all argument (*see* CANCER; CANCER RESEARCH). In the radiation therapy of cancer both the effect on the host and the effect on the diseased tissue are important. The body is not totally without natural defenses against cancer but those defenses usually are not quite adequate and new cancer cells develop faster than old ones are destroyed. The aim of the radiation therapist is to deliver major damage to cancer cells with minimum damage to the adjacent normal tissue, hoping to tip the scales to such an extent that the natural defenses of the body will regain the upper hand. When too large a dose is given, cancer growth may be increased rather than diminished because the restraining action of a healthy tissue bed has been lost. Such excessive doses were called "supralethal" by R. Paterson.

The radiosensitivity of tumours is influenced by numerous factors including cell type, tumour size and location and the age and general health of the host. Small tumours located rather superficially in young and otherwise healthy patients respond better than do large deep-seated tumours in debilitated old patients. Grouped in order of

decreasing sensitivity the response by cell type is as follows:

Lymphocytes
Granulocytes
Epithelial cells
1. Basal cells of secretory glands
2. Basal cells of testes and ovaries
3. Basal cells of skin and intestinal tract
4. Alveolar cells of lungs, bile ducts
5. Tubules of kidneys

Endothelial cells
Connective tissue cells
Muscle cells
Bone cells
Nerve cells

The probability of clinical cure is not proportional to the degree of cell sensitivity, however. For example, the cells of Hodgkin's disease are extremely sensitive to ionizing radiations but, though patients skilfully treated respond strikingly at first, this favourable response seldom is permanent.

On the other hand, cancer of the cervix of the uterus with cells much less sensitive than Hodgkin's tissue can be cured. Skin cancer is curable unless it has been neglected until it has extensively invaded bone or cartilage. Cancer of the larynx, nasopharynx and tongue are particularly suited to radiation therapy because the mutilation incident to surgical extirpation is so disabling. Cancer of the cervix of the uterus responds well to radiation and cancer of the body of the uterus to surgery combined with radiation. Cancers of the stomach and bowel are best treated surgically. In many cases where there can be no expectation of cure, radiation may provide relief from pain and frequently considerable prolongation of the period of usefulness and relative comfort. (J. W. J. C.; P. C. H.)

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RADIOMETER, an instrument of a certain type for measuring the intensity of radiant energy.

It was noticed by A. J. Fresnel that a body delicately suspended *in vacuo* is apparently repelled by radiation. Using this principle, Sir William Crookes constructed an instrument, which he called a radiometer, by pivoting a vertical axle carrying vertical vanes inside an exhausted bulb; one side of each vane was blackened and the other side bright, the black sides all facing the same way round the axle. When rays from the sun or other light source or dark radiation from a warm body fall on the vane, the black sides are repelled more than the bright sides, and the vanes are set into rotation. The more intense the radiation the more rapidly do the vanes rotate. It was Crookes's idea that the instrument might be used to measure the intensity of radiation.

Instead of allowing free rotation of the vane system on a pivot, it may be suspended by a quartz fibre. Radiation falling on the black face of the vane will then cause the system to turn round until the restoring couple, because of the torsion of the suspension, balances the deflecting couple due to the radiometer action. A small mirror, attached to the vane system and reflecting a beam of light on to a scale, enables very small deflections to be observed. Ernst Pringsheim constructed such an instrument in 1883 and used it for spectrographic investigations in the infra-red. In 1893 E. F. Nichols improved the radiometer by using mica vanes, one at each end of a horizontal arm suspended on a quartz fibre and each blackened on its front surface. Radiation falling on both vanes would tend to turn them in opposite directions, and if they were correctly adjusted the system would not move under the influence of general stray radiation. The radiation to be measured was allowed to fall on one only of the vanes, and the resulting deflection of a spot of light was observed. With such a radiometer Nichols was able to measure the radiation from individual stars. The radiometer has been applied to measurements of ultraviolet radiation and to that of short Hertzian waves (wave length one to two millimetres).

The explanation of the radiometric action has presented a problem of considerable interest. The question arises whether the rotation of the vanes may be caused by the direct impact of the radiation, somewhat as the rotation of a cup anemometer is caused by the wind. This explanation has been disproved in several ways. If, for example, the vanes are made of transparent material and blackened on the back face, they move toward the direction from which the light comes. The ordinary radiometer effect must be caused, therefore, by stresses set up in the gas. As the pressure of the gas is reduced, the rotation increases to a maximum and then decreases. Even in a very high vacuum, however, a small effect persists, directed away from the light. The magnitude of this residual effect agrees with the value as calculated from the electromagnetic theory of light, which predicts a small pressure because of incident radiation.

The ordinary radiometric action in the presence of gas has been rather definitely shown to be a consequence of the creep of the gas over the unequally heated surface of the vanes near their edges, as was suggested by J. C. Maxwell in 1879. The gas creeps toward the more heated part of the vane's surface and produces there a slight condensation of the gas and an increase in its pressure; the inequalities of pressure thus created give rise to a reverse flow in the surrounding gas, but this flow is hindered by viscosity, so that some inequality of pressure persists and forces the vane back. The existence in the gas of streaming motions such as are required by this explanation has been demonstrated by hanging tiny vanelets in the path of the streams and observing their deflections.

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RADIO RECEIVER. The two principal parts of a radio system are the transmitter and receiver. The waves radiated from transmitting antennas set up voltages in a receiving antenna, so that the first function of a receiving set is to select the signal desired. This must then be amplified and further modified so that a faithful reproduction of a program can be produced by the loud-speaker. Although a modern broadcast transmitter may have an output of 50 kw., only a few microwatts from distant stations are often available at the receiving antenna, principally because of the spreading out of the radio waves as they are propagated through space. A large amount of amplification is thus required in order to obtain a sound output of one watt, for example.

Receivers are provided also with automatic gain and manually operated volume and tone control. Other features often found include multiband reception, automatic selectivity and frequency control, push-button or remote tuning, tuning indicators, squelching circuits, etc. Some sets also include facilities for microphone pickup or for sound recording and reproduction.

History.—The first demonstration of the production and reception of radio waves was made by Heinrich Hertz in Germany in 1887. His receiver consisted of an open wire loop with spheres attached to the ends to form a gap. The presence of the waves was "detected" by observing a spark set up in the sphere gap. Hertz was interested only in studying the properties of the waves and expressed no thought of practical application. It remained for Oliver Lodge to develop a system of wireless communication in England in 1894. The receivers included an antenna, tuned circuit, a detector consisting of a glass tube filled with metal filings called a "coherer" and a relay-controlled inker for recording Morse code. Lodge subsequently received several patents on radio apparatus—two of the better-known covering tuned circuits and loop antennas.

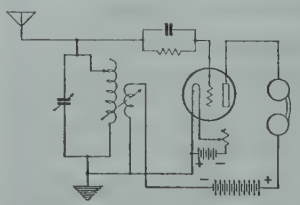


FIG. 1.—SINGLE-CIRCUIT REGENERATIVE RECEIVER (1921)

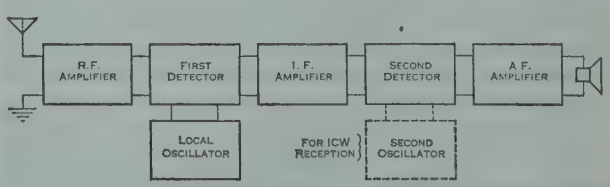
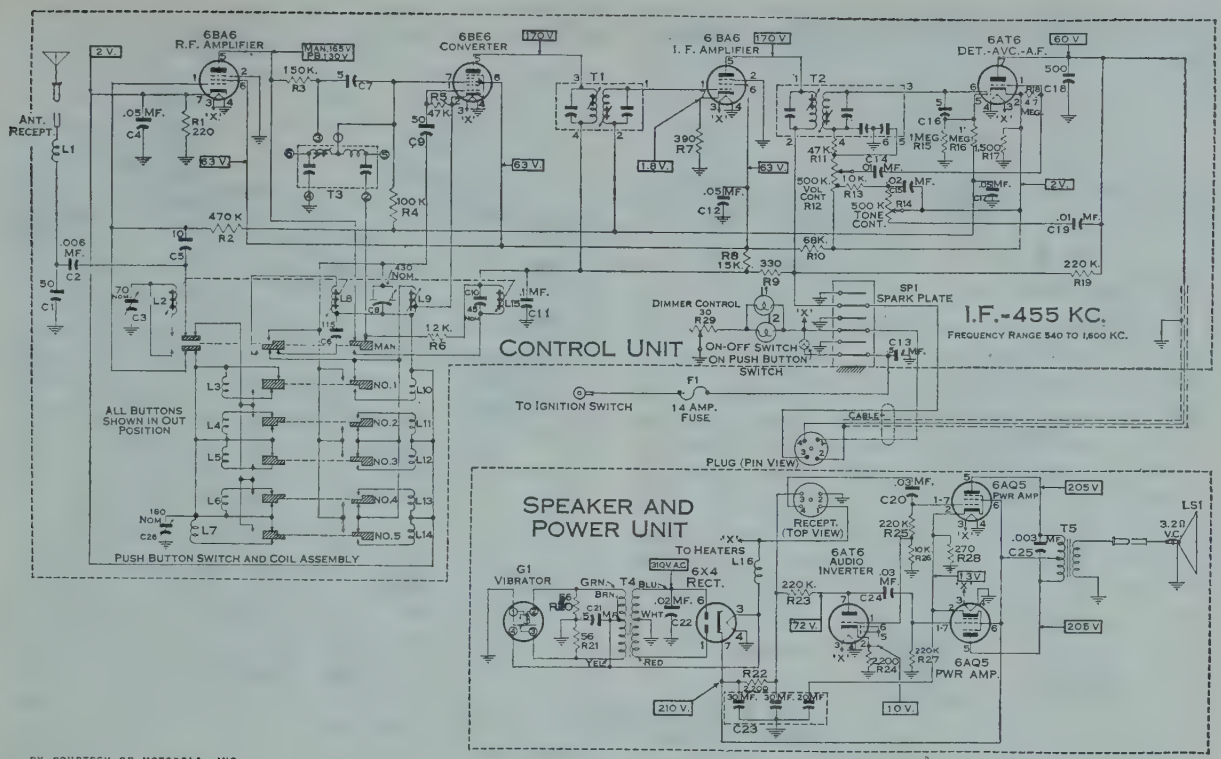


FIG. 2.—BLOCK DIAGRAM FOR SUPERHETERODYNE RECEIVER (1951)

There was much activity in wireless telegraphy following Lodge's initial disclosures. Many new and improved types of detectors or "cymoscopes" (from κῦμα, a wave) were invented.



BY COURTESY OF MOTOROLA, INC.

FIG. 3.—CIRCUIT DIAGRAM FOR AUTOMOBILE RECEIVER (1951)

These included magnetic types by Guglielmo Marconi, Ernest Rutherford and others; electrolytic by F. K. Vreeland, R. A. Fessenden and Lee De Forest; and a wide variety of crystal detectors using carborundum, galena and iron pyrites. Much progress was made also in radio measurements through the use of thermocouple and other types of hot wire instruments, the bolometer, etc.

The first electronic device to appear in radio receivers was the "Zehnder trigger tube cymoscope" in Germany. This was a glow tube in which the potential difference between anode and cathode was set to a value of several hundred volts. A discharge could then be initiated by impressing a radio signal between the pair of trigger electrodes with which the tube was provided.

The first thermionic electron tube for radio use was patented by J. A. Fleming in England in 1904. This was a vacuum diode detector tube, known as the "Fleming oscillation valve." Its apparent advantage over other types of detectors was the ability to undergo mechanical shocks and static surges without "jarring out." Its inherent insensitivity to weak signals, together with the primitive status of manufacturing, limited its application.

The three-element vacuum tube was invented by De Forest in 1906. A receiver using an "audion," as it was called, could deliver more power to an output device than was received from the antenna, so that it was operating in the dual capacity of detector and amplifier. Subsequent work showed that it could be used simply as a radio-frequency (R.F.) or audio-frequency (A.F.) amplifier, or even as a modulator. De Forest manufactured radio sets equipped with audions for several years. The audion, like the Fleming valve, was inconsistent in initial characteristics and unreliable over long periods of time, because of the inadequacy of the manufacturing techniques.

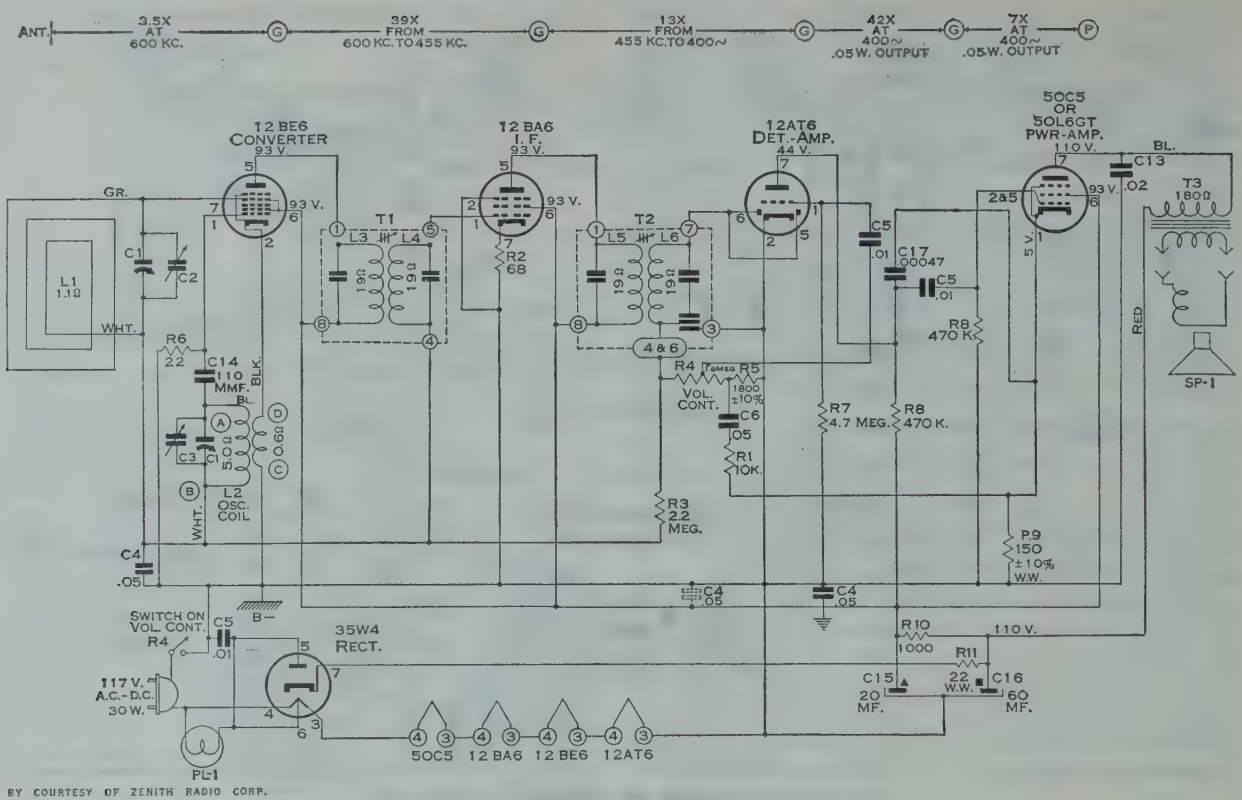
One of the most remarkable applications of the audion was to the feed-back, or regenerative, circuit. In this, coupling was introduced between the plate and grid circuits such as to produce an appreciable increase in both the selectivity and sensitivity of the circuit. By providing adequate coupling, such a circuit could be made to oscillate continuously without benefit of external grid signal.

It is difficult to place proper priority for the invention of the feed-back circuit. In 1913 Alexander Meissner was granted a patent on an oscillator in Germany and E. A. Armstrong presented a paper describing regenerative circuits. Other names associated with contemporary work were C. S. Franklin and H. J. Round in England and De Forest and Irving Langmuir in the United States. A four-way litigation initiated by Meissner, Armstrong, De Forest and Langmuir was decided finally in favour of De Forest by the supreme court of the United States in 1928, and it reaffirmed its action in 1934.

Considerable progress was made in the theory, construction and applications of vacuum tubes and their circuits between 1910 and 1920, much of it in connection with the World War I efforts and long-line carrier-current telephony. The greatest single impetus to be noted in radio history, however, was the introduction of radio broadcasting in 1921. This created a tremendous demand for receivers as transmitters were established throughout the world. The vacuum tube receiving circuits were battery operated for the first few years, but rectifier-type power packs soon appeared for plate and grid supplies. These were followed almost immediately by the self-contained alternating-current sets, which were made possible by the development of tubes whose cathodes could be operated on alternating current without introducing excessive hum in the output.

The first broadcast signals were amplitude modulated (AM) exclusively, and many types of receiving sets were in use. Some of the more common were: regenerative, superregenerative, reflex, tuned radio frequency, neutrodyne and superheterodyne. The superheterodyne came to be used almost exclusively for broadcast reception, although a few portable models are tuned radio frequency.

The difficulties of static elimination inherent in AM operation led Armstrong to develop frequency modulation (FM). Although he began work on the problem in 1914, his system was not perfected until 1933 and several more years elapsed before much use was made of it. By Jan. 1940, however, there were 20 li-



BY COURTESY OF ZENITH RADIO CORP.

FIG. 4.—CIRCUIT DIAGRAM FOR PORTABLE AC-DC RECEIVER (1951)

censed transmitting stations with applications for 150 more on file. By Dec. 1951 there were 639 FM stations operating in the 88- to 108-mc. band. The superheterodyne circuit with adaptations is universally used for FM broadcast reception.

TYPES OF RADIO RECEIVERS

Regenerative Receivers.—One of the first circuits in common usage is shown in fig. 1. In this the single tube acted as both radio-frequency amplifier and detector. The input circuit was tuned by means of the variable air condenser and taps on the "variocoupler" tuning coil, and the amount of feedback was controlled by rotating the "tickler coil." This circuit was especially common in home-built sets, principally because of its simplicity and the phenomenal results sometimes obtained with it, such as coast-to-coast reception during unusually favourable conditions, for example. Other types of regenerative receivers were the two- and three-circuit, tuned plate, Cockaday, etc. Most of them had a tendency to oscillate and to act as a radio transmitter while being tuned. The radiated output would combine with other signals present to produce obnoxious squeals and whistles in neighbouring sets. This, together with a demand for more selective receivers as the number of broadcast transmitters with closer frequency allocations increased, eventually limited applications to long-wave and marine use.

Superregenerative Receiver.—The selectivity and sensitivity of a regenerative receiver increases rapidly with the coupling and resulting approach to the condition for sustained oscillation. Armstrong first described a circuit in 1922 for taking advantage of this by superimposing a supersonic signal upon the received signal, in a manner such as to prevent the circuit from oscillating at a high frequency. This principle is used in the superregenerative receiver, which is characterized by extremely high sensitivity. Because of poor quality of output, its use is limited principally to short-wave reception in police and radio amateur sets.

Reflex Receiver.—Reflex action consists of feed-back action between the plate circuit of one tube and the grid circuit of the preceding tube. In the reflex receiver, the antenna signal was first amplified by one stage of tuned radio frequency (T.R.F.) and then applied to the grid of the detector tube. The audio-frequency output of the latter was then fed back to the grid of the first tube by means of an audio-frequency transformer, the headset or loud-speaker being connected in the plate circuit of that tube. Thus, the first tube acted simultaneously as a radio-frequency and audio-frequency amplifier, to give sufficient output to operate a small loud-speaker upon occasion. This was an important consideration in the days of high-priced tubes, parts and batteries. Poor selectivity was the principle factor which brought about an early obsolescence.

Tuned Radio-Frequency (T.R.F.) Receiver.—It was found that an increase in both sensitivity and selectivity could be obtained by introducing one or more stages of the tuned radio-frequency amplification preceding detection. However, the plate-grid capacitances in triodes created a tendency for the circuit to oscillate. Although a limited amount of feed-back action was desirable, it was necessary to control it carefully in order to prevent oscillations. Bridge circuits for accomplishing this were developed by C. W. Rice and L. A. Hazeltine. A set utilizing the last was known as the neutrodyne receiver, considered to be the last word in receivers until superseded by the superheterodyne.

Some of the weaknesses inherent in early types of tuned radio-frequency receivers were separate tuning for each stage and non-uniform neutralization, sensitivity and selectivity over the broadcast band. The first was removed by gang tuning and the need for neutralization by use of screen-grid tubes, but the problem of varying sensitivity and selectivity remained in tuned radio-frequency receivers. As a result, this type is used in only a few portable broadcast receivers and certain isolated applications where the selectivity requirements are not too stringent.

Superheterodyne Receiver.—A circuit which gave uniform performance over a wide range of station frequencies was developed by Armstrong while working in France during World War I. This made use of the heterodyne principle, which consists of combining together two frequencies to give a different

frequency. It had been introduced by Fessenden of the University of Pittsburgh in 1913, to convert radiotelegraph signals into interrupted audio-frequency code signals.

In the Armstrong superheterodyne receiver, or supersonic heterodyne receiver as it was called first in England, the incoming signal is combined with the output of an oscillator to produce a given supersonic frequency, called the intermediate frequency (I.F.). The latter is then amplified by means of one or more tuned stages, demodulated to give the required audio-frequency signal, amplified and finally fed into a loud-speaker. The selection of the particular station to be received is accomplished by adjusting the oscillator frequency so that the difference between it and the carrier frequency of the received station is equal to the intermediate frequency. Since the major part of the amplification is in the intermediate-frequency amplifier, both the selectivity and sensitivity of the set are essentially independent of the original station frequency. The advantages of the superheterodyne receiver were quickly recognized, but since the early sets required eight or ten expensive battery-operated tubes its use was limited to the more expensive models. By mid-century, however, more than 98% of the broadcast receivers in use in the United States were superheterodynes.

The accompanying block and schematic circuit diagrams show the principal features of typical modern receivers. Starting at the input terminals, the signal is first amplified with one stage of tuned radio frequency in order to provide initial selectivity and thus to reduce so-called image and cross-modulation effects and mixer tube noise. The tuned radio-frequency amplifier and local oscillator circuits are gang tuned with a single dial.

The mixer, converter or first detector tube, as it is called, changes the carrier frequency of the signal to the intermediate-frequency value. This was originally taken as 50 kc., but was later increased to 130–175 kc. Later it was further increased to 450–480 kc., with a tendency to standardize at 455 kc. in order to accommodate multiband receivers.

Although separate oscillator and mixer tubes have been used, a single tube known as a "pentagrid converter" is preferable. Referring to figs. 3 and 4, it will be noticed that grid number 1 and grid number 2 serve as grid and anode, respectively, of an oscillator. The radio-frequency signal from the tuned radio-frequency stage is applied to grid number 4 so that the electron stream will acquire a frequency component equal to the difference between the oscillator and signal frequencies (equal to the intermediate frequency) by heterodyne action before reaching the anode. Grids number 3 and number 5 are connected together to act as a shield around grid number 4 in order to prevent reactions between the radio-frequency and oscillator circuits.

The intermediate-frequency amplifier usually consists of one or two transformer-coupled stages. The primaries and secondaries are permanently tuned, aside from small "trimmers" which are used for alignment purposes. The major portion of the high-frequency gain occurs in the intermediate-frequency amplifier. Remote cutoff pentodes are used to permit automatic gain control, to be discussed below.

The function of the second detector is to convert the modulated intermediate-frequency signal into audio-frequency. Square-law detection by means of a triode was used originally. This is preferable for weak signals, but since the percentage of second harmonic distortion increases rapidly with signal strength and percentage modulation, linear detection came to be used. Among the advantages of high-level linear detection are the elimination of one stage of audio-frequency amplification, low harmonic distortion, reduction in tube noise and a lowering in cost of power pack filter.

The process of linear detection is essentially one of rectification and can be accomplished with either diodes or suitably biased grid-control tubes. Duplex tubes are often used, one part feeding into the audio-frequency amplifier, the other into the automatic volume-control system.

The audio-frequency amplifier may consist of one stage of voltage amplification and a power stage which utilizes two power-pentodes in push-pull, when considerable output is demanded. Figs. 3 and 4 show audio-frequency circuits for automobile and portable sets where less output is required.

Automatic volume, or gain, control (AVC) was one of the most important developments in radio receivers. Its principal purpose is to maintain constant detector input. In this way the output of the receiver is unaffected by the strength of incoming signals. In brief, automatic volume control is accomplished by introducing an extra bias in the variable mu tubes in the tuned radio-frequency and intermediate-frequency stages, which increases with the carrier input to the second detector. This automatically adjusts the gain of those stages so as to maintain nearly constant detector input as long as the incoming antenna signal exceeds a minimum threshold value.

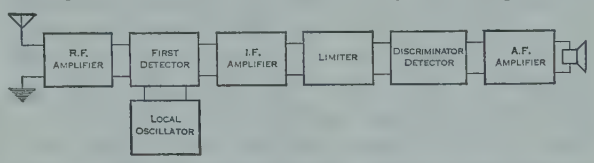


FIG. 5.—BLOCK DIAGRAM FOR FM BROADCAST RECEIVER (1951)

The output of a receiving set is adjusted to suit the listener by means of a volume control, consisting of a potentiometer in the audio-frequency amplifier. Since the sensitivity of the ear varies with frequency, some volume controls also include fixed coils or condensers such that the quality of the loud-speaker output will appear to be independent of intensity.

The purpose of the tone control is to allow the listener to vary the relative intensity of the high and low tones. The circuit for doing this consists of a variable resistance connected in series with a fixed capacitor, its effect being to enunciate the bass notes by decreasing the high ones.

Receivers for FM Reception.—The block diagram in fig. 5 is for a typical receiver designed for use in the 88- to 108-mc. broadcast band. In this, the intermediate-frequency amplifier operates in the region of four to eight megacycles and has a pass band 200 kc. wide. After leaving the intermediate-frequency amplifier, the signal passes through a one- or two-stage "limiter" which levels off the signal at about four volts, so that it is essentially devoid of amplitude modulation. This is very effective in eliminating interference as well as noise caused by static, ignition systems, etc., since the major portion of these can be considered AM. The remaining FM component can be reduced by using a large frequency swing, ± 75 kc. for 100% frequency modulation being standard in broadcast.

The first step in the process of detection is to convert the FM signal into AM. This is done with a frequency-sensitive circuit called the discriminator. This consists of a transformer with primary and secondary tuned to the same frequency and with the coupling slightly less than critical in order to obtain the desired shape of the frequency-response curve. The output of this is fed into a duplex diode detector such as to produce the required audio-frequency output which is further amplified as in AM receivers. (*See* also BROADCASTING; ELECTRIC WAVES; ELECTROMAGNETIC WAVES; ELECTRON TUBE; LOUD-SPEAKER; RADIO; TELEVISION; WIRELESS TELEGRAPHY.)

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(C. S. Rs.)

RADIOSONDE, an instrument sent aloft, attached to a freely rising balloon, for the purpose of obtaining information on the temperature, humidity and other properties of the upper atmosphere. It includes a radio transmitter which sends down signals representing the numerical values of these properties. (*See* UPPER AIR SOUNDINGS.) (W. E. K. M.)

RADIOTHERAPY: *see* RADIOLOGY.

RADISH, *Raphanus sativus* (family Cruciferae), an annual or biennial grown for its large, succulent root. The edible part of the root, together with some hypocotyl, forms a structure

varying in shape, among varieties, from spherical, through oblong, to long cylindrical or tapered. Outside colour of the root varies from white, through pink to red, purple and black. Size of edible part varies among varieties from a few grams in the most popular early American and European varieties to a kilogram or more in the late Japanese field type of radish, or daikon. As generally grown, flower stalks form the first season, bearing white or lilac-veined flowers. The seeds are borne in a spongy, non-dehiscent, beaked pod called a silicle. The small, quick-growing spring varieties have a mild crisp, moderately firm flesh, and are quite perishable. The large, slow-growing summer and winter types have pungent, firm flesh. Winter varieties can be stored through the winter. The common radish is probably of oriental origin. *R. raphanistrum* is a wild radish found along the Mediterranean. The rat-tailed radish (*R. caudatus*) has no enlarged root, but bears enormous seed pods 8–12 in. long which are eaten fresh or pickled. *R. sativus* (var. *longipinnatus*) produces deeply pinnate leaves up to 2 ft. long; the roots are large, firm and are grown as a winter radish. This type is much grown in the orient and is generally known as Chinese radish. (V. R. B.)

RADIUM (Symbol Ra, atomic number 88, atomic weight 226.05) is the heaviest element of the alkaline earth group and the most familiar of the natural radioelements. The name originally applied only to the first discovered and most important isotope of the element, that of mass number 226, but is now used as a general name for the element. It was discovered in 1898 by Pierre Curie, Marie Curie and G. Bémont at the Sorbonne in Paris. Mme. Curie had observed that the radioactivity of pitchblende, an ore of uranium, was several times that of the uranium it contained; and by chemical separation of the constituents of the mineral two highly radioactive elements were discovered and named polonium and radium. The latter was found associated with the barium of the mineral and followed it throughout the procedure. In 1902, as a result of working up several tons of pitchblende residues and carrying out tedious chemical fractionations to separate the radioactive substance from the barium, the first pure salt of radium was isolated by Mme. Curie; and in 1910 the metal was prepared by Mme. Curie and A. Debierne.

Isotopes and Radioactive Properties.—Several isotopes of radium, all radioactive, are known. Only Ra^{226} is stable enough to permit its isolation in visible and weighable amounts, and the name "radium" often refers simply to this isotope. Its half-life is approximately 1,600 years, and it disintegrates with the emission of alpha-particles. It is a member of the uranium, or radium, family of natural radioelements, following ionium in the series. Its immediate transformation product is radon, a noble gas of 3.825 days' half-life, which in turn changes into a series of shorter-lived radioelements, radium A, B, C, C′ and C″. It is rarely encountered in a radioactively pure form, for immediately after purification from its disintegration products they rapidly grow in again. Radium C emits very penetrating gamma-rays, so that, although radium itself emits only small numbers of gamma-rays of low penetrability, a sample which has been sealed up to prevent loss of the gaseous radon is a source of strong gamma-radiation. About a month is required for the gamma activity to reach its maximum, or equilibrium, intensity. The end product of the short-lived descendents of radium is radium D, which is also radioactive, and from this grow radium E and polonium, or radium F. Since the half-life of radium D is 22 years it comes to equilibrium only very slowly in radium preparations.

The half-life of radium is so great that it cannot be determined by directly observing the decay, and recourse must be had to indirect methods. Most of these involve the determination of the specific activity, or the number of disintegrations per unit weight in unit time. This can be done by counting the alpha-particles emitted in a measured interval by a sample of known weight. The first measurements were done by visual counting of the scintillations produced by the impact of the particles on a zinc-sulphide screen, while later experimenters have used electrical instruments to amplify and record the bursts of ions produced by the particles in a gas. Since alpha-particles are helium nuclei, measurement of the rate of helium generation by radium provides another means of determining the specific activity. The half-life can also be calculated from the rate of growth of radium in a sample of purified ionium relative to the amount in equilibrium with the same quantity of ionium in ancient and intact uranium minerals. Finally, from the equilibrium ratio of radium and uranium in such minerals the half-life of radium can be calculated if that of uranium is known independently. Although there is some disagreement as to the exact values, the specific activity is approximately 3.7×10^{10} alpha-disintegrations per second per gram and the half-life 1,600 years. The disintegration rate of radium is the basis of a standard unit of radioactivity, the curie, originally a rate of disintegration equal to that of a gram of radium. Now, a curie of any radioelement is by definition that amount undergoing 3.7×10^{10} disintegrations per second.

In the thorium series of radioelements occur two radium isotopes, mesothorium I (Ra^{228}) and thorium X (Ra^{224}), the former a beta-emitter of 6.7 years' half-life and the latter an alpha-emitter of 3.64 days' half-life. One of their decendents, ThC″, emits gamma-radiation even more penetrating than that of RaC, and as a result of the complex sequence of half-lives the gamma activity of freshly purified mesothorium increases for about four years and then decays steadily. A fourth isotope, actinium X (Ra^{223}), occurs in the actinium series and is an alpha-emitter of 11.2 days' half-life. (*See* RADIOACTIVITY, NATURAL.)

Several artificial radioactive isotopes of radium are also known. (*See* NUCLEUS.)

Natural Occurrence.—Although the half-life of radium, 1,600 years, is long with respect to human experience, it is infinitesimal in the geological time scale, and any radium present at the time of the formation of the earth has by now completely disappeared. It is only because a new supply of the element is continually being generated by the disintegration of uranium that any is found at the present time, and its distribution in nature is practically identical with that of uranium. There is a constant ratio between radium and uranium, 0.00000034, in all sufficiently old minerals in which radioactive equilibrium has not been disturbed by weathering or leaching. In altered minerals the radium is generally relatively lower because of the greater solubility of its oxide as compared with that of uranium and its resulting greater tendency to leach out. Springs, rivers and sea water contain small amounts of radium as do the various layers of the ocean sediments. Uranium, and consequently radium, are widely distributed in minute traces in nearly all common rocks, both igneous and sedimentary, the average concentration of radium in the earth's crust being about one part per million million. The bulk of the earth's radium is so accounted for; but in this form it is, of course, commercially unavailable. Only in uranium minerals is radium present in high enough concentrations to make its extraction feasible, and even the richest ores contain only about a quarter of a gram of radium per ton. Most deposits contain smaller amounts; and some which contain as low as 1% of uranium, or 1 g. of radium in 300 tons, have been exploited for the latter.

Radium was discovered in the mineral pitchblende, an oxide of uranium, which had been mined for centuries at Joachimsthal, Czechoslovakia, for its uranium content. More extensive pitchblende deposits have been found at Katanga in the Belgian Congo and at Great Bear lake in Canada. Second in importance as a radium source is carnotite, a double vanadate of uranium and potassium found principally as a yellowish impregnation of sandstone in the western United States. Altogether several dozen different radium-containing minerals are known, and deposits of varying extent are found in many other places including England, Portugal, Germany, Russia, Madagascar, South Africa and Australia. Many of these have been worked from time to time for radium. The increased importance of uranium, as a source of atomic energy, has resulted in intensive prospecting and the discovery of many more radium-bearing deposits.

Mesothorium is obtained principally from monazite, a mixed phosphate of thorium and rare earths occurring chiefly in alluvial sands in Travancore, Ceylon, Brazil and North Carolina. Thorium X and actinium X occur naturally in thorium and uranium minerals, respectively, but are usually obtained from their parents

rather than from natural sources. (*See* URANIUM; THORIUM.)

Industrial Production.—For a number of years following its discovery the only important source of radium was the Joachimsthal mines, operated by the Czechoslovakian government. Later some radium was produced in other European countries. The United States became the first major producer and from 1911 to 1923 was the chief world supplier, with carnotite from the western states being extracted principally at Denver, Colo., and Pittsburgh, Pa. The rich Belgian Congo pitchblende deposits were discovered in 1913; and the refinery at Oolen, Belgium, began production in 1922, immediately dominating the world market. The extensive Canadian deposits were discovered in 1930; and the refinery at Port Hope, Ont., started producing radium in 1933. For a number of years the world market was divided between the Belgian and Canadian producers on a 60:40 basis by a cartel agreement. After Belgium fell to the German army in 1940, the African ores were shipped to the United States and Canada for refining.

It is a tribute to the genius of Mme. Curie that the general method she devised to isolate radium is still used for its commercial extraction, in spite of much subsequent research. The following is a typical treatment of pitchblende. The ground ore is digested with a mixture of nitric and sulphuric acids to which a little barium is added to act as a carrier for the radium. The uranium dissolves, and an insoluble residue of radium, barium and lead sulphates and siliceous gangue remains. This is separated by filtration and boiled with sodium-hydroxide solution to leach out the lead sulphate and some of the silica. The residue is then autoclaved with sodium-carbonate solution to convert the barium and radium sulphates to carbonates, which are dissolved in hydrochloric acid. After filtering off the remaining silica, the barium and radium are again precipitated as sulphates and converted to carbonates to effect a purification. The carbonates are now dissolved in hydrobromic acid and the bromides subjected to an involved fractional crystallization process. Since radium bromide is somewhat less soluble than barium bromide, the crystals are enriched in radium. After ten recrystallizations the ratio of radium to barium in the head crystals is changed from a few parts per million to a few parts per thousand. At this stage, the bromides from several batches are accumulated, purified again and subjected to further crystallizations until radium of the desired purity, usually 95% or 99%, is obtained. This is sealed into small glass tubes to be measured and sold.

Variations in this process are dictated by differences in the nature and quality of the ores found in different locations. Canadian pitchblende contains considerable native silver, which is recovered by roasting the ore with sodium chloride to convert the silver to its chloride and subsequently leaching the latter out of the sulphate residue with sodium-thiosulphate solution. With carnotite, the treatment can be altered by leaching the ground ore with hydrochloric acid to dissolve the radium, uranium and vanadium away from the siliceous matter before adding sulphuric acid. The sulphate precipitate can alternatively be heated with charcoal to reduce the sulphates to sulphides, which dissolve readily in hydrochloric acid. In the fractional crystallization the chlorides are often used instead of the bromides.

A recently developed separation method for radium and barium employs synthetic organic cation exchange resins.

Radium was originally interchanged freely among scientific and medical investigators, but when it became an item of commerce it became extremely expensive. However, as new and richer sources have become available, the price has steadily fallen. Typical market prices per gram were $10,000 in 1904, $80,000 in 1912, $120,000 in 1915, $135,000 in 1918, $90,000 in 1920, $70,000 in 1923, $50,000 in 1929, $25,000 in 1936, $20,000 in 1941 and $25,000 in 1946. The total world production in grams was approximately 50 by 1916, 300 by 1925 and 1,000 by 1940. Production was greatly accelerated during World War II.

Chemical Properties.—Of the 88 electrons of the radium atom, the first 86 are very strongly bound, whereas the outer two are readily lost leaving a divalent cation of noble-gas structure. This property classifies it among the alkaline-earth elements, which include, in order, magnesium, calcium, strontium, barium and radium. There is a general gradation of properties in going from the lighter to the heavier members of the group, and radium continues this trend. It is very similar to barium, all of its known compounds being isomorphous with the corresponding barium compounds and differing so little in properties as to make the separation of the two elements a matter of great difficulty. The chemistry of radium is, therefore, well understood even though its scarcity has caused it to be studied comparatively little.

Radium is divalent in all of its compounds. The sulphate, $RaSO_4$, is the most insoluble sulphate known and for this reason is important in the separation of the element from its ores. However, it is only because lead sulphate is also precipitated from the solution of the ore that quantitative precipitation of radium is obtained, for the amount of radium sulphate present is far too low to precipitate by itself. This principle, whereby an element present in quantity too small to permit manipulation by itself is caused to undergo certain chemical reactions by the presence of a larger quantity of a similarly behaving element, is called "carrying" and is important both in the isolation and in the chemical study of radium. The nitrate, $Ra(NO_3)_2$, chloride, $RaCl_2$, and bromide, $RaBr_2$, are soluble in water but highly insoluble in concentrated solutions of the corresponding acids, and are consequently of use in the purification of radium, including its separation from the last traces of barium. The chloride and bromide crystallize as hydrates, $RaCl_2.2H_2O$ and $RaBr_2.2H_2O$, but form the anhydrous salts on heating. The hydroxide, $Ra(OH)_2$, is the most soluble of the alkaline-earth hydroxides. The carbonate, $RaCO_3$, is insoluble in water but soluble in acids, and the sulphide, RaS, is soluble in water.

In the elementary state radium is a shiny white metal of high reactivity, melting at approximately 700° C. It dissolves in water with vigorous evolution of hydrogen and darkens in air with the formation of the nitride. It is prepared by electrolysis from an aqueous solution of the chloride into a cathode of mercury, followed by volatilization of the mercury in a stream of hydrogen.

The optical spectrum of radium is similar to that of the other alkaline-earth elements, consisting of comparatively few relatively strong lines. The ordinary compounds of radium are all colourless but become coloured upon standing as a result of the continual bombardment by radioactive particles. Glass containers of considerable quantities of radium also become coloured, and sizable preparations can be seen to glow in the dark. Those properties are not peculiar to radium but are common to all strongly radioactive substances.

Analytical Methods.—The assay of radium is generally made not by the usual chemical procedures, such as weighing, but by methods based on its radioactivity. Strong samples, such as those for medical and radiographical use, are assayed by their gamma-radiation by means of an ionization chamber and electrometer. The sample must be sealed for at least a month before the measurement so that the equilibrium quantity of radium C is present. For calibration of the measuring apparatus, standard preparations of radium have been made. The primary international standard was prepared by Mme. Curie by precise weighing and has been preserved at Sèvres, France. Secondary standards, carefully checked against the international standard, are kept in the capitals of the principal nations. In using these standards allowance must be made for their decay, which amounts to 0.043% per year. Another assay method is the emanation technique, in which the gaseous radon generated by the radium sample in a measured time is collected in an ionization chamber and the intensity of its radiations measured. This method can be made extremely sensitive by electrically counting the individual alpha-particles, and as little as 10^{-14} gram of radium can be so detected.

Uses.—The uses of radium all result from its radiations. The most important of these have been in medicine, principally for the treatment of cancer. For this purpose the element may be used directly, sealed in a tube, or the accumulated radon may be drawn off and compressed into a small capsule which may be used until it has decayed to a low intensity. (*See* RADIOLOGY.) An increasingly large amount of radium is being employed for industrial radiography, particularly for the inspection of metal

castings. Radium is mixed, in very small concentrations, with a paste of zinc sulphide to make a luminescent paint for watch, clock and meter dials and signs which must be read in the dark. An intimate mixture of radium with beryllium is a moderately intense source of neutrons. Such neutron sources have been used extensively in scientific work and have found practical applications in searching for oil deposits.

Mention should be made of the hazards of handling radium, which result from the physiological effects of its radiations and which are enhanced by the gaseous nature of its decay product, radon. Before the dangers were recognized and adequate precautions taken a number of radium workers suffered serious injury or death. For physiological effects of radioactive substances *see* RADIOLOGY.

Mesothorium can be used in a manner similar to radium for all the purposes mentioned, but its greater expense and shorter lifetime limit its applications. It is superior to radium as a luminous paint activator because the intensity of its radiations increases for several years and thus compensates for the fatigue of the zinc sulphide. Except for scientific purposes, the other radium isotopes have no practical value.

For all the uses of radium, substitutes have become available. Artificial radioelements and high-voltage X-ray generators are supplanting radium in radiotherapy and radiography. Fluorescent paints activated by ultra-violet radiation are replacing radium paints in aeroplane panel meters. Cyclotrons and nuclear chain reactors provide much more intense neutron sources. Nevertheless, the use of radium is expected to increase because of greater availability as a by-product of uranium.

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RADIUMTHERAPY: *see* RADIOLOGY.

RADNORSHIRE, an inland county of Wales, bounded north by Montgomery, north-east by Shropshire, east by Hereford, south and south-west by Breconshire and north-west by Cardigan. Its area is 470.6 sq.mi., and it is consequently the smallest of the six south Wales counties. Pop. (1951) 19,998. The county is a highland region grading eastwards to the plain of the Severn. The western section is formed of Ordovician rocks which are succeeded eastwards by the Llandovery, Wenlock and Ludlow beds of the Silurian. This region forms part of the central Wales plateau with a general level of about 1,000 feet. To the east of the L.M.S. mid-Wales line that cuts the county diagonally from south-west to north-east the grits and shales of the lower Palaeozoic rocks are over-lain by the Old Red Sandstone which culminates in the rugged mass of Radnor forest (2,166 feet). The railway follows the lower Ithon valley (a tributary of the Wye) from near Builth Road to Llanbadarn Fawr. The Wye forms the south-west boundary of the county between Newbridge and Three Cocks, and divides Radnor forest from the Epynt mountains of Breconshire. Between Llandrindod and Builth is a disturbed area of Ordovician strata with masses of andesitic and diabasic igneous rocks. The region has also saline, sulphurous and chalybeate springs. East of New Radnor in the eastern section of the county an inlier of Wenlock rocks is surrounded by Ludlow beds; while at Old Radnor a ridge of very ancient rocks appears. The eastern half of the county is characterized by the number of river valleys that open out to the English plain and consequently offer important ways into the county from the East. In the north the Teme opens out to Knighton and Ludlow and forms the northern boundary of the county for a part of its course. The Lugg flows eastward past Presteign, and the Arrow past Kington, while the vale of Wye leads down to Hereford.

History and Early Settlement.—The heavily forested nature of the county in early times made it unsuited for settlement. Indeed, the region does not seem to have been densely peopled at any time. There are remains on the open higher ground especially in the north of the county of tumuli of uncertain date. Evidences of Bronze age and Megalithic cultures are almost entirely absent. There are, however, a few good examples of hill-top camps, especially at Burfa, and Castle Ring in the parish of Evenjobb. The Roman interests in the region seem to have centred on Castell Collen a focus of ways among the hills and on the road running due north from Brecon to Caersws. The post-Roman centuries were naturally times of difficulty in this region and the outstanding memorial of the time is the remains of Offa's Dyke that traversed the county. The best preserved sections are in the hilly districts west of Knighton and Presteign. Church dedications show the influence of the Celtic Saint movements of these centuries. Towards the close of the 9th century Maesyfed was absorbed into the middle kingdom of Powys, and in the 10th century it was included in the realm of Elystan Glodrudd, prince of Fferlys, or Feryllwg, who ruled over all land lying between the Wye and Severn. In the reign of William I., the Normans began to penetrate into Maesyfed, where, according to Domesday, the king already laid claim to Radenoure, or Radnor, in the lordship of Melenith (Moelynaidd), which was subsequently bestowed on the Mortimer family. The Domesday records are of interest in that they show evidences of cultural penetrations along the valley ways from the east. (English place-names west of Offa's Dyke, etc.) Influences from the plain have long been a feature of the social, religious and political life of the county. Later, the Norman invaders forced their way up the Wye valley, the de Braose family, lords of Elvel (Elfael), building fortresses at Painscastle and at Colwyn or Maud's Castle. The Wye valley long formed one of the debatable districts between Welsh and Normans. After the annexation of Wales by Edward I., the district of Maesyfed remained under the jurisdiction of the Lords-Marchers, represented by the families of Mortimer and Todeney.

The weakness of the Norman hold on many parts of the county is illustrated by the absence of large numbers of stone castles and the great number of those of the motte and bailey type. The valley ways show evidences of compact settlements in marked contrast to the single farms of the upland west. The difficult nature of much of the county throughout mediaeval times, together with the weak Norman hold, meant that the manorial system was very late in establishing itself. The ravages of the Black Death which were particularly severe in this region brought manorial conditions to an early end and the county became almost entirely dependent on sheep rearing. The increase in the number of sheep and the development of the wool trade and the great wool-markets of the Welsh Border—Shrewsbury, Ludlow, Hereford and Gloucester—were features of 14th and 15th century England. There was only one monastic house of consequence in this pastoral county, the Cistercian abbey of St. Mary, founded by Cadwallon ap Madoc in 1143 in "the long valley" of the Clywedog, 6 m. E. of Rhayader, and from its site commonly called Abbey Cwm Hir. Its existing ruins are insignificant, but the proportions of the church, which was 238 ft. long, are still traceable. The churches of Radnorshire are mostly poor and small.

The political instability of the county continued throughout the 15th century and in 1402 Owen Glendower entered the Marches and raided the lands of the young Edward Mortimer, earl of March.

Radnorshire (Maesyfed) was created a county on the English model by the Act of Union (1536). It was parcelled out of the suppressed marches lordships. The new county was represented in parliament by two members, one for the county and one for the group of united boroughs. Together with the rest of moorland Wales the county was conservative and royalist during the 17th century, the local clergy during the commonwealth coming in for severe criticism under the administration of the Puritan Vavasor Powell (1617–70). The developments in the wool trade and local weaving attracted in the 16th and 17th centuries numbers of continental weavers, mostly religious refugees and the county is well known for the strong points of view it took later in religious matters. It was an old stronghold of the Quakers and later of the Baptists.

During the 20th century the rise of Llandrindod as a watering-place and the construction of the Birmingham reservoirs in the Elan valley have tended to increase interest in the county.

Occupations.—Good hay and cereals are raised in the valleys, oats being by far the chief crop. The extensive upland tracts, which cover over one-third of the total area of the county, afford pasturage for large flocks of sheep. The quality of the wool of Radnorshire has long been celebrated, and also the delicacy of the

Welsh mutton of the small sheep that are bred in this county. Important sheep fairs are held at Rhayader.

The Central Wales branch of the L.M.S. enters the county at Knighton, traverses it by way of Llandrindod and passes into Brecknock at Builth Road Junction on the Wye. The G.W. railway follows the course of the Wye, by way of Builth and Hay. Two small branch lines connect New Radnor and Presteign with the G.W.R.

There is no existing municipal borough, although New Radnor, now a mere village, was incorporated in 1561, and its municipal privileges were not formally abolished till 1883. The chief centres are Presteign, Llandrindod Wells, Knighton and Rhayader, all, except Rhayader, being urban districts. Radnorshire is included in the South Wales circuit, and Presteign ranks as the county town. The whole county together with that of Brecknock returns one member to parliament. Ecclesiastically, Radnorshire is divided into 46 parishes, the majority of which lay after 1923 in the diocese of Swansea and Brecon, but, before that, had been for centuries included in the diocese of St. David's. Wartime population movements caused an increase of 10% in the Radnorshire population between Sept. 1939 and Feb. 1941.

RADOM, a town of Poland in Kielce province, 100 mi. by rail south of Warszawa. Pop. (1931) 77,400, half of whom were Jews; (1946) 69,455. St. Waclaw church, contemporary with the foundation of the town, was transformed by the Austrians into a storehouse and subsequently by the Russian government into a military prison. The old castle is in ruins. Radom has several iron and agricultural machinery works and tanneries. In 1216 it occupied the site of what is now Old Radom. New Radom was founded in 1340 by Casimir the Great, king of Poland. There Jadwiga was elected queen of Poland in 1382; the first act relating to the union of Poland with Lithuania was signed in 1401; the *sejm* or diet of 1505, where the organic law of Poland was sworn by the king, was also held there. Several great fires, and the Swedish war of 1701–07, ruined the old city. After the third partition of Poland in 1795 Radom fell under Austrian rule; it was in 1815 annexed to Russia and was returned to Poland in 1918. Germany conquered Radom after bitter fighting in Sept. 1939. It was again returned to Poland in 1945.

RADON (symbol Rn, atomic number 86, atomic weight 222) is the heaviest element of the noble gas group and an important radioelement. The name is used either for the most important isotope, that of mass 222, or for the element as a whole, although for the latter purpose the name emanation (symbol Em) is sometimes preferred. Other isotopes are thoron (Tn, mass number 220) and actinon (An, 219). Thoron was discovered in 1899 by R. B. Owens and E. Rutherford, who observed that some of the radioactivity of thorium preparations can be swept away by a current of gas. Radon was similarly discovered in radium samples by F. E. Dorn in 1900, and actinon was found associated with actinium in 1904 by F. O. Giesel and A. Debierne.

Radon is the immediate product of the decay of radium and undergoes alpha-disintegration with a half-life of 3.825 days. It yields several short-lived radioelements called the active deposit because of their tendency to adhere to solid objects. Thoron and actinon have similar properties, but because of their short half-life periods, 54.5 and 3.92 seconds respectively, are of less importance than radon. (*See* RADIOACTIVITY, NATURAL; RADIUM.)

Because of its transient existence, radon is found only in conjunction with a source of radium. The atmosphere contains traces of radon near the ground as a result of seepage from soil and rocks, all of which contain minute quantities of radium. For preparing intense samples a supply of radium is kept in a glass vessel in aqueous solution or in the form of a porous solid from which the radon can readily effuse. At intervals of a few days the accumulated radon is pumped off, purified, and compressed into a small tube which is then sealed and removed.

Radium C rapidly grows into equilibrium with the radon and, since the former is the source of the intense penetrating gamma-rays, the gamma activity is in effect transferred from the radium sample to the tube by this process. The radon can then be used for radiotherapy, radiography, or other purposes, until its strength decays to too low a value. "Dead" radon tubes are often saved for the extraction of radium D and polonium.

Radon possesses a particularly stable electronic configuration which gives it a chemical inertness characteristic of the noble gas elements. Thus it is always found in the elementary state, and no true compounds are known. Its properties are similar to those expected by extrapolation from the other noble gas elements, helium, neon, argon, krypton and xenon. It is the most easily condensed and solidified of the group, the boiling point being −62° C. and the freezing point −71° C. It dissolves more readily in water than the other noble gases and is very soluble in a number of organic liquids.

For bibliography, *see* RADIUM. (T. P. K.)

RADOWITZ, JOSEPH MARIA VON (1797–1853), Prussian general and statesman, was born at Blankenburg in the Harz mountains, his family being of Hungarian origin. As a lieutenant in the Westphalian artillery he was wounded and taken prisoner at Leipzig (1813), subsequently entered the Hanoverian service, and in 1823 that of Prussia, becoming chief of the general staff of the artillery in 1830. In 1836 he went as Prussian military plenipotentiary to the federal diet at Frankfort, and in 1842 was appointed envoy to the courts of Carlsruhe, Darmstadt and Nassau. He was an intimate friend of the crown prince (afterward King Frederick William IV), and the Prussian constitution of Feb. 1847 owed much to his *Gespräche aus der Gegenwart über Staat und Kirche,* published under the pseudonym "Waldheim" in 1846. In the Frankfort parliament he was leader of the extreme right; and after its break-up he worked for the Unionist policy of Prussia in the Prussian diet and the Erfurt parliament. On Sept. 27, 1850, he was appointed minister of foreign affairs, but resigned on Nov. 2. In Aug. 1852 he was appointed director of military education. He died on Dec. 25, 1853.

Radowitz published, in addition to several political treatises, *Ikonographie der Heiligen, ein Beitrag zur Kunstgeschichte* (1834) and *Devisen und Mottos des spätern Mittelalters* (*ib.,* 1850). His *Gesammelte Schriften* were published in 5 vol. at Berlin, 1852–53.

See Hassel, *Joseph Maria von Radowitz* (1905, etc.).

RAE, JOHN (1813–1893), Scottish Arctic explorer, was born on Sept. 30, 1813, in the Orkney Islands. He studied medicine at Edinburgh university. He made a voyage as surgeon in one of the ships of the Hudson's Bay company, and was resident surgeon for ten years at the company's station at Moose Factory, at the head of James bay. In 1846 he made a boat voyage to Repulse bay, and next spring surveyed 700 mi. of new coast line connecting the earlier surveys of Ross and Parry. He then joined the expedition under Sir John Richardson in search of Franklin; and in 1851, at the request of the government he travelled some 5,300 mi., much of it on foot, and explored and mapped 700 mi. of new coast on the south side of Wollaston and Victoria Lands. For this achievement he received the Founder's gold medal of the Royal Geographical society. In 1853 he commanded another boat expedition fitted out by the Hudson's Bay company, which connected the surveys of Ross with that of Deane and Simpson, and proved King William's Land to be an island. He subsequently travelled across Iceland, and in Greenland and the northern parts of America, surveying routes for telegraph lines. He died at his house in London in 1893 and was buried in the Orkney Islands. He wrote *A Narrative of an Expedition to the Shores of the Arctic Sea in 1846 and 1847* (1850).

RAE BARELI, a town and district of the Union of India, in the Lucknow division of the United Provinces. The town is on the river Sai, 48 mi. S.E. of Lucknow. Pop. (1941) 20,945. It possesses many architectural features, chief of which is a strong and spacious fort of solid brick. Among other ancient buildings are the magnificent palace and tomb of nawab Jahan Khan, governor in the time of Shah Jahan, and four fine mosques. It is an important centre of trade, and muslins and cotton cloth are woven.

The DISTRICT OF RAE BARELI has an area of 1,765 sq.mi. The general aspect of the district is slightly undulating, and the country is beautifully wooded. The soil is remarkably fertile, and the cultivation of a high class. The principal rivers of the district are the Ganges and the Sai. In 1941 the population was 1,064,804. The principal crops are rice, pulse, wheat, barley, millet and poppy.

RAEBURN, SIR HENRY (1756–1823), Scottish portrait-painter, was born at Stockbridge, Edinburgh, on March 4, 1756, the son of a manufacturer of the city. He was educated at Heriot's hospital, and at 15 was apprenticed to a goldsmith in Edinburgh. He began to paint miniatures; and, meeting with success and patronage, he extended his practice to oil-painting, being all the while quite self-taught. The goldsmith his master watched his pupil with interest, and introduced him to David Martin, the leading portrait-painter in Edinburgh. From him Raeburn received considerable assistance, and was given portraits to copy. When he was in his 22nd year he was asked to paint the daughter of Peter Edgar of Bridgelands and widow of Count Leslie. A month later she became his wife, bringing him an ample fortune; but the acquisition of wealth affected neither his enthusiasm nor his industry. He decided to visit Italy with his wife, and, in London, called upon and was kindly received by Sir Joshua Reynolds, who gave him excellent advice as to his study in Rome, commending to him in particular the works of Michelangelo. He also offered him more substantial pecuniary aid, which was declined as unneeded; but Raeburn carried with him to Italy many valuable introductions from the president of the Academy. In Rome he made the acquaintance of Gavin Hamilton, of Batoni, and of Byers, who advised him "never to copy an object from memory, but, from the principal figure to the minutest accessory, have it placed before him." After two years of study in Italy he returned to Edinburgh in 1787, where he began a most successful career as a portrait-painter. In that year he executed an admirable seated portrait of the second Lord President Dundas.

Interesting examples of his earlier portraits are those of Mrs. Johnstone of Baldovie and the three-quarter-length of Dr. James Hutton. The portraits of John Clerk, Lord Eldin, and of Principal Hill of St. Andrews belong to a somewhat later period. Raeburn was fortunate in the time in which he practised portraiture. Sir Walter Scott, Blair, Mackenzie, Woodhouselee, Robertson, Home, Ferguson and Dugald Stewart were resident in Edinburgh, and they all, along with a host of others less celebrated, honoured the painter's canvases. Of his fully matured manner the finest examples are his own portrait and that of the Rev. Sir Henry Moncrieff Wellwood, the bust of Dr. Wardrop of Torbane Hill, the two full-lengths of Adam Rolland of Gask, the remarkable paintings of Lord Newton and Dr. Alexander Adam in the National gallery of Scotland, and that of William Macdonald of St. Martin's Raeburn was considered less successful in his female than in his male portraits, but the exquisite full-length of his wife, the smaller likeness of Mrs. R Scott Moncrieff in the Scottish National Gallery, and that of Mrs. Robert Bell, prove that he could portray all the grace and beauty of the gentler sex.

Raeburn spent his life in Edinburgh, rarely visiting the metropolis, and then only for brief periods, thus preserving his own sturdy individuality. But though he, personally, may have lost some of the advantages which might have resulted from closer association with the leaders of English art, and from contact with a wider public, Scottish art certainly gained much from his disinclination to leave his native land. He became the acknowledged chief of the school which was growing up in Scotland during the earlier years of the 19th century, and to his example and influence at a critical period is undoubtedly due much of the virility of his followers and immediate successors. Professional honours fell thick upon him. In 1812 he was elected president of the Society of Artists in Edinburgh, in 1814 associate, and in the following year full member of the Royal Academy. In 1822 he was knighted by George IV and appointed His Majesty's limner for Scotland. He died at Edinburgh on the 8th of July 1823.

In his own day the portraits of Raeburn were excellently engraved by the last members of the great school of English mezzotint. In 1876 a collection of over 300 of his works was brought together in the Royal Scottish Academy galleries; in the following year a series of twelve of his finest portraits was included in the winter exhibition of the Royal Academy, London; and a volume of photographs from his paintings was edited by Dr. John Brown

See *Life of Sir Henry Raeburn, R.A.*, by his great-grandson William Raeburn Andrew (2nd ed., 1894), with complete catalogue of the exhibition of 1876; *Works of Sir Henry Raeburn, R.A.*, with tributes by Dr. John Brown and others (Andrew Elliot, Edinburgh); *Tribute to the Memory of Raeburn* by Dr. Andrew Duncan; the *Catalogues* of the loan exhibitions in Edinburgh of 1884 and 1901; and the Essay by W. E. Henley—*Sir Henry Raeburn* (1890) with a finely produced series of plates, printed by T. & A. (Constable); *Sir Henry Raeburn* by Sir Walter Armstrong, with an introduction by R. A. M. Stevenson and a biographical and descriptive catalogue by J. L. Caw (1901).

RAEDWALD (d. *c.* 620), king of the East Angles, was the son of King Tytili. He became a Christian during a stay in Kent, but on his return to East Anglia he sanctioned the worship both of the Christian and the heathen religions. Very little is known about his reign, which probably began soon after 600. For a time he recognized the overlordship of Aethelberht, king of Kent, but he seems to have shaken off the Kentish yoke. He gained some superiority over the land south of the Humber with the exception of Kent and is counted among the Bretwaldas. Raedwald protected the fugitive Edwin, afterwards king of Northumbria, and in his interests he fought a sanguinary battle with the reigning Northumbrian king, Aethelfrith, near Retford in Nottinghamshire, where Aethelfrith was defeated and killed in April 617. He was followed as king of the East Angles by his son Eorpwald.

See Bede, *Historiae ecclesiasticae*, edited by C. Plummer (Oxford, 1896); and J. R. Green, *The Making of England* (1897–99).

RAEMAEKERS, LOUIS (1869–), Dutch cartoonist, was born at Roermond, Holland, on April 6, 1869. He was educated in Amsterdam and Brussels, and began his career by painting landscapes, portraits and posters. In 1908 he produced his first political cartoons, and subsequently gained international fame by his violent anti-German cartoons in the Amsterdam *Telegraaf* and other papers during and after the World War.

His cartoons have been published in *The Great War in 1916; The Great War in 1917; Devant l'Histoire* (1918); and *Cartoon History of the War* (1919).

RAETIA (so always in inscriptions, in classical mss. usually RHAETIA), in ancient geography, a province of the Roman empire, bounded on the west by the country of the Helvetii, on the east by Noricum, on the north by Vindelicia and on the south by Cisalpine Gaul. It thus comprised the districts occupied in modern times by the Grisons, the greater part of Tirol, and part of Lombardy. The land was very mountainous, and the inhabitants chiefly supported themselves by cattle-breeding and cutting timber, little attention being paid to agriculture. Some of the valleys, however, were rich and fertile, and produced corn and wine. Trade was also carried on in pitch, honey, wax and cheese Little is known of the origin or history of the Raetians, who are described as one of the most powerful and warlike of the Alpine tribes. It is stated by Livy (v. 33) that they were of Etruscan origin At the time when the land became known to the Romans, Celtic tribes were already in possession of it and had amalgamated so completely with the original inhabitants that, generally speaking, the Raetians may be regarded as a Celtic people, although non-Celtic tribes (Lepontii, Euganei) were settled among them They retained their independence until their subjugation in 15 B.C. by Tiberius and Drusus. At first Raetia formed a distinct province, but towards the end of the 1st century A.D. Vindelicia was added to it; hence Tacitus (*Germania*, 41) could speak of Augusta Vindelicorum (Augsburg) as "a colony of the province of Raetia." The whole province (including Vindelicia) was at first under a military prefect, then under a procurator; it had no standing army quartered in it, but relied on its own native troops and militia for protection In the reign of Marcus Aurelius it was governed by the commander of the *Legio iii. Italica*. Under Diocletian (*q.v.*) it formed part of the diocese of the *vicarius Italiae*. During the last years of the Western empire, the land was in a desolate condition, but its occupation by the Ostrogoths in the time of Theodoric, to some extent revived its prosperity. The chief towns of Raetia were Tridentum (Trent) and Curia (Coire or Chur). It was traversed by two great lines of Roman roads—one leading from Verona and Tridentum across the Brenner to Oenipons (Innsbruck) and

thence to Augusta Vindelicorum; the other from Brigantium (Bregenz) on Lake Constance, by Coire and Chiavenna to Como and Milan.

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RAFF, JOSEPH JOACHIM (1822–1882), German composer and orchestral conductor, was born near Zürich, Switzerland, on May 27, 1822, and educated chiefly at Schwyz. He was encouraged and assisted by Liszt and von Bülow, his opera, *König Alfred*, being produced at Weimar under Liszt's direction.

Raff lived at Weimar until 1856. In 1859 he married Doris Genast, an actress of high repute, and thenceforward devoted himself with renewed energy to the work of composition, displaying an inexhaustible fertility of invention and great technical skill. He resided chiefly at Wiesbaden till 1877, when he was appointed director of the Hoch-Conservatorium at Frankfort, an office which he retained until his death on June 25, 1882.

Raff's compositions included symphonies, quartets, concertos, sonatas and songs.

RAFFIA. A fibrous product consisting of the epidermal strips of the leaves of *Raphia ruffia* (from Madagascar) and *R. taedigera* (from Japan) largely employed as a binder twine in horticulture and in various kinds of handwork.

RAFFLE, a special kind of lottery, in which a particular article is put up as the prize, the winner being drawn for by lot out of the number of those who have paid a fixed sum for admission to the drawing; the total amount realized by the sale of tickets is supposed to approximate to the value of the object raffled for. The word appears in English as early as Chauçer (*The Parson's Tale*), where it is used in its original sense of a game of dice, the winner being that one who threw three dice all alike, or, next, the highest pair. The Fr. *rafle*, Med. Lat. *raffla*, was also used in the sense of a "sweeping-off" of the stakes in a game; it has been connected with Ger. *raffen*, to carry off.

RAFFLES, SIR THOMAS STAMFORD (1781–1826), English administrator, founder of Singapore, was born on July 5, 1781, on board a merchantman commanded by his father, Benjamin Raffles, when off Port Morant, Jamaica. He became a clerk in the office of the East India Company, and in 1805 was sent out to Penang as assistant secretary to the first governor. In addition to his duties as secretary he acted as Malay interpreter, and in 1807 he became secretary.

In 1808 his health gave way, and he was ordered for a change to Malacca. The East India Company had decided to abandon Malacca, and orders had been issued to dismantle it. Raffles drew up a report explaining the great importance of Malacca, and urging in the strongest manner its retention. Lord Minto was so impressed by the report that he at once gave orders for suspending the evacuation of Malacca, and in 1809 the company decided to reverse its own decision. In June 1810 Raffles, of his own accord, proceeded to Calcutta, where Lord Minto gave him the kindest reception. Raffles remained four months in Calcutta, and gained the complete confidence of the governor-general. He brought Lord Minto round to his opinion that the conquest of the island of Java, then in the hands of the French, was an imperative necessity. To prepare the way for the expedition, Raffles was sent to Malacca as "agent to the Governor-General with the Malay States." He did his work well and thoroughly—even to the extent of discovering that the short and direct route to Batavia by the Caramata passage would be a safe one for the fleet to take.

In August 1811 the expedition, accompanied by Lord Minto, and with Sir Samuel Auchmuty in command of the troops (11,000 in number, half English and half Indian), occupied Batavia without fighting. On the 25th a battle was fought at Cornelis, a few miles south of Batavia, and resulted in a complete English victory. On Sept. 18 the French commander, General Janssens, formally capitulated at Samarang, and the conquest of the island was completed. Lord Minto's first act was to appoint Raffles lieutenant-governor of Java. From September 1811 until his departure for England in March 1816, Raffles ruled this large island with conspicuous success. He increased the revenue eightfold at the same time that he abolished transit dues, reduced port dues to one-third and removed the fetters imposed on trade and intercourse with the Javanese by Dutch officialdom. In his own words, his administration aimed at being "not only without fear, but without reproach." He had a still greater ambition, which was, in his own words, "to make Java the centre of an Eastern insular Empire," and to establish the closest relations of friendship and alliance with the Javanese, whom he described as "a highly polished people, considerably advanced in science, highly inquisitive and full of penetration." It is interesting to note that when another great Englishman, Rajah Brooke, began his career in Sarawak in 1838, he announced: "I go to carry Sir Stamford Raffles's views in Java over the whole Archipelago."

In November 1817 Raffles quitted England on his return to the East, where the lieutenant-governorship of Fort Marlborough (Sumatra) had been kept in reserve for him. His administration of Sumatra (1818–23) was characterized by the same breadth of view, consistency of purpose and energy in action that had made his government of Java remarkable. He had not, however, done with the Dutch, who, on their recovery of Java, endeavoured to establish a complete control over the Eastern archipelago, and to oust British trade. This design Sir Stamford set himself to baffle, and by a stroke of genius and unrivalled statecraft he stopped for all time the Dutch project of a *mare clausum* by the acquisition and founding of Singapore on Jan. 29, 1819.

In 1824 Raffles returned to England to vindicate his acts to the East India Company. The court exonerated him from the charges made against him, but censured him for "his precipitate and unauthorized emancipation of the Company's slaves," and after his death charged his widow to pay £10,000 for various items, which included the expense of his mission to found Singapore. Harassed by these personal affairs, he still found time to help in the foundation of the zoological society in London. His fine Sumatra collection formed its endowment. He died July 5, 1826.

See Lady Raffles, *Memoir of Sir Thomas Stamford Raffles* (1830); D. C. Boulger, *Life of Sir Stamford Raffles* (1897); Hugh Egerton, *Sir Stamford Raffles* (1899); J. Buckley, *Records of Singapore* (1903).

RAFFLESIA, a genus of plants of the family Rafflesiaceae with six species confined to Malaya. They are all parasitic on the roots of vines (*Vitis*). *R. Arnoldi* has the largest flower known, measuring 18in. across and weighing 15lb. with a smell like decaying flesh. It is pollinated by carrion-flies, and is the only part of the plant visible above ground, the remainder being reduced to a fungus-like mycelium.

RAFTER. A beam in a sloping roof to which is attached the framework for the slating, tiling or other external covering (*see* ROOFS).

O.E. *raefter*, a beam, in the special sense of a floating collection of timbers, gives the English "raft."

The ultimate base of this word is the root *raf-*, to cover, seen in Gr. *ὄροφος*, roof.

RAGAZ or RAGATZ, a famous watering-place in the Swiss canton of St. Gall, situated on the left bank of the Rhine, and by rail 61½ m. S.E. of Zürich. It stands at a height of 1,696 ft., at the entrance to the magnificent gorge of the Tamina, about 3 m. up which by road are the extraordinarily placed Baths of Pfäfers. Since 1840 the hot mineral waters of Pfäfers have been conducted to Ragaz, which has much increased in importance as a result. In 1930 its native population was 2,162, mainly German-speaking, while there were 1,500 Roman Catholics and 500 Protestants. About 2 m. by road above Ragaz are the 17th-century buildings (now the cantonal lunatic asylum) of the great Benedictine abbey of Pfäfers (720–1838), to which all this region belonged till 1798; while between them and Ragaz are the ruins of the 14th-century castle of Wartenstein.

RAGGED ROBIN (*Lychnis Flos-cuculi*), a perennial plant with pink, divided petals, belonging to the pink family, Caryophyllaceae (*q.v.*), native to Europe and Asia, common in Great Britain and naturalized in the eastern United States. It is a slender herb, about 1½ ft. high, and is much parasitized by a fungus,

Ustilago antherarum, which forms its spores in the stamens, whence they are transported from plant to plant by insects.

RAGLAN, FITZROY JAMES HENRY SOMERSET, 1st Baron (1788–1855), British field marshal, was the eighth and youngest son of Henry, 5th duke of Beaufort, by Elizabeth Boscawen, and was born on Sept. 30, 1788. Lord Fitzroy Somerset was educated at Westminster school, and entered the army in 1804. He served on the staff of Sir Arthur Wellesley in the expedition to Copenhagen (1807), and went with him to Portugal in 1808. During the whole of the Peninsular War he was at his right hand, first as aide-de-camp and then as military secretary. He was the first to mount the breach at Badajoz, and afterwards showed great resolution and promptitude in securing one of the gates before the French could organize a fresh defense. During the short period of the Bourbon rule in 1814 and 1815 he was secretary to the English embassy at Paris. On the renewal of the war he again became aide-de-camp and military secretary to the duke of Wellington. About this time he married Emily Harriet, daughter of the 3rd earl of Mornington, and Wellington's niece. At Waterloo he was wounded in the right arm and had to undergo amputation, but on the conclusion of the war resumed his duties as secretary to the embassy at Paris. From 1818 to 1820, and again in 1826–29, he sat in the house of commons as member for Truro. In 1819 he was appointed secretary to the duke of Wellington as master-general of the ordnance, and from 1827 till the death of the duke in 1852 was military secretary to him as commander-in-chief. He was then appointed master-general of the ordnance, and was created Baron Raglan.

In 1854 he was promoted general and appointed to the command of the British troops sent to the Crimea (*see* Crimean War) in co-operation with a strong French army under Marshal St. Arnaud and afterwards, up to May 1855, under Marshal Canrobert. Here the advantage of his training under the duke of Wellington was seen in the soundness of his generalship, and his diplomatic experience stood him in good stead in dealing with the generals and admirals, British, French and Turkish, who were associated with him.

For the hardships and sufferings of the British soldiers in the terrible Crimean winter before Sevastopol, owing to failure in the commissariat, both as regards food and clothing, Lord Raglan and his staff were at the time severely censured by the press and the government; but it afterwards appeared that the chief neglect rested with the home authorities. He was made a field marshal after Inkermann. During the trying winter of 1854–55 his health was undermined. Disappointment at the failure of the assault of June 18, 1855, finally broke his spirit, and on June 28, 1855, he died.

See Kinglake, *Invasion of the Crimea* (1863–87); Hamley, *War in the Crimea* (1891).

RAGMAN ROLLS, the name given to the collection of instruments by which the nobility and gentry of Scotland were compelled to subscribe allegiance to Edward I of England between the conference of Norham in May 1291 and the final award in favour of Baliol in Nov. 1292, and again in 1296. Of the former of these records two copies were preserved in the chapterhouse at Westminster (now in the Record office, London), and it has been printed by Rymer (*Foedera,* ii. 542). Another copy, preserved originally in the Tower of London, is now also in the Record office.

The derivation of the word "ragman" has never been satisfactorily explained, but various guesses have been made. One is that the Scots spoke of such an instrument as "ragman" because of the numerous seals attached to it. The name "ragman roll" survives in the colloquial word "rigmarole," a rambling, incoherent statement.

RAGNAR LODBROK, Scandinavian ruler of the 8th or 9th century, supposed to have invaded England and France. It is nearly certain that such a person existed, but he has become a Scandinavian hero and the myths surrounding him are so extensive that it is difficult to separate the true from the fictional and to determine precisely what took place during his reign. One theory is that there were two men around whom the stories are woven: a prince named Ragnar Lodbrok, who died in 794; and another prince named Raginfrid or Regnier, who actually led the invasions of France and England, which did not take place until the 9th century, but who is known in Scandinavian history and legend as Ragnar Lodbrok also. In any case, the myths about the two men of the same name have become inextricably intertwined.

The story is that Ragnar Lodbrok sailed up the Seine river to Paris, which he captured and which was only redeemed by a ransom of 7,000 lbs. of silver. Later, the story runs, jealous of the reported achievements of his two sons, he planned to outdo them by invading England. He constructed two ships, the largest that had ever been built in Scandinavia, and sailed for Northumberland. He was captured by Aella, the Saxon king of Northumberland, after a valiant fight, and thrown alive into a pit of snakes, which stung him to death. His death song, the *Lodbrokar-quida,* has become a Scandinavian epic. His sons revenged him by killing Aella, and Northumberland ceased to be a Saxon kingdom and was looted and plundered by the Norsemen.

RAGNAROK, a Scandinavian myth telling of the death of the gods and the destruction of the world. The name is probably derived from the Old Norse words *regin* or *rogn,* god, and *rok,* reason, origin or history, although it is sometimes thought that the word comes from the Icelandic *ragna,* gods, and *rokr,* twilight. The story is contained in the Icelandic saga *Völuspá.* It tells of the war between the gods, led by Odin, and their evil opponents, led by Loki. The Ragnarok combines three common stories of the destruction of the world: the sinking of the earth into the sea and the devouring of the sun by a monster; a devastating winter; and the destruction of the earth by fire. In addition to the annihilation of the earth, the chief protagonists on each side are killed and there is a period of darkness and chaos. Afterwards, however, some of the gods who were not destroyed return to the earth, which has risen from the sea, and with them return a human couple, Lif and Lifthraser (Life and Vitality), who are the progenitors of a new race. This is the story used by Richard Wagner, the German composer, in his opera *Götterdämmerung,* the German word for "twilight of the gods."

RAGS. With the growth of the textile industries throughout the world, the consumption of rags of various sorts became enormous. The aggregate cannot be computed, but some conception of the dimensions of the trade may be gathered from the fact that the United Kingdom, in addition to consuming the greater part of her own production of rags, has a substantial import trade in linen, cotton and woollen rags. The linen and cotton rags are used in paper manufacture, and the woollen rags are employed in the textile industries. (*See* Paper Materials; Shoddy.)

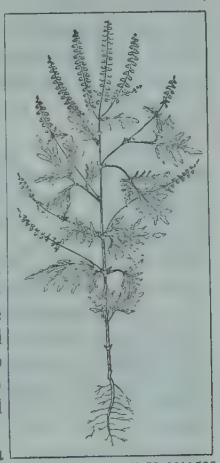
RAG-STONE, a name given sometimes to work done with stones which are quarried in thin pieces, such as the Horsham sandstone, Yorkshire stone, the slate stones, etc.; but this is more properly flag or slab work. Technically, rag-stone is an excellent material from the neighbourhood of Maidstone, near London; a very hard limestone of bluish-grey colour, peculiarly suited for mediaeval work. It is often laid as uncoursed work, or random work, sometimes as random coursed work and sometimes as regular ashlar. (*See* Masonry.)

RAG-TIME: *see* Jazz.

RAGUSA, a town and provincial capital of Sicily in the province of Ragusa, 70 mi. S.W. of Syracuse by rail and 32 mi. direct. It consists of an upper and a lower town united into one commune in 1926. Pop. (1936) 40,480 (town); 49,530 (commune). The city has an entirely new quarter, called Littorio. It has some churches with fine Gothic architecture, and is commercially important, a stone impregnated with bitumen being quarried and prepared for use for paving slabs by being exposed to the action of fire. Oil suited to Diesel motors is extracted. On the hill occupied by the castle of the lower town (Ragusa Ibla) stood the ancient Hybla Heraea, a Sicel town, under the walls of which Hippocrates of Gela fell in 491 B.C. During World War II Ragusa was severely bombed by the U.S. and British air forces prior to its occupation.

RAGUSA, Yugoslavia: *see* Dubrovnik.

RAGWEED, the name given in North America to native plants of the genus *Ambrosia* (family Compositae). They are chiefly coarse annuals, with rough hairy stems, mostly lobed or divided leaves, and greenish flowers borne in small heads, the male in terminal spikes and the female in the upper axils of the leaves. The common ragweed (*A. artemisiifolia*), called also Roman wormwood, hogweed and bitterweed, found across the continent, grows from 1 to 7 ft. high, with thin, alternate or opposite, much-divided leaves. The great ragweed (*A. trifida*), called also bitterweed and horse cane, native from Quebec to Saskatchewan and southward to Florida, Arkansas and Colorado, grows from 3 to 17 ft. tall, with opposite, entire or palmately three- to five-lobed leaves. Both the foregoing are annuals and often become pernicious weeds; their pollen, which is shed in great abundance in late summer, is a prolific source of hay fever. The western ragweed (*A. psilostachya*), found from Illinois to Alberta and southward to California, Texas and Mexico, is similar to the common ragweed, but is a perennial and has thicker leaves.



FROM NEW YORK STATE COLLEGE OF AGRICULTURE AT CORNELL UNIVERSITY

COMMON RAGWEED (AMBROSIA ARTEMISIIFOLIA), WITH SPIKES OF POLLEN-BEARING FLOWERS, READY TO SHED THE POLLEN WHICH CAUSES HAY FEVER

RAGWORT (*Senecio jacobaea*), a common plant in European pastures and wasteland, growing to a height of over 2 ft., with heads of bright yellow flowers. It is allied to the groundsel (*q.v.*) and is one of the five noxious weeds whose removal in Great Britain is enforced by law. This weed, known also as staggerwort, is sparingly naturalized in North America from Newfoundland to Ontario and southward to Pennsylvania. In the United States and Canada various other species of *Senecio* are called ragwort, *e.g.*, the golden ragwort or swamp squawweed (*S. aureus*), a conspicuous wild flower of early summer, inhabiting swamps and wet meadows.

RAHAB, a Biblical character, who sheltered the spies sent by Joshua to investigate Jericho before the Jews crossed into Canaan. Rahab, whom *Joshua ii* speaks of as a harlot, admitted the spies to her house and concealed them from the messengers of the king of Jericho by hiding them under sheaves of flax on the roof. She sent the king's messengers away and then let Joshua's spies out of her window by a cord; and, since her house was built on the town wall, they escaped. In return, she asked that she and her family be spared from injury if the Israelites should take Jericho. This request the spies granted, telling Rahab that when the Israelites came, she should hang a red cord from the window through which the spies had escaped. This she did, and she and her family were saved. Later, when the Israelites had taken Jericho, Rahab was admitted to the community. Jewish tradition is that Rahab married Joshua and that eight prophets were descended from them. Another story is that she married Salmon, one of the spies, and that they were the parents of Boaz and thus she is an ancestor of David and of Jesus Christ. The Roman Catholic Church has made her a saint, whose day is celebrated Sept. 1. The Targum and the majority of older Jewish commentators translate the Biblical word *zōnāh,* used to describe Rahab as "innkeeper," deriving it from the root, *zūn,* "to feed," instead of from the root, *zānāh,* "to be a harlot"; but most versions translate "harlot."

RAHWAY, a city of Union county, N.J., U.S., on the Rahway river, 20 mi. S.W. of New York city. It is served by the Pennsylvania railroad and motorbus lines. Population in 1950 was 21,290; it was 17,498 in 1940 and 16,011 in 1930 by federal census. The city has attractive parks and many houses dating from colonial times. At the Old Peace tavern (still standing) the marquis de La Fayette was entertained in 1824.

The city's manufactures include vacuum cleaners, office equipment, furniture, automobile bodies and accessories, books, oil, bleaches, chemicals, cotton and wool waste and cereals. In the outskirts of the city is the New Jersey reformatory (1903) for men from 16 to 30 years of age. Rahway was settled in 1720; named after the Indian chief Rahwack of the tribe which owned the site; and was chartered as a city in 1858. A skirmish of the Revolution (called the battle of Spanktown, from the name by which the town was popularly known at the time) took place there in Jan. 1777.

RAICHUR, a town and district of India, in the state of Hyderabad, at the junction of the Madras and Southern Mahratta and Great Indian Peninsula railways, 351 mi. N.E. from Madras. Pop. (1941) 34,972. It gives its name to the *doab,* or tract between the rivers Kistna and Tungabhadra, which was the scene of much fighting between Mohammedans and Hindus as debatable land during the 16th century. The district has an area of 6,791 sq.mi. and a population of 922,322. The town contains a well-preserved fort and palace. It is a thriving centre of trade, with a number of cotton ginning and pressing factories.

RAIGARH, a feudatory state of India in the Chhattisgarh division of the Central provinces. Area 1,444 sq.mi.; population (1941) 312,643. It is traversed by the Bengal-Nagpur railway with a station at Raigarh Town, 363 mi. from Calcutta. Fine tussore silk is produced at Raigarh Town; pop. (1941) 20,327.

RAIL, the general English name for birds of the family *Rallidae,* to the two British species of which it originally applied. The first of the latter is the corncrake or land rail, *Crex crex,* recognizable by its monotonously repeated grating cry which has been aptly likened to the sound made by a rusty gate hinge. It is a summer visitor to north Europe, retiring south in winter. The plumage is of various shades of brown above and yellowish white below, rendering it very inconspicuous. It haunts the open country and agricultural land, the nest being on the ground, usually in long grass. Nine to 11 eggs are laid, of a cream colour blotched with light red and gray. The young are hatched clad in black down.

The water rail, *Rallus aquaticus,* is less abundant than the preceding, but has a wide distribution, extending all over the old world north of the tropics. The call is harsh, loud and uttered only at intervals. It has a long, partly red bill and the plumage is darker than that of the land rail. It inhabits marshes. Closely related is the sora, or Carolina rail, *Porzana carolina;* also the coot (*q.v.*), moor hen (*q.v.*) and ocydrome.

The finfoots (*Heliornis* and *Podica*) show the extreme in adaptation to aquatic life in the development of a fringe round the toes (*see* Coot).

RAILWAY EXPRESS AGENCY, INC., THE, was formed in 1929 by the class I railroads of the United States to take over and carry on the express business formerly handled by the predecessor company, American Railway Express. It is a common carrier under jurisdiction of the Interstate Commerce commission. Express is carried on approximately 10,000 passenger trains daily. The air express service was established Sept. 1, 1927.

See also Express.

RAILWAYS. The term "railway" or "railroad" is commonly applied to a method of transportation, and the facilities therefor, consisting of a permanent way whose distinctive feature is a line, or lines, of steel rails, in pairs, over which roll, on flanged wheels, freight and passenger cars pulled by locomotives. In the United States "railway" and "railroad" are used interchangeably, with the latter probably favoured; "railway" is preferred in British usage.

Transportation by railroad is based upon four familiar elements. They are (1) track, a roadway unlike anything else, affording strong support and a smooth surface with a minimum of friction, and thereby facilitating a high ratio of load to tractive effort; (2) trains made up of separate cars assembled according to the needs of traffic; (3) flanged wheels, which cause the trains of cars to "track," or follow the line of the rails; and (4) locomotives to haul the trains over the tracks.

Economics of Location.—The ideal location for a railway line is one which connects large centres of trade and travel, in a straight line and over level ground. The actual location usually

is the best available compromise between cost for construction and annual costs for operation and maintenance, topography considered, on the one hand, and the probable flow and revenue value of traffic, on the other hand. The usual result is that in older and more highly developed and industrialized regions it is common to find lines which represent large capital costs for original construction and subsequent improvement to provide easy gradients and curvature for high train speeds with heavy loads, with low annual maintenance and operating costs. By contrast, in countries of more recent development, with sparse population and low agricultural and industrial output, the railway line is more likely to represent a relatively low initial investment for construction, costlier forms of improvement being deferred until warranted by traffic development.

Gauges.—The distance between the inner edges of the running surface of the pair of rails comprising a track is called the "gauge." That which has come to be known as standard gauge is 4 ft. 8½ in. The origin of this curious measurement is not definitely known, and has become a matter of legend. Of total world mileage of railway line, approximately three-fifths is of standard gauge. This gauge is practically universal for Canadian, United States, Mexican and Cuban railways. Main trunk lines of Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, France, Germany, Great Britain, Greece, Hungary, Italy, the Netherlands, Norway, Sweden, Turkey and Yugoslavia are all 4 ft. 8½ in., or so close to that gauge as to permit through running of locomotives and rolling stock. In Ireland the gauge is mainly 5 ft. 3 in., while in Spain and Portugal the lines are mainly 5 ft. 6 in. and in the U.S.S.R. 5 ft. On the European continent there are considerable mileages of metre (39.37 in.) and other smaller gauges, especially in mountainous districts, such as parts of Germany and Switzerland.

The South American railways are mainly of metre gauge, but with substantial mileages also of 5 ft. 6 in. and of standard gauge; in addition, there are smaller mileages of several other gauges. Railroads of Central America are all narrow gauge, mainly 3 ft. and 3 ft. 6 in., with a small mileage of 5-ft. gauge in Panamá.

The gauge in India is mainly 5 ft. 6 in., but there are large mileages of metre and other narrow gauges. In Japan the normal gauge is 3 ft. 6 in. The South African railways are of the 3 ft. 6 in. gauge, as also is the Sudan government system, but the Egyptian state lines are built to standard gauge, while the Kenya and Uganda railway is built to a metre gauge.

Development of railways in Australia has suffered because of the difference in gauges adopted by the various state systems. These include 3 ft. 6 in., standard gauge and 5 ft. 3 in. New Zealand railways are 3 ft. 6 in. gauge.

History and Development.—The steam railway originated in Great Britain. It was a development of the wagonway or tramway for horse-drawn vehicles, frequently employed there during the 16th, 17th and 18th centuries to haul minerals to rivers and ports, notably in the areas of the Clyde (Scotland) and the Tyne (England) and in South Wales.

Invention of the steam engine induced Richard Trevithick (1771–1833) (*q.v.*) to design a steam engine, mounted on wheels, which generated sufficient power to move itself; in fact, it became a locomotive. (*See* LOCOMOTIVE.) In Feb. 1804 this engine successfully pulled "10 tons of iron, 5 waggons and seventy men" on a tramway at Pen-y-darran, near Merthyr, Wales. It was not a commercial success, and horse traction continued to prevail on the wagonways and tramways. In 1811 John Blenkinsop (1783–1831) patented a design of a rack railway, a toothed wheel on his locomotive working into a toothed rail; this system proved successful on his Middleton colliery railway at Leeds, and is still employed in different form on some mountain railways with very steep gradients. In 1813 William Hedley built two steam locomotives for the Wylam colliery near the Tyne, which relied on their own weight for traction by adhesion, and in 1814 George Stephenson (1781–1848) (*q.v.*) built his first locomotive.

The success Stephenson achieved enabled him to propose steam locomotives as the means of traction on the Stockton and Darlington railway. Projected in 1818 and opened Sept. 27, 1825, this was the first public passenger-carrying railway in the world. It was of single track, 38 mi. long, with passing places every quarter mile. Stephenson drove the first train, weighing about 90 tons, from Brusselton Incline, nine miles above Darlington, to Stockton; for some years the passenger traffic was carried by horse-drawn coaches but these were withdrawn in 1833.

Before 1830 several short railroads were incorporated, but the Liverpool and Manchester was noteworthy because from the first it adopted locomotive power as the sole form of traction, and was built to carry passenger traffic as well as freight. Opened Sept. 15, 1830, it was 31 mi. long, with double-track line throughout. The average time for a passenger train to complete the journey was about 90 min.

In 1829 a contest was held among various locomotive designers, and the engines were tested at Rainhill, near Liverpool, George Stephenson's "Rocket" carrying off the prize of £500. Other locomotives in the contest were the "Novelty" of John Braithwaite and the "Sans Pareil" of Timothy Hackworth. Both the "Rocket" and "Sans Pareil" are preserved in the Science museum, South Kensington, London.

In the western hemisphere, John Stevens (*q.v.*), called in the United States "the father of the railroads," and his associates received from the state of New Jersey on Feb. 6, 1815, the first American railroad charter, but he could obtain neither the money nor the credit to do the work. About this time, there was considerable use of tracks of wood, iron or stone, over which cars were drawn by horses or stationary engines, the latter used principally in the operation of inclined planes. In 1826 Gridley Bryant built in the United States such a set of tracks, called the Quincy railroad. The little line, three miles long, was used for hauling granite, by horsepower, from quarries near Quincy, Mass., to the Neponset river. It was not a passenger line nor did it use a locomotive. It was built of pine ties, atop which were laid oak timbers faced with iron.

Also in 1826 the Delaware and Hudson Canal company was authorized to build a 16-mi. line of rails between Carbondale and Honesdale, Pa., connecting its canal with coal mines. This was the first railroad on which a locomotive was ever operated in the western hemisphere. The "Stourbridge Lion," a British-built locomotive, made one trip on it in Aug. 1829, without cars, but the track structure was too light for the locomotive to be operated with safety. Thus early was demonstrated the inescapable relationship between the size, weight and speed of the vehicle and the strength of the way on which it runs.

The Baltimore and Ohio, the first railroad built in the United States for general transportation of passengers and freight (but not projected specifically for the use of locomotives), was chartered by the state of Maryland on Feb. 28, 1827, and construction was formally commenced on July 4, 1828. In Feb. 1829 work began on laying the track of the South Carolina Canal and Rail Road company between Charleston and Hamburg, S.C., the first railroad in the United States built for public transportation by use of steam locomotives, without a path down the middle for horsepower. On Dec. 25, 1830, the "Best Friend of Charleston," a locomotive built in New York to the railroad's own design and shipped by ocean to Charleston, pulled on the railroad's first six-mile stretch of completed track the first train of cars ever drawn by a steam engine upon a track on the American continent.

World Mileage.—From these beginnings, railroads developed to a world total of approximately 780,976 mi., distributed by continents as follows:

Continent	Miles of road
North America	283,802
Europe	262,875
Asia	95,588
South America	61,937
Africa	43,389
Australasia	31,551
Central America and Canal Zone	1,834
Total	780,976

Subsequent discussion will review the railroads of the several continents in the order of their mileage.

In some instances, especially in Europe, it has been necessary

to use figures for 1937. Mileage includes so far as possible only intercity main-line railroads open for public traffic. However, difficulties of consistent definition and inclusion are such that mileage figures should be regarded only as approximate and perhaps not always comparable.

NORTH AMERICA

Railway mileage in North America, by countries, for the years indicated was as follows:

	Year	Miles of road
United States	1948	225,149
Alaska	1948	507
Canada	1948	41,909
Newfoundland	1948	705*
Mexico	1949	12,517
Cuba	1945	3,015
Total		283,802

*All 3 ft. 6 in. gauge. Newfoundland became a province of Canada on April 1, 1949.

UNITED STATES

General Description.—With scarcely more than 6% of the world's population and 5% of its land area, the continental United States has 29% of the world's railway mileage, and probably an even larger share of its freight and passenger transportation capacity. The United States has about four-fifths of the railway mileage of North America.

Origin and Growth of Railways.—In 1815, when John Stevens received the first state charter for construction of a railroad in the United States, approximately four-fifths of the country's total population of 8,350,000 resided along the Atlantic seaboard. Most of the remaining one-fifth was in the Ohio valley, with scattering but growing settlements elsewhere in the Mississippi valley.

The War of 1812, the Napoleonic wars and the tariff of 1816 had given an impulse to domestic manufactures and to internal trade and had created aspirations toward an economic progress that would require transportation facilities far larger and better than then existed. Territorial division of labour had commenced, promising enormous expansion of internal commerce. Machinery, iron products and textiles for use west of the Allegheny mountains were being manufactured in the Atlantic states; farms west of these mountains produced grain and food supplies for the south. The east, because of the increased population of industrial centres following a rush of foreign immigration, had also become dependent upon the west for food supplies; the southern states were experiencing a rapid expansion of the cotton-growing industry, and their exports made up two-thirds of total United States exports.

The great obstacle to interstate trade and internal development was slow and costly transportation. Routes of movement had assumed sharply defined lines, at first following natural waterways. Areas not served by such channels had demanded facilities to enable them to compete with their more fortunate neighbours. Turnpikes and canals had been constructed, but the services of these two agencies were sharply restricted by geographic and climatic conditions. In short, the picture was that of a growing number of economically detached communities, increasing rapidly in population and industrial importance, and each possessing the foundation for profitable commercial interchanges, if only the machinery for interchange could be created.

Government Aid to Construction.—In early years there was keen competition among communities in promoting for themselves the benefits of railway service, and railroads (as well as turnpikes and canals) were granted substantial amounts of public land and various other types of aid by the federal government, states and other public bodies. The extent of such aid to railroads is often exaggerated. Only about 8% of present route mileage of the country had the benefit of federal land grants-in-aid toward construction. In few instances, moreover, did these aids take the form of outright gifts; rather they were business transactions. In return for the federal land grants, the railroads agreed to handle government traffic at reduced rates, which reductions, up to the time the agreement was abrogated by act of congress in 1946, had amounted to more than nine times the original value of the grants. In other cases, government bodies made loans to pioneer railroads, which were expected to be, and for the most part were, repaid with interest. In some other cases, government bodies invested in the stock of railroad companies, and thus acquired a share in the ownership of the property. Some government bodies—for example, the states of Virginia, North Carolina and Georgia and the city of Cincinnati, O.—still (1950) retain these ownership interests in railroads.

Railway Construction.—Within ten days after Charles Carroll of Carrollton, the sole surviving signer of the Declaration of Independence, formally initiated construction of the Baltimore and Ohio, on July 4, 1828, by turning a bit of soil, bids were requested for work on the first 12 mi. of line, from Baltimore to Ellicott City (then Ellicott's Mills), and on May 24, 1830, this section was opened for operation. The line reached Harper's Ferry, W.Va., in 1834, Cumberland, Md., in 1852 and Wheeling, W.Va., in 1853. The branch line from Relay, Md., to Bladensburg (near Washington, D.C.) was opened on Aug. 25, 1835. Subsequent additions and acquisitions extended the road to the Ohio river, the Great Lakes, Chicago and St. Louis.

The South Carolina Canal and Rail Road company (now part of the Southern Railway system) started in Feb. 1829 in Charleston, S.C. When this 136-mi. railroad was completed to Hamburg, S.C., across the Savannah river from Augusta, Ga., in 1833, it was the longest in the world. Southern Railway system lines now interlace the southeastern states and reach Washington, D.C., Cincinnati, O., and St. Louis, Mo.

The Mohawk and Hudson Rail Road was chartered by the state of New York on April 17, 1826, to build a railroad between the Hudson and Mohawk rivers. After legal delays, construction was started in July 1830, and the first train ran on Aug. 9, 1831, between Albany and Schenectady. Other sections of the present New York Central system which were incorporated and opened for operation between 1836 and 1842 made up together the first line of railroad connecting Lake Erie and the Hudson river. The Hudson River railroad, from New York to Troy, near Albany, was opened in 1852, and the West Shore railroad, from a point on the west shore of the river opposite New York to Buffalo, in 1883. The Lake Shore and Michigan Southern, from Buffalo to Chicago, was formed by the consolidation of several small lines and acquired by the New York Central in 1869. The Michigan Central, begun at Detroit in 1836 and partly constructed by the state of Michigan from 1837 to 1846, was completed to Chicago in 1852. Consolidation of other independent lines formed the "Big Four" route, connecting the Great Lakes with the Ohio and Mississippi rivers. Subsequent acquisition of these and other lines rounded out what is now the New York Central system.

The first New England railroad was the Boston and Lowell (now part of the Boston and Maine railroad), which was chartered in 1830 and opened for traffic in June 1835. Also in June 1835 the Boston and Providence (earliest ancestor of the present New York, New Haven and Hartford railroad) was opened from Boston to Providence, R.I. Completion in July 1835 of the Boston and Worcester (now part of the present Boston and Albany railroad, which is part of the New York Central system) established rail communication between those two Massachusetts cities.

In the south, the Pontchartrain railroad (later absorbed by the Louisville and Nashville Railroad company) was chartered in Jan. 1830 to build a short line connecting New Orleans, La., with Lake Pontchartrain, an inland extension of the Gulf of Mexico. This road opened for business in April 1831. The Richmond and Petersburg railroad, incorporated in 1836, was the start of the present Atlantic Coast Line Railroad company, while the Seaboard Air Line Railroad company had its inception with the charter in March 1832 of a short line between Roanoke and Portsmouth, Va. The City Point railroad, chartered in 1836 and started in April 1837, was the parent of the Norfolk and Western railway. The Louisville and Nashville railroad was chartered by the states of Kentucky and Tennessee early in 1850, and the first through train was operated between these cities at the end of Oct. 1859. The Chesapeake and Ohio railway originated with the charter in Feb. 1836 of the Louisa railway in Virginia, and was completed from

Chesapeake bay to the Ohio river in 1873.

The Pennsylvania railroad had its inception in popular demand for a through rail line from Philadelphia to Pittsburgh, eliminating the canals and inclined planes then existing between the Susquehanna river and Pittsburgh. It was incorporated in April 1846 and construction began in 1847 at both Harrisburg and Pittsburgh. A continuous rail route from Philadelphia to Pittsburgh was opened Dec. 10, 1852, and on Feb. 15, 1854, the use of inclined planes to cross the Alleghenies was discontinued. Before its own rail line was completed, the Pennsylvania was extending financial aid to western connections. By purchases of securities, by traffic arrangements and eventually by long-term leases and corporate consolidations, the present system was built up with lines from the eastern seaboard to the Great Lakes, Chicago, St. Louis, Louisville and Cincinnati.

In 1851 the Erie railroad was completed from Piermont, N.Y. (on the Hudson river just above New York city), to Dunkirk, N.Y., on Lake Erie, affording the first connection by a single railroad between the Atlantic ocean and the Great Lakes.

Railroads began to extend westward from Chicago in 1848 when the Galena and Chicago Union (now part of the Chicago and North Western railway) reached the Des Plaines river, ten miles from the city. However, the Chicago and Rock Island (now part of the Chicago, Rock Island and Pacific Railroad company) was the first to link Chicago with the Mississippi river, which it reached in 1854, two years after construction was begun in 1852. Its bridge was the first across that river. Soon after the bridge was placed in service, a steamboat collided with it and caught fire, and both the bridge and the steamboat were burned. A subsequent lawsuit to prevent the bridge from being rebuilt was successfully defended for the railroad by Abraham Lincoln.

Lines now part of the Chicago, Burlington and Quincy Railroad company reached the Mississippi at a point opposite Burlington, Ia., in 1855 and at Quincy, Ill., in 1856. An extension of the Galena and Chicago Union (C. & N.W.) reached the Mississippi river at Fulton, Ill., in 1855. As a result of these extensions much of the trade along the west bank of the Mississippi and of that part of Illinois which is contiguous to the navigable portion of the Illinois river was diverted from New Orleans. In 1856 the Illinois Central was completed between Chicago and the junction of the Mississippi and Ohio rivers at Cairo, Ill. Using this line, there was by 1860 a through rail route between Chicago and New Orleans, except for an 18-mi. ferry trip between Cairo and Columbus, Ky.

Railway construction west of the Mississippi river began in July 1851, when the Pacific railway of Missouri broke ground for a line which by July 1853 had reached 37 mi. to the westward. On it the first locomotive operated west of the Mississippi made a five-mile run from St. Louis in Dec. 1852. This railroad later became part of the Missouri Pacific system, which operates to New Orleans, La., Denver, Colo., and the southwest.

In 1859 rails were extended to the Missouri river by the completion of the Hannibal and Saint Joseph railroad (now part of the C.B. & Q.); a C. & N.W. line reached the Missouri at Council Bluffs, Ia., early in 1867.

A railway journey completely across the continent was made possible in 1869, when the Union Pacific, building from the Missouri river at Omaha, Neb., met at Promontory, Utah, the Central Pacific (now part of the Southern Pacific lines), built from Sacramento, Calif., making a line 1,776 mi. long. Active construction was started by both lines in 1864, ground having been broken the preceding year. Many hardships and difficulties were encountered in completing this feat of railroad engineering.

Other great transcontinental lines, opening up large areas of rich territory, were then under way, and still others were to come. Work commenced in 1868 on the Atchison, Topeka and Santa Fe railway, building southwestward from Kansas City, and on the Southern Pacific route, building eastward from California, at the end of the following year. In 1881 the A.T. & S.F. and the S.P. joined rails at Deming, N.M., forming the second transcontinental rail route to the Pacific coast and the first direct rail route to southern California.

In 1883 the Southern Pacific opened its eastern extension to New Orleans, completing the first through rail connection between the Pacific coast and the Gulf of Mexico. In the same year the last rail was laid in the connection of the present Northern Pacific railway route between Lake Superior and Puget sound with the line of the Oregon Railway and Navigation company, which had been built 210 mi. eastward from Portland, Ore. The Northern Pacific reached tidewater with its own rails at Tacoma, Wash., in 1887. In 1884 the rails of the Oregon Short Line and the Oregon Railway and Navigation company were joined, forming the Union Pacific route to the Pacific northwest. In 1888 the Santa Fe completed its road from Chicago to California. In 1893 the Great Northern Railway company completed its road from St. Paul, Minn., to Puget sound. And in May 1909 construction of the Chicago, Milwaukee and St. Paul was completed to form still another rail route from Chicago to the Pacific northwest.

On Nov. 1, 1909, rails of the Western Pacific railroad being extended eastward from Oakland, Calif., and those being pushed westward from Salt Lake City, Utah, met near Keddie, Calif., completing the final link in the last transcontinental railway route. This line connected at Salt Lake City with the Denver and Rio Grande Western system of lines, incorporated in 1870 and extended to Salt Lake City and Ogden, Utah, in 1883.

In 1830 the total length of railway lines in the United States was less than 40 mi.; in 1831 it had increased to 95 mi.; in 1832 to 229 mi.; and by 1835 to 1,089 mi. The growth of mileage, by state groups, from 1840 to 1948 is shown in Table I.

TABLE I.—*Length of Railway Lines*

Year	New England*	Middle Atlantic†	North central‡	South§	West of Mississippi river‖	Total length of line
1840	517	1,566	80	636	None	2,799
1850	2,507	3,105	1,272	1,799	None	8,683
1860	3,660	6,353	9,592	8,838	1,840	30,283
1870	4,494	10,991	14,701	11,501	12,191	53,878
1880	5,997	15,949	26,382	14,908	31,435	94,671
1890	6,718	19,842	36,923	20,492	70,622	163,597
1900	7,521	24,691	41,006	35,546	84,582	193,346
1910	7,922	27,379	44,929	47,025	113,084	240,293
1920	7,941	28,096	44,905	49,556	122,347	252,845
1930	7,596	27,602	43,771	47,900	122,183	249,052
1940	6,677	25,703	41,281	44,483	115,526	233,670
1946	6,467	24,982	40,088	43,019	111,882	226,438
1947	6,467	24,784	40,052	42,824	111,679	225,806
1948	6,397	24,634	39,946	42,605	111,567	225,149

*Includes Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut. †Includes New York, Pennsylvania, New Jersey, West Virginia, Maryland, Delaware and District of Columbia. ‡Includes Michigan, Indiana, Illinois, Ohio and Wisconsin. §Includes states south of the Ohio and Potomac rivers and east of the Mississippi river; Louisiana also included. ‖Including Minnesota.

Consolidation of Railroads.—Early railroads were local affairs, designed to accommodate the limited commercial needs of fairly small areas. This local character was reflected in the large number of separate companies; there once were more than 6,000 operating railroads in the United States. As settlement and general development of the country progressed, economic considerations brought about the voluntary consolidation of these many small local railroads into a much smaller number of relatively large systems. As a single and not unusual example, the present New Haven railroad is composed of what were once about 200 separate enterprises. The decision of the supreme court of the United States, in the Northern Securities case (1904), that the Sherman Anti-Trust act applied to railroad consolidation retarded such projects, especially where any element of reduction in competition may have been present.

In the Transportation act of 1920 (see *Governmental Regulation,* which follows) under which the railroads were returned to independent private operation after two years of operation under governmental control during World War I, the Interstate Commerce commission was directed, among other things, to prepare a plan for consolidation of the railroads of the country into a limited number of large systems of fairly equal earning power. This represented a considerable change in national policy from the previous emphasis on competition.

The commission's tentative plan was published in 1921. After prolonged discussion thereof, and many fruitless requests by the commission that it be relieved of the task, the final plan was published in Dec. 1929. It called for 21 consolidated systems. The

great business depression, then in its first stages, diverted attention from the plan, and the low levels of railway earnings through 1931–38, which threw many railroads into the hands of receivers or trustees, were severe deterrents to plans for consolidation. The Transportation act of 1940 omitted former provisions in respect to the commission's consolidation plan, leaving consolidation entirely subject to economic impulsion. However, the act requires commission approval as a condition of any consolidation.

Instead of a country-wide, comprehensive plan of consolidation imposed by statute, present emphasis is on voluntary consolidations along natural economic lines, subject in each case to a finding by the Interstate Commerce commission that the plan proposed is sound and in the public interest. Illustrative is the development of the present Gulf, Mobile and Ohio Railroad company, beginning with consolidation of three small lines in 1916 to form the Gulf, Mobile and Northern, followed by merger with the Mobile and Ohio railroad in 1940 and acquisition of the Alton railroad in 1945–46.

Governmental Regulation.—Railway companies are incorporated under the laws of a state or states. Because the availability and character of railway transportation have such great economic importance and value to the public, and also because the large investment in facilities and equipment required for construction and operation of a railroad tends to hinder easy entrance into the field, the railway industry has come to be customarily regarded as "affected with a public interest" which warrants its supervision and regulation by government.

From their beginning in the late 1820s until after the end of the American Civil War, railroads were subjected to little regulation. However, as the economic importance of the new form of transportation grew and became more apparent, and as contemporary commercial pricing practices were reflected in railway usages, there was increasing public sentiment in favour of governmental regulation of railroads, and especially of the rates charged for their service.

The initial steps were taken by individual states, through creation of railway commissions with supervisory powers. In the early 1870s this tendency received an impetus in central western states in what was known as the Granger movement, as a result of which several states enacted regulatory legislation. State commissions created under this legislation were clothed with extensive powers over railway management, particularly with respect to rates. Experience indicated, however, that regulation of rates by individual states was ineffective, as most traffic was interstate in character and therefore not subject to state regulation. The demand for interstate regulation was met in 1887 by congressional enactment of the Interstate Commerce act (Act to Regulate Commerce), based on the constitutional power of congress to regulate commerce between states. The regulatory powers authorized under the original act were subsequently increased and broadened by enactment of several amendments, notably the Elkins act of 1903, the Hepburn act of 1906, the Mann-Elkins act of 1910, the Panama Canal act of 1912, the Valuation act of 1913, the Clayton Anti-Trust act of 1914, the Transportation act of 1920, the Emergency Transportation act of 1933 and the Transportation act of 1940. Several laws, generally designated as the Safety Appliances acts, also were added.

Under the Interstate Commerce act, the Interstate Commerce commission was created by the congress in 1887 as its agent to administer the provisions and carry out the purposes of the act. As all but a small fraction of railway mileage carries traffic which in some degree is interstate in character, the Interstate Commerce commission is virtually the supreme regulatory authority, although important duties and powers with respect to intrastate commerce remain with regulatory bodies in the several states. The commission comprises 11 members, appointed by the president and confirmed by the senate. They serve for terms of seven years, and not more than six members may be of one political party.

The Transportation act of 1920 marked an important milestone in the development of federal government regulation of railroads. Prior thereto, legislation on the subject had been, in the main, restrictive in character, with emphasis on restraining the rates and earnings of railroads. By 1920, however, there had come to be increasing realization that restrictive policies had been carried too far. For the first time there was incorporated in the basic regulatory statute an affirmative recognition of the need and importance, in the public interest, of adequate railway earnings.

In the Transportation act of 1920 the commission was directed to set rates so that the railways, as a whole or in territorial groups, should be able, under honest, efficient and economical operation, to earn a fair return on the value of property devoted to public service, such value and the rate of "fair return" thereon to be determined by the commission. The fair return, originally set at 6%, was, in 1922, reduced to 5.75%, but the railroads as a whole did not, while this provision of the law was in effect, attain such a return, even in the prosperous years 1926–29.

The provision for a prescribed rate of return was repealed in the Emergency Transportation act of 1933, but this did not alter the basic legislative policy in favour of adequate railway earnings. The declaration of policy of the Emergency Transportation act of 1933, slightly amended in 1940, explicitly declared the intent of the congress that policies and methods of regulation carried on under the Interstate Commerce act should be such as to encourage "sound economic conditions . . . among the several carriers." As adequate earnings are an essential element of sound economic conditions, the congress expressed its legislative approval of such earnings, leaving the exact measure of adequacy to the administrative judgment of the commission.

In view of the importance of this declaration, it is quoted in full, as follows:

> It is hereby declared to be the national transportation policy of the Congress to provide for fair and impartial regulation of all modes of transportation subject to the provisions of this Act, so administered as to recognize and preserve the inherent advantages of each; to promote safe, adequate, economical, and efficient service and foster sound economic conditions in transportation and among the several carriers; to encourage the establishment and maintenance of reasonable charges for transportation services, without unjust discriminations, undue preferences or advantages, or unfair or destructive competitive practices; to cooperate with the several States and the duly authorized officials thereof; and to encourage fair wages and equitable working conditions; —all to the end of developing, coordinating, and preserving a national transportation system by water, highway, and rail, as well as other means, adequate to meet the needs of the commerce of the United States, of the Postal Service, and of the national defense.

The nature and extent of regulation by the Interstate Commerce commission (often paralleled by regulatory commissions of the states) may be indicated by the following summary of present regulatory provisions.

Railroads are required to establish and observe just and reasonable classifications, rates, fares and rules relating to the movement of freight and passengers. Preferential rates, rebates and other forms of discrimination are forbidden. Except upon special authority from the commission, a higher rate may not be charged for transportation for a shorter than for a longer distance over the same line or route, in the same direction, the shorter being included within the longer distance. The commission has authority to correct discriminatory or unreasonable rates and to prescribe maximum, minimum or precise rates. It may establish through routes over the lines of two or more railroads, prescribe joint rates for service over these routes and prescribe the division of these rates among the participating carriers. Rates and fares must be published in tariffs prepared in prescribed manner. Without special permission, they may not become effective except after 30 days' notice. Rates may be suspended for up to seven months pending public hearings as to their reasonableness or other compliance with the law.

Railroads are required to furnish adequate car service under reasonable rules and regulations. The commission has authority in emergency to suspend the operation of these rules and issue such orders with respect to car service and joint or common use of terminals as it considers to be in the public interest. It also may give directions as to priority for movement of traffic.

A railroad may not construct a new line, extend an existing line or acquire or operate any new line without first obtaining a certificate of convenience and necessity from the commission. A

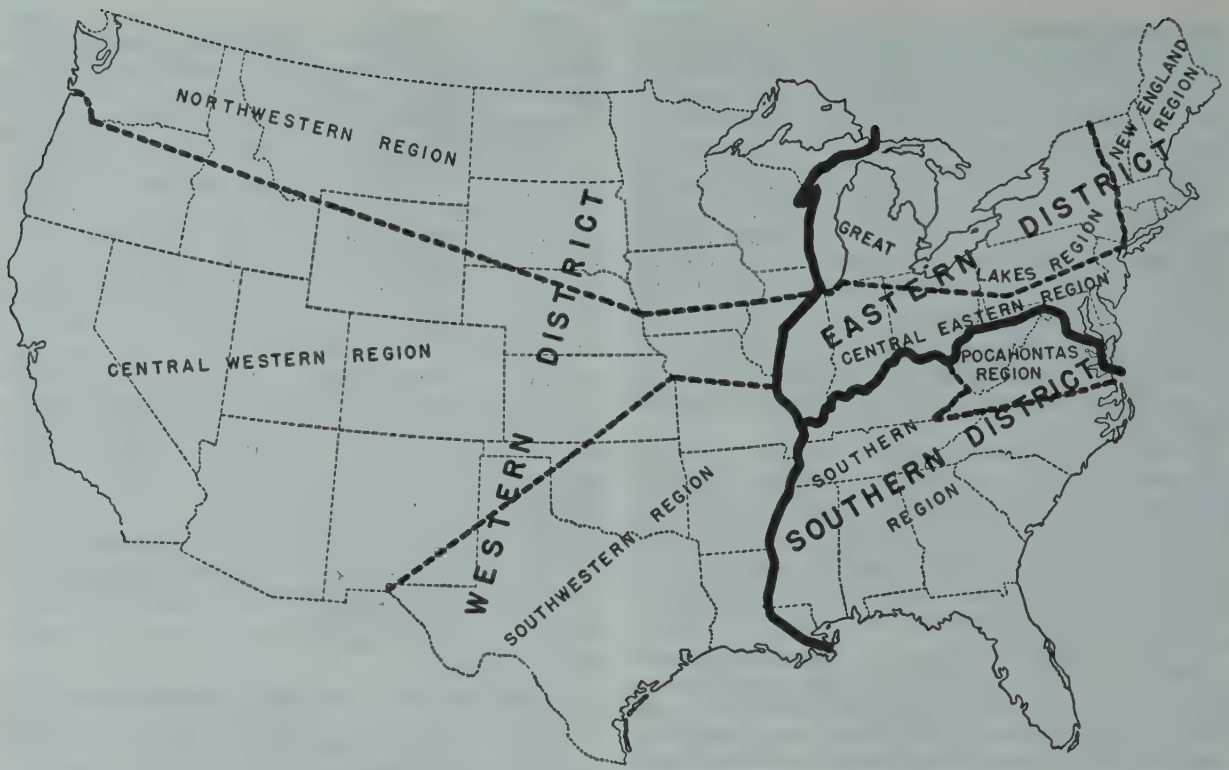


FIG. 1.—GEOGRAPHICAL GROUPING OF U.S. RAILROADS BY THE INTERSTATE COMMERCE COMMISSION

similar certificate must be obtained before it can abandon any portion of a line or the operation thereof. A railroad may not contract or combine with another carrier for the pooling or division of traffic or earnings without specific approval of the commission, upon a finding that such pooling will be in the public interest and will not unduly restrain competition.

As heretofore stated, consolidations and mergers of carriers are subject to commission approval in the light of certain specified factors. A railroad must obtain the approval of the commission before it may issue capital stock, bonds or other evidences of ownership or indebtedness, or assume any obligation with respect to the securities of others.

The commission also has extensive jurisdiction over the installation and operation of safety appliances, including automatic signals of various types. Under the Transportation of Explosives act, it formulates regulations for the safe transportation of explosives and other dangerous articles. The Safety Appliances acts, the Ash Pan act, the Locomotive Inspection act and the Accident Reports act, among others, extend the responsibilities and authority of the commission in matters of safety.

The principal framework of economic regulation is built around the rate provisions—the requirements that rates shall be published and observed, and that they shall be just, reasonable and not unduly discriminatory. Through issuance of certificates of convenience and necessity, the commission has broad powers to control development of the transport structure. Through controls over acquisition, influence can be exercised to prevent lessening of competition thought to be desirable in the public interest. Associated with these three large groups of authority are those having to do with the duty of common carriers to serve adequately and without discrimination in service. The finance powers are also important, as they afford opportunity to supervise carriers' financial structures and practices.

The Interstate Commerce commission also can and does prescribe the form and manner in which accounts of the railroads must be kept. All railway accounting must conform to its rules, and railroads are required to file with the commission periodic reports in extensive detail covering numerous particulars of their operations and finances. Of few industries do public authorities and the public generally have so much and such prompt information as about the railway industry.

For accounting and statistical purposes, railroads were allocated by the Interstate Commerce commission, on a roughly geographical basis, into three districts: eastern, southern and western. These districts were similarly subdivided into regions as follows:

Eastern district: New England region, Great Lakes region and central eastern region.

Southern district: Pocahontas region and southern region.

Western district: northwestern region, central western region and southwestern region.

Location of districts and regions is shown in fig. 1. Railroads were assigned to the district and region in which most of their mileage lies.

Employee Relations.—Collective bargaining between management and employees on matters relating to wages and working conditions is traditional on the railroads, antedating its development in most other industries. Unionization of railroad employees began with an association of locomotive engineers in 1855. By 1950 there were 22 so-called "standard railroad labour organizations." These represented various crafts or classes of railway employees, such as engineers, firemen, trainmen, shopmen, clerks, yardmasters and so on. The so-called operating unions are those composed of men who actually move engines, cars and trains. They comprised about 21% of the total railway organization. The nonoperating unions represented other classes of employees, including clerks, telegraphers, track and shop workers and the like. In addition, there were several other union organizations, not generally referred to as among the standard organizations, but which represented varying numbers of employees on some railroads.

Wages and working conditions on railroads are negotiated directly by local representatives of the respective organizations with individual railroad companies. When negotiations are continued beyond the local level, representatives of the national labour organizations negotiate as a group with railroad officers

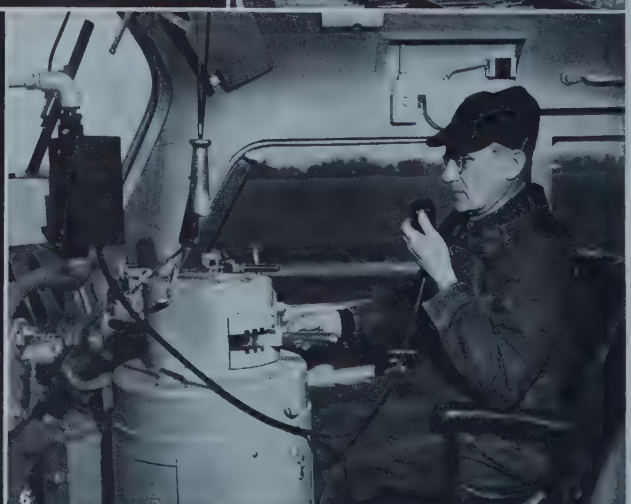
RAILWAYS

BY COURTESY OF (1) THE PENNSYLVANIA RAILROAD, (2) MISSOURI PACIFIC RAILROAD, (4) FRENCH NATIONAL RAILROADS, (5) GREAT NORTHERN RAILWAY COMPANY, (6) THE GERMAN TOURIST INFORMATION BUREAU, (7) CHICAGO, BURLINGTON & QUINCY RAILROAD, (8) CANADIAN NATIONAL RAILWAYS, (9) LONDON AND NORTH EASTERN RAILWAY; PHOTOGRAPH (3) UNION PACIFIC RAILROAD PHOTO

RAILROAD PASSENGER ACCOMMODATIONS

1. Twin-unit dining car aboard a U.S. streamliner
2. Master bedroom arranged for night use aboard a U.S. passenger train
3. Dining-car kitchen on a U.S. train
4. Second-class sleeping compartment, French National railways
5. Reclining coach seats aboard a U.S. streamliner
6. Private compartment on a German train
7. Observation seats on a U.S. car with overhead vision
8. Buffet and lounge accommodations, Canadian National railways
9. First-class dining car, former London and North Eastern railway

RAILWAYS



BY COURTESY OF (1) CHICAGO & NORTH WESTERN RAILWAY, (2, 4) NORFOLK AND WESTERN RAILWAY COMPANY, (3, 5) NEW YORK CENTRAL SYSTEM, (6) CHICAGO, BURLINGTON & QUINCY RAILROAD

RAILWAY SIGNALS AND TRAFFIC CONTROL

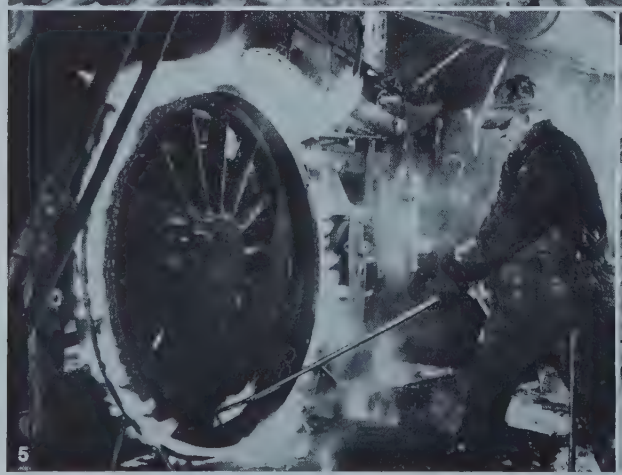
1. Tower from which the general yardmaster can be heard over a public address system reaching all points of the yard; at many points there are facilities for two-way communication
2. Position-light signal
3. Bridge signal at the end of a station platform
4. Semaphore signals along the roadway
5. Interior of a signal station at a terminal, showing train director before his control cabinet
6. Radio used either for end-to-end, train-to-train or train-to-station communication

BY COURTESY OF (1) SOUTHERN RAILWAY SYSTEM, (2, 7) NORFOLK AND WESTERN RAILWAY COMPANY, (3) THE PENNSYLVANIA RAILROAD, (4) FRENCH NATIONAL RAILROADS (SOCIETE NATIONALE DES CHEMINS DE FER FRANÇAIS), (5) BRITISH RAILWAYS, (6) SEABOARD AIR LINE RAILROAD

FREIGHT OPERATION AND SERVICES

1. Freight classification yards at Birmingham, Ala.
2. Tank car for hauling liquids
3. Specially equipped flatcar for carrying containers used for shipping merchandise freight
4. French car for hauling grain. There is no similar type of car in use in the United States, where grain is hauled in boxcars
5. British all-steel welded freight car for carriage of mineral traffic
6. Icing refrigerator cars carrying perishable freight
7. Loading hopper cars with coal

RAILWAYS



BY COURTESY OF (1) NORFOLK AND WESTERN RAILWAY COMPANY, (2) ERIE RAILROAD, (3) THE NASHVILLE, CHATTANOOGA & ST. LOUIS RAILWAY, (4, 6) ATCHISON, TOPEKA & SANTA FE RAILWAY, (5) ASSOCIATION OF AMERICAN RAILROADS

RAILROAD CONSTRUCTION AND MAINTENANCE

1. Rail-laying machine
2. Adzing machines cutting uniform seats for tie plates before the laying of new rail
3. Multiple tie tamper, used in maintaining roadway, which tamps four ties per minute to a uniform surface
4. Specially constructed rug-cleaning room for weekly cleaning of passenger-train carpeting. The automatically fed cleaning solution is later removed by vacuum suction, and the rugs placed in a drying compartment
5. Sweating a tire on a locomotive wheel
6. Refuelling a diesel-electric locomotive

authorized to represent the individual railroad companies. In recent years, railroad labour organizations, especially in dealing with questions involving pay increases, generally divided themselves into two groups, comprising the operating employees group and the nonoperating employees group.

Bases of Pay.—Nonoperating railroad employees are paid on an hourly, daily or monthly basis. In a few instances, certain shopcraft workers are paid on a piecework basis. For most nonoperating employees, eight hours is a basic day's work; time worked in excess of eight hours per day is paid for at 150% of the basic rates. As the result of recommendations by a presidential emergency board, nonoperating employees were placed from Sept. 1, 1949, on a five-day 40-hour work week and their rates of pay were adjusted upward so as produce for 40 hours of work as much as had previously been paid for 48 hours. Penalty pay at one and one-half times straight-time rates is paid for all hours in excess of eight hours per day, as well as for all hours in excess of 40 straight-time hours per week.

The operating group of railway employees may be divided for pay purposes into two classifications: yard employees and those on road trains. Yard employees, representing about 40% of the operating group as a whole, are paid on an hourly or daily basis. Eight hours constitutes a day's work, and overtime thereafter is paid for at the rate of 150% of the basic rate.

Road employees are paid on the basis of miles run. However, if it takes longer than a certain time to run the miles paid for, they then receive overtime in addition to payment for the mileage made. For all employees in road freight service, "eight hours or less—100 miles or less" constitute a day's work for pay purposes. For engineers and firemen in through passenger service, "five hours or less—100 miles or less" constitute a day's work for pay purposes. For conductors and trainmen in through passenger service, a day's work is "seven and one-half hours or less—150 miles or less."

Contract rates of pay for operating employees are expressed in amounts per basic day. The employee receives at least one day's pay if he actually commences work, no matter how few miles he runs or how few hours he works. On the other hand, where an employee runs more than his basic day's mileage, he is paid proportionately for each excess mile run. Average earnings of road employees per run, therefore, are more than the average basic daily rate. In the case of engineers and firemen, basic daily rates of pay are graduated according to the weight on the driving wheels of the locomotives they operate.

Employees in engine service, and to a limited extent in train service, have for many years imposed a limitation on the mileage that a man may run in a calendar month. Mileage limitations vary somewhat on different railroads. Generally, they are 4,800 mi. per month for regular engineers and firemen in passenger service, and 3,800 mi. per month for engineers and firemen in freight service. Where mileage limitations apply to trainmen, the maximum limit runs from about 5,500 mi. to 6,600 mi. per month for passenger trainmen, and 3,500 mi. to 4,500 mi. per month for freight trainmen.

As a result of changes incident to World Wars I and II, and in accordance with findings of governmental boards in a number of instances, average earnings of railway employees of all classes increased during the period 1922 through 1949 to the extent indicated in Table II. After the beginning of World War II, railway employees were granted general wage increases effective in 1941, 1943, 1946, 1947, 1948 and 1949.

TABLE II.—*Average Earnings of Railway Employees*

	Average straight-time hourly earnings (in cents)	Average compensation per employee	
		per week	per annum
1922	60.6	$31.11	$1,622
1930	69.1	32.88	1,715
1940	77.5	36.59	1,913
1946	116.4	58.85	3,068
1947	122.4	61.74	3,219
1948	136.8	68.74	3,594
1949	150.6	71.14	3,709

Settlement of Labour Disputes.—Legislative action to promote peaceful settlement of disputes grew out of the belief that a matter of such importance deserved statutory recognition. The first such legislation was enacted in 1888, one year after enactment of the original Interstate Commerce act. Even prior to that time, however, mediation and arbitration for the settlement of railway labour disputes had received considerable attention. As far back as 1873, the chief officer of a union of locomotive engineers publicly stated that his organization had always favoured arbitration.

The act of 1888 was the initial federal legislation on this subject and the foundation stone upon which all subsequent legislation of this character has been built. Its essential elements remain in the law to this day: voluntary arbitration, investigation and fact-finding recommendations by a presidential board in case of emergency having to do with the impending possibility of a strike, and reliance upon the force of public opinion after such investigation. The only really significant change is that under present legislation an award of an arbitration board may be enforced in court, whereas under the 1888 statute, an award had no sanction other than the force of public opinion.

Title III of the Transportation act of 1920 set up procedure for dealing with disputes between railroads and their employees. Its provisions included the establishment of the Railroad Labor board, to hear disputes and make decisions. This enactment was superseded by the Railway Labor act of 1926, amended in 1934. By custom on the railroads, disputes not settled locally are referred to joint management-employee conferences. Under the Railway Labor act, the next step is handling by the National Mediation board (which replaced the Railroad Labor board). If the board cannot induce a settlement or obtain agreement to arbitrate, and considers that a substantial interruption of interstate commerce is threatened, it so advises the president of the United States. He is authorized by the act to create an emergency board to investigate the controversy and report to him within 30 days. After creation of an emergency board and for 30 days after it has reported to the president, no change may be made, except by agreement, in the conditions out of which the dispute arose. This completes the procedure provided in the act, and the findings of an emergency board are not binding on either party to a dispute.

One of the most fundamental changes in the Railway Labor act was its amendment in 1934 to provide for establishment of the National Railroad Adjustment board. This board consists of 36 members, half selected by the railroads and half by railway labour organizations. It is divided into four divisions, each having jurisdiction over disputes involving certain particular crafts or classes of employees. Upon failure of a division to agree, a neutral referee is selected by the division or, upon its failure to agree on such selection, by the National Mediation board. The adjustment board has jurisdiction over disputes growing out of the interpretation or application of agreements concerning rates of pay, rules and working conditions. If a carrier does not comply with an order of the adjustment board, any person for whose benefit such order was made may sue for enforcement in a federal district court, in which suit the findings and order of the adjustment board are prima-facie evidence of the facts.

Railroad Social Security.—Pension plans voluntarily established by individual railroads for the benefit of superannuated employees were among the earliest pension systems in the United States. The Railroad Retirement act of 1935, as amended in 1937, established a pension system for railway employees on a national basis. This system is distinct from and more liberal than parallel provisions for workers in other industries covered by the Social Security act. The companion Carriers Taxing act of 1937 levied a pay roll tax on the first $300 per month of compensation paid to railway employees, the tax to be borne equally by the railroad and the employee. Subsequent amendments enlarged the scope and amount of benefits and also increased the pay roll tax for retirement purposes to a maximum of 12½% beginning Jan. 1, 1952, half to be borne by each, as before.

The Railroad Unemployment Insurance act of 1938 removed the railroads from the unemployment provisions of the various

state unemployment compensation laws established under the Social Security act of 1935 and brought them under a separate national system of unemployment compensation. The system under the 1938 act was financed by a pay roll tax of 3% on the first $300 per month of compensation paid to railway employees, which tax is borne entirely by the railroads. An amendment in 1946, besides increasing unemployment benefit payments, added to the unemployment system an entirely new system of benefit payments to railway employees for illness and accidents, whether or not these were in any way related to or connected with railway employment.

Prior to 1948 the railroad unemployment system contained no provision for merit or experience ratings whereby the pay roll tax rate assessed against railroads might be scaled in accordance with actual unemployment experience, as was the case in most states in regard to other industries covered by the Social Security act. The railroad unemployment pay roll tax rate was, therefore, much higher than that of other industrial employers and much higher than was required to meet benefit payments accruing under the Railroad Unemployment Insurance act. As a result, by early 1948, the amount to the credit of the unemployment reserve fund exceeded $900,000,000. An amendment in 1948 modified the railroad tax rate by establishing a sliding scale which varied according to the size of the reserve fund. The rate, which applied to wages and salaries up to $300 per month, ranged from 0.5% while the fund was $450,000,000 or more, up to 3% whenever the fund fell below $250,000,000.

Both the Railroad Retirement act and the Railroad Unemployment Insurance act are administered by the Railroad Retirement board. This board, composed of three members appointed by the president of the United States, has the somewhat unusual feature that one of its members is nominated by representatives of the employees and one by representatives of the railroads, the chairman being appointed without designated recommendations, as a representative of the public.

Number of Railways and Mileage.—For statistical purposes the Interstate Commerce commission divides operating railways of the United States into four groups: classes I, II and III and switching and terminal. Class I includes line-haul railroads with operating revenues of more than $1,000,000 annually; class II, those with revenues of $100,000 to $1,000,000; and class III, those with annual revenues of less than $100,000. Switching and terminal companies perform the named types of service for line-haul railroads, are usually owned by one or more such railroads and for the most part derive their revenues from payments made by their user railroads. For the latter reason, they are customarily omitted from revenues and earnings statistics of class I railways, to avoid duplication.

Besides operating companies, there also are lessor and proprietary companies. Lessor companies maintain a separate legal existence, but their properties are operated by the lessees, who may or may not be financially interested in the securities of the lessors. Proprietary companies are also nonoperating companies, but are distinguished by the fact that their outstanding capitalization is owned by other railway companies. Statistics of the Interstate Commerce commission also include those from a few small railroads which file only brief circulars or do not submit official returns.

Table III shows the number, miles of road and percentage distribution of revenues of operating railroads, the number of lessor and proprietary companies, and also the number of circular and unofficial railroads. While the table shows 133 class I operating companies, many of these are operated as parts of systems under unified or co-ordinated management. Figures shown for miles of road operated include some duplication of road owned by one company and used by another company under agreements for this purpose which are called trackage rights. They do not include multiple running tracks nor yard tracks and sidings. Neither do they include the many miles of industry-owned sidings and connecting tracks.

TABLE III.—*Number of Railway Companies and Their Classification (1948)*

Item	Line-haul			Total	Switching and terminal	Grand total
	Class I	Class II	Class III			
Number of operating companies	133	171	176	480	213	693
Lessors to operating companies	192	6	8	206	13	219
Proprietary	—	—	—	117	15	132
Circular and unofficial	—	—	—	32	11	43
Miles of road operated	226,704	8,569	2,483	237,756	*	237,756†
Percentage of total revenues	96.7	1.0	0.2	97.9	2.1	100.0

*Miles of road not reported for switching and terminal companies, which operated 7,430 mi. of track in 1948. †Includes 1,384 mi. in Canada.

Because data for class I railways are more promptly available and more comprehensive than those pertaining to classes II and III, and because figures for classes II and III are relatively small, statements in the following text will, unless otherwise specified, apply to class I railways only.

The total mileage of trackage, of all kinds, operated by class I railways is shown in Table IV.

TABLE IV.—*Total Miles of Track Operated by Class I Railways**

Year (Dec. 31)	Road—first main track	All other main track	Yard track and sidings	Total all track
1921	223,957	32,739	103,672	360,368
1930	230,602	36,702	115,772	383,076
1940	220,288	34,823	106,967	362,078
1945	215,488	34,589	105,362	355,439
1948	214,726	34,375	106,383	355,484

*Excludes duplication of trackage owned by one company and used by another company under trackage rights. Figures include mileage operated by United States railroads in Canada.

For every road mile operated in 1948 there were 1.69 mi. of track, including yards and sidings. The ratio of track miles to road miles had changed little since 1918, and was considerably higher in the eastern district than elsewhere.

Total miles of road operated by class I railways declined after its peak in 1930, when it was 230,602, as mileage abandoned exceeded mileage of new railway constructed. The abandoned mileage consisted mainly of unprofitable branch lines, on which the volume of traffic, adversely affected by depletion of natural resources or by competition of motor vehicles, had been so seriously diminished as not to warrant continued operation. From 1931 to 1948, inclusive, the road miles constructed by class I railways totalled 948 and the miles abandoned totalled 12,157. (Because of changes between 1930 and 1948 in classification of some railroads as between class I and other classes, these figures are not in agreement with changes indicated in Table IV for all class I railways.)

Investment and Capitalization.—The value of railway facilities and properties as represented in the investment accounts on the books of the railroads is shown in Table V.

TABLE V.—*Investment in Railroad Property: Railways of Classes I, II and III and Their Lessors*

Year (Dec. 31)	Investment in road and equipment* (millions)	Investment per mile of road owned	Total property investment† (millions)	
			Before depreciation	After depreciation
1921	$20,329	$ 82,699	$21,450	$20,213
1930	26,051	105,661	26,956	24,595
1940	25,646	110,449	26,641	23,546
1945	26,968	119,664	28,581	23,031
1948	28,665	127,625	30,403	24,183

*Road and equipment investment of switching and terminal companies on Dec. 31, 1948, was $1,085,000,000, making a total of $29,750,000,000 for railroads of all classes reporting to the Interstate Commerce commission.
†Property investment includes investment in road and equipment, material and supply inventories, and cash on hand.

Stocks, bonds and other forms of capitalization outstanding against the values represented in the investment of the railroads are shown in Table VI.

With a total investment in road and equipment of $19,800,000,000 at the end of 1920, the railroads in the 29 years 1921–49 made capital expenditures for improvements and additions to their property exceeding $17,100,000,000, or at an average annual rate of more than $590,000,000. (This $17,100,000,000 represents gross expenditures, before allowance for retirements of worn-out and obsolete facilities.) During these 29 years the railroads put $2.34 into their properties in improvements for every $1 paid out in dividends to stockholders.

TABLE VI.—*Railway Securities Outstanding and Net Capitalization: Railways of Classes I, II and III and Their Lessors*
(in millions of dollars)

Year (Dec. 31)	Total railway securities outstanding	Capital stock*	Total funded debt unmatured†	Net capitalization‡	Ratio to gross investment in road and equipment (per cent)	
					Net capitalization	Funded debt unmatured
1921	$20,248	$ 8,890	$11,358	$17,083	84.0	55.9
1930	22,783	10,012	12,771	19,066	73.2	49.0
1932	22,832	10,043	12,789	18,894	72.4	49.0
1940	21,047	9,770	11,277	17,630	68.7	44.0
1945	18,681	9,423	9,258	15,667	58.1	34.3
1948	18,249	9,242	9,007	15,467	54.0	31.4

*No-par stock included at book value. †Funded debt includes equipment obligations. ‡Amount in the hands of the public, not held by railway companies.

The railroads greatly reduced their funded debt and annual interest charges between 1932 and 1948. During those 16 years there was a net reduction in outstanding unmatured funded debt of all railroads of $3,782,000,000, or at the average annual rate of $236,000,000. More than half this decrease ($2,019,000,000) was effected in the five years 1941–45. While court reorganizations of bankrupt railroads accounted for part of the reduction in debt, for every $1 of reduction thus brought about there was a reduction of almost $2 by voluntary action of solvent railroads in paying off or buying back outstanding debt.

As the result of additions to investment and reductions in debt, the ratio of net capitalization in the hands of the public to investment in road and equipment for all railroads fell from 84% in 1921 to 54% in 1948. In relation to total investment, debt fell from 56% in 1921 to 31% in 1948. Annual interest and rental charges (total fixed and contingent) of the railways of class I were reduced from $666,000,000 in 1932 to $463,000,000 in 1949.

Rolling Stock.—Locomotives and cars owned and operated have declined in number from their peak in the 1920s; the trend over a considerable period has been toward fewer, larger and more efficient units. Average tractive effort of locomotives has increased by about one-half and average freight-car capacity by about one-quarter since 1921. Such increases in tractive capacity and efficiency of locomotives and in capacity and efficiency of utilization of freight cars have enabled railroads to handle a much greater volume of freight traffic than in the 1920s with fewer units of equipment.

Table VII shows number of units of locomotives and cars and illustrates increases in capacity and efficiency of utilization.

In addition to railway-owned freight cars, the railroads also haul freight in 266,700 privately owned freight cars belonging to car rental companies, oil companies, meat packers and other shippers with large use of specialized types of cars. The loaded car mileage made by these cars is included in Table VII. Freight-carrying car ownership of class I railways and private-car lines on Dec. 31, 1948, was divided by types as shown in Table VIII. These types are described and discussed later in this article.

TABLE VII.—*Locomotives and Cars of Class I Railways*

Locomotives

Year (Dec. 31)	Steam		Diesel (units)	Electric (units)	Other (units)	All Locomotive units
	Number	Average tractive capacity (in pounds)				Average tractive capacity (in pounds)
1921	64,585	36,935	—	364	—	36,981
1930	55,875	45,225	74	618	15	45,298
1940	40,041	50,905	797	858	25	51,095
1945	38,853	53,217	3,816	842	19	53,528
1948	32,914	55,170	8,089	829	19	55,466

Cars

Year (Dec. 31)	Passenger train cars* (number)	Freight cars (number)	Average capacity per freight car (in tons)	Loaded freight car-miles (millions)
1921	54,331	2,315,692	42.5	12,521.4
1930	52,130	2,276,867	46.6	15,845.0
1940	37,817	1,653,663	50.0	14,699.0
1945	38,273	1,760,297	51.1	22,575.0
1948	39,142	1,759,561	51.9	20,651.6

*Includes passenger, mail, express, baggage and combination cars.

TABLE VIII.—*Freight-Carrying Cars, by Types*

	Owned by class I railways	Owned by other railways	Total railway-owned	Private	Grand total
Box	734,872	3,716	738,588	2,263	740,851
Refrigerator	20,210	23	20,233	111,179	131,412
Gondola and hopper	873,738	16,170	889,908	8,362	898,270
Flat	63,988	3,244	67,232	247	67,479
Stock	49,872	46	49,918	1,747	51,665
Tank	8,089	717	8,806	141,819	150,625
Others	8,792	1,590	10,382	1,114	11,496
Total	1,759,561	25,506	1,785,067	266,731	2,051,798

*Includes class II, class III and switching and terminal railways.

Railroads also have more than 120,000 cars devoted to uses incident to their own operations. These include 24,700 of the familiar caboose or cabin cars, which are the headquarters of the train crew while en route, and 95,900 company service cars for housing workers and hauling materials incident to maintenance and operating activities.

Passenger-train car ownership of class I railways and the Pullman company, by types, on Dec. 31, 1948, is shown in Table IX.

TABLE IX.—*Passenger-Train Cars, by Types*

Passenger-carrying*	23,150
Mail	1,724
Baggage, express and all other	14,268
Total railroad-owned	39,142
Pullman company cars	5,305
Total railroad and Pullman cars	44,447

*Includes coach, combination coach, parlour, sleeping, dining, club, lounge and observation cars.

Freight Traffic.—In the wartime year 1918, freight traffic of the railroads exceeded all previous records. There was a postwar recession in 1921, followed by traffic in 1929 which established a peak not exceeded prior to World War II. The low spot of the general business depression of the 1930s was in 1932. Figures as to freight traffic immediately before entry of the United States into World War II, the peak during that war (1944) and for various postwar years are shown in Table X.

TABLE X.—*Revenue Freight Traffic, Class I Railways*

	Tons originated (millions)	Ton-miles* (millions)	Average miles of haul	Revenue per ton-mile (in cents)
1918	1,263.3	405,379	297	0.849
1921	940.2	306,840	304	1.275
1929	1,339.1	447,322	317	1.076
1932	646.2	233,977	347	1.046
1939	901.7	333,438	351	0.973
1944	1,491.5	737,246	473	0.949
1947	1,537.5	654,728	408	1.076
1948	1,506.9	637,917	406	1.251
1949	1,226.5	526,437	409	1.340

*One ton carried one mile is equivalent to one ton-mile.

Freight Commodity Classifications.—For purposes of accounting and statistics, the Interstate Commerce commission has prescribed certain commodity classifications for railroad freight. As of Jan. 1, 1947, all commodities—except forwarder traffic and merchandise (or less-than-carload) freight—were allocated into 260 classifications, assembled into five major commodity groupings. Prior to that date, there were 156 corresponding commodity classifications. Tonnage and revenue statistics covering movement of these commodities on all class I railways are published periodically by the commission. According to the commission's accounting rules, any shipment of 10,000 lb. or more from one consignor to one consignee is statistically recorded as a carload, even though the minimum weight on which the carload rate applies may be higher than 10,000 lb. Distinctions between carload and less-than-carload (often expressed as L.C.L.) shipments are further discussed hereafter. Freight forwarders engage in the business of assembling numerous L.C.L. shipments for consolidation by them into carload shipments.

Classified by principal commodity groups, the 1949 revenue freight traffic of the class I railways was as shown in Table XI.

TABLE XI.—*Revenue Freight Traffic, by Commodity Groups, Class I Railways, 1949*

	Tons originated (thousands)
Products of agriculture	140,383
Animals and products	15,284
Products of mines	653,758
Products of forests	69,257
Manufactures and miscellaneous	331,564
Forwarder traffic	3,665
Total carload freight	1,213,911
Less-than-carload freight	12,592
Total freight originated	1,226,503
Received from connections	1,076,577
Total freight carried	2,303,080*

*Freight carried on more than one railroad is counted by each railroad involved in the haul.

Of products of agriculture, by far the principal items of tonnage are grain and its products, mainly flour and wheat, followed by fresh fruits and fresh and dry vegetables. Meats and other packing-house products are the leading commodities in the animals and products group, with hogs next. Among products of mines, coal greatly predominates in tonnage; sand, gravel and stone make up the next largest tonnage, followed by iron ore. Lumber, shingles and lath constitute much the largest tonnage of products of forests, with pulpwood as the second largest tonnage. Among manufactures and miscellaneous, the greatest individual tonnage group is iron and steel products; other important tonnages are made up of petroleum products, chemical products, food products and vehicles.

In terms of tons originated by class I railways in 1949, the 10 leading commodities, together with the rail tonnage of each, are shown in Table XII. These 10 commodities constituted 54% of all tonnage originated on these railroads in that year.

TABLE XII.—*Ten Principal Commodities, Class I Railways, 1949*

	Tons originated
Bituminous coal	303,200,000
Iron ore	91,351,000
Gravel and sand	51,507,000
Stone and rock: broken, ground and crushed	43,201,000
Wheat	37,335,000
Anthracite coal	36,859,000
Manufactured iron and steel	28,680,000
Cement: natural and portland	27,646,000
Lumber, shingles and lath	23,468,000
Pulpwood	20,242,000
Total	663,489,000

Passenger Traffic.—Years shown for passenger traffic in Table XIII mark the highest level attained during World War I (1918), the all-time peak in number of passengers carried (1920), the first full year of private operation after the railroads were returned to their owners following World War I (1921), the interwar low (1933), the level just before World War II (1939), the peak attained during that war (when longer average trips resulted in the highest passenger mileage ever performed) (1944) and a three-year period following the war.

TABLE XIII.—*Revenue Passenger Traffic, Class I Railways*

Year	Passengers carried (millions)	Passenger-miles* (millions)	Average miles travelled†	Revenue per passenger-mile (in cents)
1918	1,085.0	42,677	39	2.414
1920	1,234.8	46,849	38	2.745
1921	1,035.5	37,313	36	3.086
1933	433.0	16,341	38	2.013
1939	450.4	22,651	50	1.839
1944	910.3	95,549	105	1.874
1947	703.3	45,921	65	2.097
1948	642.8	41,179	64	2.341
1949	554.5	35,100	63	2.452

*One passenger carried one mile is equivalent to one passenger-mile.
†A passenger may travel on two or more railroads during one trip, and this figure represents the average journey on an individual railway basis, not the average for the entire trip.

Statistics in Table XIII include commutation travel to and from suburban areas of certain metropolitan centres. In 1949 commutation passengers numbered 309,000,000, transported for a total of 5,500,000,000 passenger-miles, with an average journey per passenger of 17.8 mi. Other than commutation passengers numbered 246,000,000, transported for 29,600,000,000 passenger-miles, with an average journey of 120 mi.

Other Service by Railroads.—Besides transporting freight and passengers, railroads also transport baggage, express, mail and milk in passenger trains and provide meal service for passengers on trains and at stations. Meal service on trains is made available in dining or cafe cars, which are restaurants on wheels. Sleeping accommodations also are available for passengers who desire them, in what are usually termed Pullman cars, after their original designer, George M. Pullman. The charge for transportation in Pullman (and also in parlour) cars is higher than the basic or coach passenger fare, in addition to which there is a charge for the accommodations used. The transportation charge in these cars is higher because of the fact that the average weight hauled per passenger transported is much greater than for coaches.

Railroads carried in 1948 approximately 142,000,000 express shipments, averaging about 45 lb. each in weight and travelling an average of about 650 mi. They carried almost all the parcel post shipments and the newspapers and magazines which moved in mail service. They also carried more than 90% of the poundage of intercity first-class mail, for which they received from the post office department not quite .2 cent per piece of mail, or less than one-seventeenth of the postage paid. This payment to the railroads covered not only the transportation of the mail but also the provision of special railway post office (R.P.O.) cars, with facilities for sorting mail en route.

Record of Wartime Performance.—The demands of World War II challenged the elasticity and efficiency of the railroads—a challenge which was successfully met. The extent of the test to which the railroads were subjected is reflected in the fact that the freight service which class I railways were called upon to perform jumped from 290,000,000,000 ton-miles in 1938 to 737,000,000,000 ton-miles in 1944, multiplying more than two and one-half times within six years. Passenger travel climbed even more spectacularly. From 21,600,000,000 passenger-miles in 1938, it rose to more than 95,500,000,000 passenger-miles in 1944, or more than four times as much.

During 45 months from Dec. 1941 through Aug. 1945, railroads transported 97.6% of all military personnel moving in organized groups and 90.5% of all military freight hauled by inland transportation. These figures do not include the movement of raw materials which went into military products and of supplies for the civilian population engaged in war work. Moreover, railroads supplied about 40,000 officers and men for army transportation corps rail units, in addition to more than 300,000 railway employees in other branches of the armed services.

An outstanding example of the emergency war service of the railroads was the greatly increased volume of oil traffic which they successfully handled. When enemy submarines interrupted the operations of tank vessels which normally supplied the great bulk of oil consumption in the northeastern part of the country, the railroads were called upon to take care of this movement. As only a small fraction of the traffic in question normally moved by rail, extraordinary procedures had to be set up for the emergency. From 11,250 bbl. daily in the summer of 1941, the movement quickly mounted until by July 1943 a peak of more than 1,000,000 bbl. of oil daily was being delivered by rail from the southwest to the east.

Safety of Operation.—Railroads were among the pioneer industries to undertake organized campaigns for promotion of safety among their employees and for their users. Training of railway workers in habitual use of safe working methods and practices is thoroughly organized, both through collective activities of the industry and on individual railroads. Despite handicaps growing out of the far-flung nature of railway operations, with workers distributed over thousands of miles, many of them in more or less isolated groups, this training begins with entrance into railway service and goes on continuously during the worker's active career. It takes many forms, including safety manuals and pamphlets; constant reminders by posters, bulletin boards, employee publications and the like; group meetings for the discussion of safety, organized safety contests among various units of a railroad, and

also among the railroads; and daily observation and admonition by supervisors. Every book of rules for railway workers enjoins "safety first," prescribing safe methods in detail and stressing the general rule that "in case of doubt, the safe method shall be followed."

The railway industry also co-operates with national organizations sponsoring and promoting activities in the entire field of safety. The Harriman safety awards, made annually by one of these organizations to railroads in various categories of size, are objects of keen competition throughout the industry.

Although human error and misunderstanding and failures of materials cannot be wholly avoided, the safety-promotion activities of the railroads have been fruitful of substantial progress in safety. During the 28 years from 1921 to 1949, the safety of passenger travel doubled and the safety of workers more than trebled. In relation to total transportation service performed and total hours worked, the chance of the average passenger or worker's being fatally injured is infinitesimal—too small for figures to have meaning. The chance of the average passenger's sustaining even a nonfatal injury amounts to about 1 for every 14,000,000 mi (1949) of travel, while a railway worker averages only about one chance in a lifetime of sustaining injury on the job.

Efficiency of Operation.—Performance by the railroads in regard to efficiency and economy of operation from 1921 through 1949 are illustrated in Table XIV, which shows results attained in factors which are recognized indicators of operating performance.

TABLE XIV.—*Statistics of Railway Operating Performance, Class I Railways*

Year	Cars per train	Net tons per train	Net ton-miles per train-hour	Gross ton-miles per ton of fuel	Miles per locomotive per day
Freight					
1921	37.4	651	7,506	12,367	78.2
1930	47.9	784	10,836	16,497	89.6
1939	48.5	813	13,450	17,774	104.0
1944	53.0	1,139	17,623	17,469	122.8
1947	52.9	1,146	18,126	17,505	120.0
1948	54.5	1,176	18,778	17,986	117.2
1949	56.8	1,138	19,023	*	112.5

Year	Passenger-miles per train-hour	Miles per locomotive per day
Passenger		
1921	not available	142.0
1930	1,881†	165.7
1939	2,049	184.2
1944	6,975	222.9
1947	4,000	219.0
1948	3,710	220.9
1949	3,417	228.5

*No longer compiled.
†1936, earliest available.

Table XIV shows that between 1921 and 1949 cars per freight train increased by half, and tons of net load (exclusive of the weight of cars) handled by the average freight train increased by three-quarters. Net ton-miles per freight-train hour—an especially significant indicator because it combines the factors of net load per train and train speed between terminals—were more than two and one-half times as much in 1949 as in 1921. Work done per ton of fuel in freight service was almost half again as much in 1948 as in 1921. Gains in efficiency of passenger operation also were notable; passenger-miles per hour of train operation increased by more than four-fifths from 1936 to 1949. Both passenger and freight locomotives performed about half again as much work each day in 1949, compared with 1921.

Revenues, Expenses and Income.—The revenues, expenses and income of class I railways for 1926, 1933 and 1949 are shown in Table XV. The year 1926 represented the year of peak gross revenues prior to World War II; 1933 marked the low point of the depression. Total operating revenues of these railroads reached a wartime peak of $9,437,000,000 in 1944.

The excess of dividends over net income in 1933 results from the fact that the figures are aggregates for all class I railways, some of which earned much more than the dividends paid but which earnings were offset in the aggregate figures by deficits of other railroads; also, dividends were paid in some instances from earnings set aside for that purpose in previous years.

TABLE XV.—*Condensed Income Account, Class I Railways*
(millions)

Item	1926	1933	1949
Operating revenues			
Freight	$4,808	$2,491	$7,048
Passenger	1,043	329	861
Other	530	274	671
Total	6,381	3,094	8,580
Operating expenses			
Maintenance of way and structures	867	322	1,284
Maintenance of equipment	1,283	599	1,607
Transportation	2,182	1,078	3,416
Other	337	250	585
Total	4,669	2,249	6,892
Net operating revenue	1,712	845	1,688
Railway tax accruals	389	250	832
Hire of equipment—net Dr.	83	85	131
Joint facility rents—net Dr.	27	36	38
Net railway operating income	1,213	474	687
Other income	298	211	254
Total income	1,511	685	941
Deductions from income			
Rent for leased roads and equipment	166	150	120
Interest on funded debt	496	486	299
Interest on unfunded debt	12	26	
Other deductions	28	29	84
Total deductions	702	691	503
Net income	809	Def. 6	438
Dividend appropriations			
From income	224	28	—
From surplus	175	68	—
Total	399	96	253
Net property investment*	$22,670	$23,407	$23,624*
Return on net property investment (net railway operating income divided by net property investment)	5.35%	2.03%	2.91%*

*Net property investment includes investment in road and equipment, material and supply inventories and cash on hand, less depreciation. Figure shown for 1949 is investment at the beginning of the year. Percentage return on net property investment is computed on this investment.

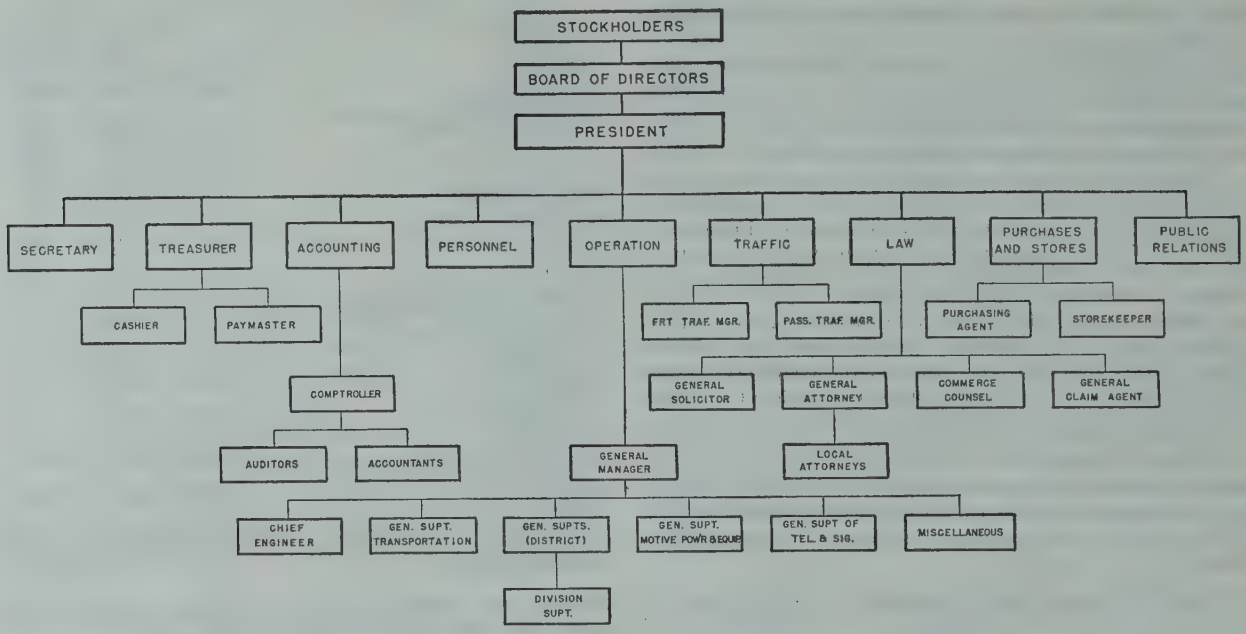
The primary financial problem of the railroads of the United States is lack of adequate earnings from their operations. This lack, despite notable advances from year to year in operating efficiency and economy and reductions in debt and annual fixed charges, results principally from increased costs of materials and labour, without fully compensating increases in the rates which railroads may charge for their services. In part, the failure of rates to keep pace with operating costs is a result of competition from other means of transportation. In part, it is a result of the effect of federal and state regulation upon railway rates.

The result of the disparity between rates and costs is that during the 29 years from 1921 through 1949 the return earned by the railroads on their net investment in transportation property (after depreciation) averaged less than 3¾% yearly. This was the average return for a period which included the good business years of the 1920s and the five years of World War II when railroads performed their greatest service and collected their greatest revenues. With the rapid rise in costs following the end of the war, the average return earned in 1946 dropped to 2.75% on the net property investment, although total traffic in that year far exceeded any previous peacetime peak. However, the average unit charges at which this traffic was handled actually were below the levels of the 1920s and closely approximated those of years just before the war.

In recognition, and toward the improvement, of this situation, the Interstate Commerce commission, during a period of about three years beginning in the middle of 1946, authorized increases in rail freight rates. These increases in the aggregate were estimated to have raised the general level of these rates by approximately 57%. Increases in levels of passenger rates, varying according to types of service and in different parts of the country, also were authorized during approximately the same period; their aggregate effect was to raise passenger rates by approximately 34%. The percentage of increase in 1949 unit costs of railway operation, compared with prewar (1939), was about double the increase in average freight charges per ton-mile and treble the increase in average fares per passenger-mile.

Operating Methods and Procedures.—*The Railroad Organization.*—A modern railroad is an intricate and highly developed transportation plant, requiring for its maintenance and operation many types of facilities and skills. All these must be closely and continuously integrated and co-ordinated, in order to perform

TYPICAL GENERAL ORGANIZATION OF A RAILROAD



(Organizational plan and titles of positions vary somewhat among the different railroads.)

FIG. 2.—TYPICAL GENERAL ORGANIZATION OF A RAILROAD

safely and efficiently their appointed task of moving great numbers of heavy vehicles at high speeds, over all sorts of terrain, day and night, in all kinds of weather. Consequently, there must be a well-knit organization, with established channels of communication and lines of authority.

The basic unit in the railroad industry is the individual railroad. Although the corporate form is common to all railroads, there are many variations in the type of functional organization. Differences are dictated in part by size and individual characteristics, and in part by the desire of each company to evolve the form of organization considered most effective for its activities.

The general functions of a railroad organization are:

1. To procure traffic for the railroad and promote the economic development of the area traversed by its lines; to acquaint the public with the service available for its use; and to arrange for the facilities and personnel required to accomplish the sale of the service.
2. To receive, transport and deliver the traffic offered; to provide and maintain the facilities necessary to do so; and to recruit, train and supervise the necessary personnel.
3. To receive and disburse the railroad's funds, supervise its financial affairs and account systematically for its income, expenditures and financial transactions, in accordance with requirements of the railroad and methods prescribed by the Interstate Commerce commission.
4. To procure, store, safeguard and issue materials and supplies required for operation.
5. To administer the railroad's legal affairs.

Basically, these functions are performed by each railroad in somewhat similar departments. The organizational plan of a typical railroad in the United States is illustrated in fig. 2. Not all railroads are organized exactly in accordance with this chart; plans of organization, lines of authority and titles of positions vary somewhat among different railroads.

Paramount in the organization are the stockholders, who own the company. They elect a board of directors to represent them in supervising its management. One or more higher officers of the company often are elected as members of the board to assist in its deliberations and to keep it informed as to operations of the company. The board holds frequent meetings, at which matters of policy are discussed and decisions made or advice given on problems of the company, including such matters as authorization of large capital expenditures and declaration of dividends.

Heading the actual management, and having responsibility for day-to-day conduct of the company's affairs, is the president, who usually has certain personal assistants. The president determines general policies and sees to their proper execution. He may be elected to that office directly by the stockholders. More often he is elected by the board of directors, who also elect or appoint the secretary, treasurer, vice-presidents and other officers of the company whose responsibilities are of such importance as to suggest that board approval be required. Under the direction of the board, the president and his executive staff (usually the department heads) supervise and direct the business of the company. On most roads, periodic meetings are held by the president and his staff, so that they may keep fully informed at all times on important matters and bring forward matters requiring discussion and decision.

Operating Department.—The operating department, usually under the direction of a vice-president or a general manager, carries all responsibility incident to moving the traffic, and is by far the largest organization on every railroad. A railroad generally divides its lines into a number of smaller units, such as regions, districts and divisions. As a rule, divisions are the primary operating units; essentially, they are small railroads in themselves. Each division is the responsibility of a superintendent.

Functions of a division are subdivided into three major categories: maintenance of way, mechanical (or maintenance of equipment) and transportation, which may be described briefly as follows.

Maintenance of Way.—Maintenance-of-way functions pertain to right of way, track, bridges and signals, as well as stations and structures along the line. The division engineer is responsible for their upkeep, renewal and frequent inspection. He has a staff of supervisors in charge of various phases of the work on his division. Track is divided for maintenance purposes into sections, with a section gang in charge of work on each section. Extra gangs supplement the work of section gangs when necessary, and gangs specialized for various types of work construct and maintain other roadway facilities. On some railroads, responsibility for

track and structures is segregated in an engineering department, separate from the operating department.

Mechanical.—Mechanical functions are primarily the inspection, servicing and maintenance of rolling stock—cars and locomotives—and the operation of shops, roundhouses and other mechanical facilities. The division staff is usually headed by a master mechanic, under whom are foremen in charge of enginehouses and other maintenance shops, and motive-power and car inspectors. The division organization usually is responsible for minor repairs and for necessary servicing between trips; major repairs and periodic overhauling are performed as a rule in large centralized shops equipped for those tasks. In some cases, these latter shops are under the division superintendent's direction; in others, they are in charge of the principal mechanical officer of the railroad.

Transportation.—Transportation functions are concerned directly with the receipt, movement and delivery of freight and the transportation of passengers, mail and express. The transportation staff of the division is headed by the trainmaster, who has immediate supervision over all trains and terminal activities. His subordinates include yardmasters, who have charge of switching and terminal work; dispatchers, who direct train movements; stationmasters and agents; and the engine, train and yard crews.

Departmental or Divisional Organization.—Although organization structures of most railroads follow the same general pattern, with variations as to detail, there may be substantial difference in organization of the operating department. Some railroads have adopted what is known as the departmental type of organization, while others are organized along divisional lines. Other railroads utilize various combinations of both types of organizations.

Under a departmental organization, each of the three general functions (maintenance of way, mechanical and transportation) is the responsibility of a department extending from top to bottom of the railroad's organization. Thus, the divisional trainmaster or superintendent of transportation reports to a transportation department in the general or headquarters offices, the master mechanic reports to a mechanical department and the division engineer reports to a maintenance or engineering department. This plan finds justification in the technical character of these functions and places reliance upon reports, interdepartmental co-operation and carefully designed working arrangements for co-ordination. The function of the division superintendent in a departmental organization is to co-ordinate and supervise the departmental activities in his territory.

In the divisional plan, the superintendent is in command of the division, and the trainmaster (perhaps more than one on some divisions), master mechanic and division engineer report to him. This arrangement places responsibility for all divisional functions on the superintendent, with the officers just mentioned functioning as his staff. Higher echelons are similarly organized, with each operating executive flanked by staff maintenance, mechanical and transportation representatives.

In one form of combination arrangement, the division superintendent applies himself mainly to supervision of train movement, with some supervisory attention to mechanical and maintenance-of-way activities, especially as they affect train performance; however, detailed supervision of mechanical and maintenance-of-way matters is exercised by the departmental head in charge.

Other Operating Activities.—Besides its three principal components—maintenance of way and structures, mechanical (or maintenance of equipment) and transportation—the typical operating department has a number of other subdepartments. These latter may variously include such functions as mail service, highway transport service, car service and distribution, station and freight transfers, police protection, safety promotion and supervision and labour and wage bureaus.

There were in 1949 about 1,200,000 workers on the U.S. railroads, of whom about 90% were in the operating department. Those who actually manned the trains numbered about 130,000 and another 120,000 or so were in the yards and terminals. With this force of train and yard workers, the railroads performed in 1949 more than 526,000,000,000 ton-miles of freight service and 35,000,000,000 passenger-miles of travel service. This relatively small number of workers could perform so great a volume of transportation service because of efficient plant and facilities and because of the co-operation received from their teammates in the railroad organization—the 235,000 who maintained the roadway and track, the 320,000 who worked in the shops and storehouses, the 145,000 working in stations or out on the line as station agents, telegraphers, towermen, crossing flagmen, etc., and the numerous clerks and supervisors having to do with these and miscellaneous other activities of the department.

Traffic Department.—The traffic department is the commercial or sales organization of the railroad. It is responsible for development and procurement of traffic and for formulation of rates and charges, plus the duty of keeping the public informed as to the various services provided by the railroad. Usually it is divided into freight and passenger departments, and often there are other departments in charge of industrial development, agricultural matters and foreign or other specialized traffic.

The chief traffic officer and the traffic manager, his lieutenant, keep constantly informed of conditions affecting traffic along their lines, and also conduct relations with customers of the railroad and with connecting carriers in respect to interchange of traffic. The general passenger and general freight agents, working under the direction of department heads, seek freight and passenger traffic for the railroad, compile and publish rates and rules pertaining to the movement of traffic, and directly attend to special needs and problems of patrons. Subordinate traffic agents are located along the line and in principal off-line cities to serve shippers and passengers.

The industrial development officer assists new industries to find locations along the line, and in general seeks to increase the railroad's traffic by increasing business activity in the territory it serves. The agricultural development officer is concerned with promoting productivity and general welfare of agriculture in the railroad's territory. The foreign traffic officer seeks to develop export and import traffic. In addition, the traffic organization may include some or all of the following: coal traffic manager, livestock agent, mail and express manager, baggage agent, superintendent of dining car service and others.

Secretary, Treasurer and Finance Department.—The secretary is responsible for keeping the records of the board of directors; he maintains custody of its minutes, and the contracts and agreements authorized by it. In addition, he keeps books showing the ownership of capital stock, and he issues, transfers and cancels stock certificates.

The treasurer is custodian of the company's funds and securities. He is responsible for collection of all money due the company and for payment of all money owed by it. The same person may be both secretary and treasurer.

On large railroads, the treasurer generally performs his duties under the direction of a vice-president in charge of finance, who has the responsibility of seeing that financial needs of the company are properly met. The finance department is responsible for the issuance and acquisition of the railroad's own securities and the sale or exchange of stocks, bonds and other securities owned by the railroad.

Accounting Department.—The accounting department, usually headed by a vice-president, comptroller or general auditor, records transactions of the railroad, performs accounting required in connection with its operations and makes reports thereof to the management and to regulatory authorities as required. Among its responsibilities are the auditing of accounts, bills, vouchers and pay rolls and the compilation of statistics.

Law Department.—The law department advises the management on financial and corporate matters and legal matters generally, and represents the railroad in litigation. It is concerned with all the legal problems which confront any large employer or the owner of large holdings of real estate and other property. In addition, it also has to do with many special legal problems arising

from the fact that the railroad industry is subject to comprehensive regulation, with respect to rates and innumerable other features, by federal, state and municipal authorities. Duties of the law department cover a wide field, including corporate matters, all forms of taxation, labour disputes, damage suits and claims, contracts, and rate cases and other proceedings before governmental regulatory bodies.

Purchasing and Stores Department.—The purchasing and stores department procures stocks of materials and supplies—including 100,000 or more items—required by the railroad and distributes them as and where needed. It is responsible for seeing that materials and supplies ordered meet the specifications of the railroad, are purchased at a fair price and are received at the proper time. Stocks must be maintained at an efficient level, avoiding unnecessary investment in inventory while ensuring availability of quantities needed for current requirements. They must be properly and economically received, checked, stored and issued upon requisition, with proper maintenance of necessary records. Conservation and reclamation of materials and the preparation, classification and sale of scrap also are responsibilities of the purchasing and stores department.

The department is usually headed by a vice-president or purchasing agent. Supervision of the stores of materials and supplies, both at central locations and at convenient distribution points along the line, is customarily the responsibility of a general storekeeper. Materials inspectors check the quality and uniformity of supplies received. The department also may include such subordinate officers as a fuel purchasing agent, stationer, equipment assistants, division and local storekeepers, managers of scrap and reclamation, and so on.

Personnel and Public Relations.—Because of the increased complexity and importance of employee relationships and the negotiation and administration of the contracts between railway management and labour organizations, many railroads have set up special personnel departments in charge of such matters. The head of such a personnel department is usually a senior officer of the railroad, reporting directly to the operating vice-president or to the president. On some railroads he has the rank of vice-president.

Responsibility for the railroad's relations with the public is and must be that of the chief executive officer. He alone can give direction to the policy of the entire organization as it affects these relations. Therefore, public relations usually is a function of the president's office, under the immediate direction of a staff assistant, in some instances a vice-president. An important part of his work is to provide public information.

Other Departments.—Some railroads have other departments, the names of which describe their functions. These include the medical department, the real estate and tax department, the insurance department and the police department. On large railroads, these are good-sized departments; on small railroads, their functions often are part of departments already described.

Close Working Relations Among Railroads.—Every railroad (or system of railroads) in the United States has its own separate organization and is operated by its own management for the profit of its owners, subject to government regulation. At the same time, co-operation and reciprocal working relations among these railroads have progressed to such a degree that, so far as users of their service are concerned, they constitute in a real sense a unified and integrated system of transportation. This close working relationship also embraces railroads of Canada and is shared in important respects by those of Mexico and Cuba.

The extent of such co-operation among railroads in serving the public is indicated by the fact that any shipper anywhere may load a freight car for direct movement, without transfer or other break of bulk, to any receiver of carload freight anywhere in the United States, and also in Canada and large areas of Mexico and Cuba. Moreover, co-operative arrangements among railroads are such that a freight shipper need have only one transaction with one railroad—although his shipment may travel over lines of several railroads on way to its destination. Similarly, a passenger may buy a ticket in one transaction for a journey of any length, although he may actually ride in cars and over lines owned by several railroads during his trip. All accounting and financial procedures for collection of charges for such interline movements, and their distribution, are handled by joint arrangements in which all railroads participate.

All this standardization and co-operation, and other features which will be described, have come about entirely through the initiative of private ownership and management and not through force of governmental direction or compulsion. Some of the co-operative arrangements along these lines had their beginning as far back as the 1860s.

Railway Associations.—A large share of the standardization and co-operation of the railroads of the United States—with those of Canada, Cuba and Mexico also participating in important respects—has come about through activities conducted by or under the auspices of the Association of American Railroads (and its predecessor groups). This association is a voluntary organization in which are represented approximately 200 of the principal railroads of the United States, Canada, Cuba and Mexico. Other railroads all over the world, numbering more than 160, are associate members and share in the benefits of the association's work. Activities of the association are carried on under the supervision and guidance of a board of directors, elected by votes of the member railroads.

Among accomplishments of co-ordinated joint activities are standardization of gauge of track, standard time, standard rules of operation and standard equipment of cars. Others include effective arrangements for interchange of cars among railroads, for return of cars to their owning railroads after use by or on other railroads, for establishment of charges for such use, for repair of cars when away from owning railroads, for collection and remittance of revenue from interline movements, and other interline working arrangements. These joint arrangements enable the user of railway service to have the benefit of facilities of several railroads while dealing with only one railroad.

The American Short Line Railroad association serves a membership of somewhat more than 300 smaller railroads (including some which also are members of the Association of American Railroads). Other associations through which standardization, co-operation and progress in the railroad industry are promoted include the American Railway Car institute, American Railway Engineering association, National Railway Appliances association, Railway Association of Canada, Railway Business association, Railway Supply Manufacturers association, Railway Tie association and numerous regional and professional groups.

American railroads also co-operate with those of other countries. In the western hemisphere this co-operation is through participation in activities of the Pan American Railway Congress association, with headquarters in Buenos Aires, Arg. The United States government is an official member of this hemispheric organization, by act of congress. The Association of American Railroads also is a member and takes part in the activities of the International Railway Congress association, with headquarters in Brussels, Belg., and with membership composed of railroads all over the world.

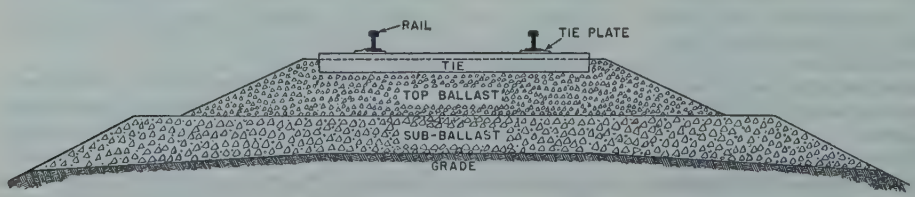


FIG. 3.—TYPICAL SECTION OF RAILROAD ROADBED AND TRACK

Track, Structures and Communications.—The track is the responsibility of the engineering branch of the operating department—or, on some roads, of a separate engineering department. This responsibility includes also the numerous bridges, tunnels,

passenger and freight stations, water and fuel facilities, crossing-protection devices, whistle posts, mileposts and right-of-way markers, snow fences and cattle guards, and all the other large and small structures that go to make up a railroad. In addition, the chief engineering officer may have charge of the communications department, including the signal, telephone, telegraph, printing telegraph and radio communications systems.

Track.—Track has three main functions, simple to state but involving many difficult problems of economics and technical skill. It must support the load, provide a smooth surface for easy movement and guide the wheels of the train.

Grade and Curvature of Line.—The railroad line should be as level and straight as can be achieved without excessive cost, because grades and curves increase the burden on the locomotive and the wear on track. The tractive effort required to pull a load up a 1% grade is about five times what is required on straight level track, and a curvature of 1° requires an increase of from 12½% to 25% in tractive effort.[1] The effect is greatly to reduce the load which a given locomotive can pull, or the speed it can make, or both.

This is an important question of transportation economics, often involving intricate calculations of cost of avoiding or removing grades and curvatures against operating savings which may be expected to accrue from so doing. The key factor in such a calculation usually is the volume of traffic, present or expected; as traffic volume increases, additional operating costs caused by grades and curves also increase, thereby tending to encourage investment to flatten and straighten the line.

Where it is uneconomical or physically impossible to avoid or remove heavy grade or curvature—as in mountainous country—additional locomotives must be used to handle a given tonnage at a prescribed speed. The extra power may be assigned either to the individual train, by double-heading with two or more locomotives or units, or by assigning helper or pusher locomotives to assist all trains at some particular locality, such as the approaches to the summit of a mountain pass.

Roadbed.—Good track starts with the roadbed, or foundation, which should be firm, well drained and of adequate dimensions. It may be necessary in some localities to dig out the original soil to the proper depth and replace it with suitable earth or other material brought in from elsewhere. (Fig. 3 shows a cross section of roadbed and track on a typical single-track railway line.)

Rail.—Steel rails support the load which locomotives and cars impose on the track, ties support the rails and ballast supports the ties. To get the right combination of materials and design requires extensive and continuing research and experimentation. The present shape and weight of rail have evolved gradually to meet operating needs. At the beginning of the 20th century, rail weighing as little as 56 lb. to the yard was not uncommon. Today, rail weighing as much as 150 lb. or more to the yard is in use, on lines handling heavy traffic. The average weight, per yard, of rail in main tracks of railroads in the United States increased from 83 lb. in 1921 to 101 lb. in 1948.

The use of the so-called T-rail (from its shape) has persisted in the United States since about the middle of the 19th century, because experience has shown that it is the most practical and economic form of rail. Recent development and use of methods of electronic measurement, by means of which strains in any portion of the rail under service conditions may be accurately determined, has made possible marked refinements and improvements in the contour, or cross section, of rail.

Ties and Appurtenances.—The tie keeps the rails the proper distance apart, supports them and transmits the load to the ballast cushion or shock absorber beneath. There are 1,000,000,000 ties in the tracks of American railroads, and approximately 35,000,000 to 40,000,000 of them are replaced each year because of decay or mechanical wear. With modern methods of chemical treatment, the service life of ties has been approximately trebled, from less than 10 years to more than 20 years, on the average. In many places, treated ties which have been in use for 25 to 30 years are still giving good service. To reduce mechanical wear from impact of loads transmitted through the rail, metal tie plates are inserted between the rail and the tie. These plates spread the rail burden over a wider tie area, and thus help to protect the tie from the cutting or wearing effect of the rail base. Much study has been given to improving the design of tie plates. Wheel friction causes a tendency for rails to "creep" longitudinally, especially on multiple tracks where the trains generally run in the same direction on each track; Small anchors, or "anti-creepers," applied to the rail and bearing against the edge of the tie, are used to check this movement.

Ballast.—Ballast, usually of crushed rock, cinders, gravel or mine waste and tailings, supports and cushions the ties and helps to keep them in proper position, as well as helping to distribute the track load over the roadbed. It also facilitates drainage, thereby promoting firmness and smooth-riding qualities of track. Ballast tends after a time to become foul with dirt, which impedes its drainage qualities. It then needs to be cleaned or replaced. Grass, weeds and other vegetation also must be removed or prevented from growing.

Superelevation.—As a train enters a curve, its natural tendency is to continue going straight ahead. It turns only because the outside rail forces it to do so. To permit trains to traverse curves with safety and greater smoothness, the outer rail is superelevated, or raised above the height of the inner rail, so as to balance the forces set up when the movement of the train is diverted from a straight line by the rails of a curve. Too little superelevation throws excess weight and pressure on the outside rail, too much throws it against the inside rail. The right amount of superelevation for a given curve depends on the train speeds which the track must accommodate; high speeds call for more superelevation, but the amount needed for a fast train may constitute an appreciable excess for a heavy freight train. In practice, therefore, the superelevation on a curve usually is a compromise between the speed ranges of the trains which use the curve. A 2° curve can be smoothly and safely rounded at 80 mi. an hour with a superelevation of five inches for the outside rail. For sharper curves, or if the track is also used for slow trains which do not permit so much superelevation, speed must be reduced. For smooth riding qualities, both superelevation and curvature are introduced gradually, being slighter at the approaches to the curve, building up gradually as the curve is fully entered, and then tapering off again as the end of the curve is approached.

Track Developments and Improvements.—Developments in track have proceeded along two principal lines: (1) strengthening and improving it to bring about better riding qualities and permit greater wheel loads and train speeds, and (2) providing a track structure which can be more economically and efficiently maintained.

Maintenance-of-way work has become increasingly mechanized for greater productivity and economy. Railroads now use large numbers of adzing machines, power augers, ballast cleaners, ballast plows, bolt wrenches, bulldozers, ditching machines, power jacks, rail cranes, power rail drills, power rail saws, power shovels, spike drivers, spike pullers, tamping machines, tie borers, track motor cars, weed burners, weed mowers and power wood saws. Many of the larger items of track machinery are self-propelled and work from alongside—instead of on—the track, thus both avoiding interference with train movements and saving certain costs.

Bridges.—About 3,750 mi. of railway line in the United States are on bridges, made of wood, steel or concrete. (*See* also BRIDGES.) Railway bridges involve unique problems of design to allow for forces resulting from the pounding wheels of cars and engines, the thrusting motion set up by the sideway of the train; the initial, concentrated impact when the engine first comes onto the bridge; the drag effect of the train should it be braked on the bridge, and the push of the driving wheels when it starts again.

All these forces vary with the size, weight and other character-

[1] A grade of 1% means a rise of 1 ft. in a distance of 100 ft. A curvature of 1° means that radii drawn from the ends of a 100-ft. chord of the curve form the sides of a 1° angle.

istics of cars and engines to be used. After a bridge is built, newer types of locomotives and cars often come into use, setting up greater stresses and strains than the original design anticipated. The bridge then must be strengthened, or else train operation must be restricted as to weight or speed, to keep stresses within safe limits.

Much the same is true with respect to other roadway structures; the design must conform to and be integrated with other phases of operation. For example, inauguration of larger types of locomotives may entail lengthening stalls and raising roofs in roundhouses to accommodate them, and call for changes also in train sheds at stations. It may also require strengthening turntables or installing larger ones. Again, a change to diesel locomotives requires the provision of facilities to store and deliver their fuel oil and otherwise service them.

In short, every important change in any one aspect of railway operation involves more or less extensive changes elsewhere. Hence, new equipment and devices for railroading must be thoroughly tested and their performance fully demonstrated before they are adopted on a general scale. Railroad service is the sum of many interacting and co-ordinated details, each of which must measure up to prescribed standards of reliability and efficiency.

Communications.—Speedy, safe and dependable operation of trains requires good communication between operating headquarters and train crews, way stations, signal towers, yards and so on. The far-flung nature of railroad plant and organization also requires good communication for managerial co-ordination and control of operations. Communications systems generally consist of telephone, Morse telegraph, telegraphic typewriter, radio, induction and loudspeaker facilities.

Telegraph and Telephone.—With development of the telegraph, the telegraphic train order was used to supplement rules and running rights for train operation prescribed in the operating timetable. By 1889 a standard code of rules had been adopted by all major railroads to systematize and standardize the issuance and interpretation of train orders. The telephone, too, has become indispensable to railway operation since it was first installed on the railroads in 1877. The telegraphic typewriter, by means of which messages typed out at the sending end are transmitted by telegraph and automatically retyped at the receiving end, likewise has made for itself an important place in railway operation. Morse telegraph is still used to some extent for train orders in dispatching trains, and also for reports and other communications.

Over the years, the telephone and telegraph systems of the railroads have become closely interrelated, especially since it has become practicable to use the same wires for both telephone and telegraph circuits. It is possible for the same group of wires to carry two train-dispatching circuits between train-order offices; several message circuits to freight houses, yard offices, passenger ticket offices and other points; a so-called "overhead" system for messages and conversations; and printing-telegraph circuits.

Radio.—Radio is extensively and advantageously used on the railroads in the following ways: end-to-end train communication—between men in the engine or caboose and the conductor, or other employee on the ground, and between one train and another train when approaching or passing each other; fixed point and train—for yard operation and between a dispatcher or other fixed point and a moving train (including emergency situations where communication is desirable between a central point and a derrick, snowplow, fire-fighting apparatus or the like); emergency service to bridge gaps in communications resulting from flood, storm or accident; remote direction and control of train operations in areas where centralized traffic-control systems (described under *Signals*) are used.

Induction Systems.—Results similar to those obtainable by the use of space radio are achieved on railroads through the use of induction systems. Such a system makes use of the rails and of wire lines adjacent to the track to convey telephone messages by means of a carrier current, picked up by induction. Continuous wire connections are not needed, as with ordinary telephone communication. Induction systems have sometimes been described as "wired wireless."

Radar.—Radar is being used by railroads for speeding up, with safety, the operation of ferryboats and of tugboats used in connection with railroad lighters and car ferries in large port cities. However, there are important physical differences between using reflected-beam electronic devices on an aircraft above the earth's surface, or a ship at sea, with free radio or radar access to any point on the surface within range of its radio equipment, and the use of these devices on a surface vehicle passing roadside obstructions and threading around curves, through hills or tunnels and across bridges. (*See* also RADAR.)

Signals.—Signals are a form of communications which are addressed to employees in charge of trains, and especially to the locomotive engineer, to inform them concerning the track ahead. Originally, trains in the same direction were spaced on a time-interval basis, and meets of trains moving in opposite directions were made either according to operating timetables or on special instructions from the dispatcher, delivered to engine and train crews in the form of written train orders. As traffic density increased, on certain lines, the principle of block signals was developed to substitute space intervals for time intervals between trains. Under this system, a line of railroad is divided into blocks or segments of various lengths, depending on traffic conditions, and trains are restricted in following or moving against each other into any one block. On lines of still greater traffic density, the manual block system has been largely replaced by automatic block systems, which by 1950 were in use on more than 105,000 mi. of track. In that year, more than 90% of all railway passenger travel was over tracks equipped with block signals.

Automatic Block Signals.—With automatic block-signal systems, the train itself operates the signals. The key to the system is the track circuit, with the rails acting as conductors of an electric current. If the normal flow of current is short-circuited, or shunted, by the wheels of a train in the block, or interrupted by the opening of a switch, a break in a rail or otherwise, the signal automatically displays a "stop" indication at the entrance to the block. At the same time, the next signal back (and ahead, on single track) will also change, to show that the second block forward is occupied.

With this development, train movement is not dependent on a block-signal operator or other employee to obtain the necessary information and set the signals, and the capacity of the individual line is greatly increased. More trains can be handled, and service is improved.

New methods of transmitting electrical impulses have increased the flexibility and efficiency of block-signal systems. The faster the train, the more space needed to stop it. One way to meet this need is to increase the length of blocks, but this means that slower trains are impeded by the greater distance between signals. With the use of "coded circuits," it is feasible to have signals display five indications—clear-proceed, three degrees of caution and stop—the position of signals being controlled by means of coded variations in rate of pulsations in the current. Thus, it is possible to give the engineman information on conditions three blocks ahead. In at least one installation, there were five-indication signals which covered the situation four blocks ahead.

Cab Signals.—Cab signals, located on a panel in the locomotive cab, facing the engineer, are sometimes used to supplement or replace signal indications on a pole or mast beside the track. The cab signal reproduces in miniature the indication of the wayside signal. Where cab signals are used, any change within a block after the train has passed the wayside signal at the entrance is immediately conveyed to the engineer.

Automatic Train Control.—Further in connection with the use of block-signal systems, automatic train-control (A.T.C.) devices are used in some situations. Different methods have been adopted, but their common purpose is to stop a train, or reduce its speed, automatically, if the engineman fails to act in accordance with requirements of the signal indication.

Automatic Interlocking.—Where tracks cross, automatic interlockings are extensively used to increase safety and reduce costs. In these devices, switches, locks and signals are so interconnected that their movements must follow each other in predetermined

order, thus ensuring that conflicting movements cannot take place. Thus, when switches and signals have been set for a train to move over the crossing, the mechanism is automatically locked against any conflicting movement until the first movement has been completed; and signal indications are displayed, close to the crossing and also at a considerable distance from it, against any such conflicting movement. The interlocking mechanism may function either electrically or mechanically.

Interlocking devices not only provide positive protection at track crossings but also obviate the necessity for many train stops, either to see if the crossing is clear, or to wait for another train to clear it. Thus, they often save the considerable cost of stopping and starting a train.

Route-Type Interlocking.—A similar device, for the same purpose and also based upon the automatic-interlocking principle, is the "entrance-exit" (NX) or route-type mechanism, which has been installed in many large passenger and freight terminals and other localities where movements are made through an intricate track layout. With such an installation, the tower operator presses a button for the track on which the layout is to be entered and another for the track of exit. The mechanism then automatically selects the proper route of movement through the layout, sets all the switches and signals involved and locks them against conflicting movement, the locks being released as the engine or train clears various points on the route.

Centralized Traffic Control.—As a further development of block-signalling techniques, it is possible by means of centralized traffic control (C.T.C.) to direct train movements entirely by remote control. Orders to train crews are not needed. Instead, switches and signals over many miles of line are controlled by a single operator, sitting before a panel or switchboard in a control room. Before him, the location of each train is shown automatically on an illuminated diagram of the line. Below the diagram are knobs which govern each signal and small levers which govern each switch on the line. By his exact visual knowledge of where trains are, the operator can arrange closer meets between opposing trains as well as faster run-arounds of slow trains by fast ones. Track capacity is so greatly increased under C.T.C. operation that this increase often postpones or eliminates the expense of multiple tracking.

Rolling Stock.—Design and upkeep of railroad locomotives and cars and, usually, their construction are under the charge of the mechanical department of a railroad. Men involved, at headquarters and on the divisions, include the chief mechanical officer, chief of motive power, chief of fuel and locomotive performance, mechanical engineer, electrical engineer, superintendent of rolling stock, machinery supervisors, chemists, engineers of tests, master mechanics, shop superintendents, chief locomotive and car inspectors, air brake and steam heat supervisors, supervisors of electrical equipment, supervisors of boilers and welding and so on. Functions of the mechanical department are carried on in locomotive and car shops, roundhouses and engine terminals and like locations.

Locomotives.—Locomotives may be classified in several ways: according to use, as freight, passenger and switch (or yard); according to kind of power, as steam, electric or diesel; according to fuel used, as coal, oil, gasoline or distillate; and according to method of power production or utilization, as diesel-electric, reciprocating-piston, steam-turbine and gas-turbine. Whatever the source of power or method of its utilization, all locomotives depend on adhesion of wheels to rails to transform power into motion. Given enough weight, the application of power will cause the wheels to turn along the rail, instead of slipping and spinning in one spot, and the locomotive will move in the desired direction. (*See* also LOCOMOTIVE.)

Steam Locomotives.—Capacity and efficiency of the modern steam locomotive have been increased steadily by improvements in its component elements. Higher sustained speeds, with greater economy of operation, are achieved through increased boiler pressure and improvements in combustion efficiency. The modern locomotive produces more steam per pound of fuel used and accomplishes more work per pound of steam produced than its predecessors.

Steam locomotives are often described in terms of wheel arrangement, listing in order the numbers of leading or "pony" wheels, the drivers and the trailing wheels. In a 2-8-4 locomotive, for instance, the engine has two small wheels on a leading axle, then four axles with eight driving wheels, connected, and finally a trailing truck with four small wheels. The leading axle helps to support the front end and also is important in guiding the locomotive around curves. The trailing truck supports the firebox and part of the boiler.

A modern 2-8-4 steam freight locomotive in working order weighs about 575,000 lb. Contained within its 49-ft. length is a boiler developing steam pressure of about 270 lb. per square inch. Its tender carries 30 tons of coal and 20,000 gal. of water. The coal is burned in a firebox approximately 13 ft. long and 8 ft. or 9 ft. wide—the size of an apartment bedroom. The heating surface provided by its many tubes and flues is about 6,000 sq.ft., and superheaters add another 3,000 sq.ft. An articulated type of locomotive with two sets of driving wheels, such as the 4-8-8-4, is even larger. These huge machines have the frames hinged in the middle to facilitate movement around curves; hence the term "articulated."

Much research and many new devices contributed to the attainment of this stage of development. For example, the power of a locomotive increases in direct proportion to the steam pressure in the boiler (other factors being equal), and working pressures now commonly used are 25% to 50% higher than before World War I. By passing steam through nests of small tubes inside the fire flues of the boilers, it is superheated and dried so that its temperature can be brought up from around 375° F. to 700° F. or more, and the power of the locomotive thus further increased, without additional increase of steam pressure.

Good combustion of fuel is an important element of steam locomotive efficiency. Elimination of smoke is important, not only because smoke indicates imperfect combustion but also because it is otherwise objectionable. Therefore, special research has been devoted to improvement of combustion by locomotives. Overfire air jets, which inject additional air to bring about more complete burning of coal particles in the firebox, and new designs of air passages are among means adopted to this end.

Similar research and development have taken place all along the line. The automatic stoker feeds coal into the firebox to supply the quantities of fuel needed by large modern locomotives and to keep the right kind of fire over the entire grate area. Arch tubes, circulators and siphons installed in the firebox promote water circulation in the boiler and increase heating surface. Feedwater heaters draw heat from otherwise wasted exhaust steam and use it to preheat water passing from the tender to the boiler. Welded boilers reduce both weight and maintenance cost. With improvements in foundry practice, the entire frame of the locomotive can be cast as one huge, integral part, thus solving certain important technical problems. Roller bearings permit easier starts and increase the availability (working time) of locomotives. Automatic oilers provide lubrication to the multitude of working parts. Booster engines, working through gears on the trailing axles, give additional tractive power for starting and for slow-speed operation. Flues, valves, grates, pistons, cylinders and so on have been improved as research produced new materials and new designs.

Changes such as these do not ordinarily attract general public notice. Their greatest effect has been on the type and amount of work output of the locomotive. In 1918 the railroads had 63,500 steam locomotives in service; in 1948 they had approximately 33,000. During these three decades, however, the pulling power of the average steam locomotive had increased by about 60%, and the work performed by a freight train in one hour, measured in tons carried one mile, had increased by about 150%. This increase of 150% represents advances not only in locomotive work output but in general operating efficiency in all its elements.

Improvements for one purpose often bring problems in some other direction. Treatment of boiler water for locomotives affords an illustration. Virtually all water contains natural impurities. Certain of these impurities may damage the boiler or form a scale

which shortens the life of the metal and also reduces the ability of the surfaces to conduct heat. Numerous chemicals have been developed to treat water by eliminating or neutralizing impurities, either in the boiler, the tender or the wayside water station, and to prevent or remove scale deposits in the boiler by flushing out the impurities as sludge. Water-softening plants treat the water before it is delivered to the tenders. Automatic blowoff systems are installed on locomotives to control foaming and sludge. Experimental installations have been made with ion-exchange resins, which remove calcium and carbonate materials.

Electric Locomotives.—The electric locomotive draws its power from central generating stations, unlike other locomotives, which are limited to the capacity of their own power equipment. Since a relatively small percentage of all trains use maximum power at any one time, large reserves of power are available when needed. The initial investment in power lines and other appurtenances of electrified train operation is high, but operating cost is low. Hence, electrification is most efficient under dense traffic conditions, where current for power can be centrally generated in great volume and delivered to motors on trains at low cost. Systems of electrified operation vary in type and voltage of current used, methods of transmitting current to the locomotives and types of locomotives. Later installations use an overhead line carrying 3,000 v. to 11,000 v.

Because the electric locomotive does not contain power-generating equipment, it is generally lighter in proportion to horsepower than the steam or diesel-electric locomotive. Its ability to draw on reserves of power provides overload capacity which enables it to accelerate rapidly and smoothly. It also has a high degree of availability for service, and can be used interchangeably for freight and passenger operations. A distinctive feature is that on long downgrades electric motors on the locomotive may be used as generators. In so doing, they serve to hold back the train without using the regular brakes, which has some operating advantages. This regenerative braking produces electricity which flows back into the power line. Thus, the weight of a descending train helps to provide power for ascending trains.

Electrified service was operated on approximately 2,700 mi. of road as of 1950, with about 6,600 mi. of trackage of all kinds. Among principal operators were (in descending order of track mileage): the Pennsylvania railroad; the Chicago, Milwaukee, St. Paul and Pacific railroad; the New York, New Haven and Hartford railroad; the Illinois Terminal railroad; the New York Central railroad; the Long Island railroad; the Virginian railway; the Norfolk and Western railway; the Reading company; the Sacramento Northern railway; the Delaware, Lackawanna and Western railroad; and the Illinois Central railroad.

Diesel-Electric Locomotives.—The diesel-electric locomotive is essentially an electric locomotive which supplies its own power instead of drawing it from a central generating station. It thus provides some of the distinctive operating advantages of the electric locomotive, while avoiding the high initial investment required for electrification. Its power supply is derived from an internal-combustion engine that compresses air in a cylinder and then introduces a spray of oil fuel, which is ignited by the heat of compression. Because the diesel engine burns its fuel right in the cylinders where it is to work, instead of in a separate boiler, it gets out of a pound of fuel about four times as much work as does the steam locomotive. It also is able to use compression ratios much higher than those of gasoline engines, which means that again it gets more work out of its fuel.

Illustrating its high degree of fuel efficiency, the diesel engine can produce 625 gross ton-miles of service with one gallon of diesel fuel oil. By comparison, the average automobile produces only 20 to 30 gross ton-miles on a gallon of gasoline, and a four-engine cargo aeroplane produces 30 to 40 gross ton-miles on a gallon of high-octane gasoline. A tankful of 5,000 gal. of diesel fuel will take a 100-car freight train about 650 mi.

The steam engine drives the wheels directly, with the power controlled through the amount of steam admitted to the cylinders to drive the pistons. By contrast, the diesel engine, like the automobile engine, requires a transmission arrangement to vary the power application from a high level in starting to lower levels as required. Mechanical, hydraulic and pneumatic methods of transmission have been used, especially on smaller units, but most diesels now in use on railroads have electric transmission, and hence are called diesel-electric locomotives. In these locomotives the diesel engine drives a generator, producing a variable current of electricity to operate electric motors, which are geared to the wheels.

Perhaps the greatest advantage of the diesel-electric over the steam locomotive—surpassing in importance the higher fuel efficiency—is its high availability factor; it can work more hours of the day and more days of the year without the time out needed by the steam locomotive for attention to its fires, boiler, coal and water replenishment and the like. The diesel can carry enough fuel for long nonstop runs, and it needs little water other than that required to generate steam for heating the train. Like the electric locomotive, the diesel-electric also can reverse its motors to use them as brakes on long downgrades. Since there is no trolley wire into which the electricity thus generated can be fed, it is dissipated as heat, through radiators in the roof.

Questions of weight and size make it desirable to build diesel locomotives in units, each of which may have one or two engines. It is not uncommon for trains to be pulled by three or four of these units, each having a capacity of from 1,350 h.p. to 2,000 h.p. A high-speed passenger locomotive may comprise three units, producing a total of 6,000 h.p. One or more of these units can be cut out of use at times, as needs for power vary during the run, thus enhancing flexibility and economy of operation. A 5,400-h.p. freight locomotive with four units may be more than 190 ft. long and weight 900,000 lb. in working order. Each of its eight sets of trucks has two traction motors, with gear ratios according to type of service.

Diesel-electric locomotives are more costly to build than steam locomotives of equivalent power, but where they can be scheduled so as to keep them intensively working they can make at least twice the monthly mileage of similar steam locomotives. Thus, their higher costs may be distributed over enough mileage to obtain the benefits of diesel-electric service at no additional, or in many cases substantially less, cost per mile.

The distinctive advantages of diesel-electric locomotives under favourable conditions led to rapid progress in their utilization. In 1949 these locomotives performed somewhat more than one-third of all freight service and approximately one-half of all passenger and switching service of class I railways (including switching and terminal lines).

New Types of Locomotives.—Tests of turbine locomotives indicate that they have considerable promise in the way of greater fuel efficiency, lower operating costs and smoother operation. There were several types of turbine locomotives under development in 1950: coal-burning steam turbine, coal-burning gas turbine and oil-burning gas turbine, with some variations among these according to whether the power is mechanically or electrically transmitted. In the steam-turbine locomotive, steam under pressure is directed against the blades of a turbine wheel, instead of against reciprocating pistons operating in cylinders. In one type of gas turbine, a crushing process using compressed air breaks up coal into fine powder. This powder is burned under pressure to produce a very hot gas, which drives the turbine. Similar experiments were being made with the use of oil for fuel.

Choice of Power Types.—With steam, electric and diesel-electric locomotives already developed to high degrees of efficiency, and with several types of turbine locomotives under energetic research, development and test, railroads have a wide range of types of power supply. Each type has certain characteristics which adapt it for certain kinds of service, thus facilitating selection on the basis of operating economy and efficiency.

Passenger-Train Cars.—Passenger-train cars are of two principal types, passenger-carrying and "head-end." The latter, so called because in trains they usually are placed just behind the engine, include cars for transporting mail, baggage and express or some combination of two or more of these. There also are some

combination head-end and passenger-carrying cars. Mail cars are of two principal types—cars for transportation only, and railway post office (R.P.O.) cars, in which mail is received, distributed and otherwise handled enroute by postal clerks, as in any other post office.

Passenger-carrying cars are of several types. They include coaches and sleeping, parlour, dining, club, lounge and observation cars. Some of these types also are combined. Virtually all passenger cars now in regular use are built of steel or some metal or alloy of equivalent strength and are equipped with air conditioning. Great strides have been made in designing passenger cars to save weight while maintaining ample safety factors. One innovation in car design is a type of car permitting passengers to sit high up in a glassed enclosure, whence they can see in all directions. Other features of modern passenger equipment include: tight-lock couplers, holding cars tightly together and thus helping to provide smooth starts and stops; rubber insulation to serve as a buffer against transmission of noise and vibration; fluorescent lighting; circulating ice water, provided by an electric cooling unit which pumps the water to rooms in the train; double panes of glass, sealed into the sash, to improve vision by preventing fogging of windows; rooms having radio service, with channels for wire-recorded programs and for radio reception; public-address systems for transmitting information of interest and making announcements such as for dining-car service (reception being under push-button control by the passenger); and telephone service to and from trains while moving. On many trains, the services of a stewardess, hostess or secretary are available.

An important development in passenger-train car equipment was the introduction in 1934 of the lightweight streamline passenger train. The first of these trains to be constructed was the Union Pacific railroad's aluminum alloy streamliner "City of Salina." It entered regular service Jan. 31, 1935, after a year of exhibition. The stainless steel streamliner "Pioneer Zephyr" of the Chicago, Burlington and Quincy railroad was the first train of this type to use diesel locomotive power and the first operated in regular, scheduled service, which began Nov. 11, 1934. Incorporating many novelties of design and appearance, and decorated in bright, distinctive colours, these new trains met with instant popularity and were quickly followed by many others, on railroads in every part of the country. In 1949 there were almost 300 streamline trains in operation in the United States.

The sleeping car was developed and popularized by the Pullman company, which operates these cars over most railroads under contracts. In 1947 the Pullman company was acquired by a group of 59 railroads, without material change in its operations except that a large proportion of the sleeping cars in regular use are now owned by individual railroads and operated by the Pullman company.

For many years sleeping cars were essentially open-section cars, featuring lower and upper berths, with some drawing-room and compartment accommodations. Commencing in 1927, several new types of rooms were introduced, such as the bedroom and roomette and duplex (or staggered-level) rooms. The trend away from open-section accommodations became quite evident in sleeping-car construction with the advent of lightweight streamline cars. Sleeping cars with open-section accommodations were largely replaced by cars having principally or entirely room accommodations.

Passenger-Car Operating Features.—There is much more to a passenger car than the seats, lights, windows and other details that engage the traveller's personal attention. It is the complex of equipment under the car that contributes most to his safety, comfort and convenience. This equipment includes the car trucks and running gear, the automatic air brakes and appurtenances, and the electrical system which supplies current for lighting and for fans, ventilators and air-conditioning mechanism. Design of all such equipment must be such as to require minimum upkeep and repair, and if repairs are needed, to promote their speedy accomplishment, so that cars can be kept moving.

Car trucks, comprising the wheel assemblies, have many important parts besides wheels. The wheels themselves, despite their apparent simplicity, perform many functions. They not only roll on the rails but they also must support the weight of the car and contents (140,000 lb., more or less) under varying conditions of load stress, and must transmit the braking forces to the rail.

Passenger-car wheels may be made of cast iron, cast steel or wrought steel. They may be one-wear, two-wear or multiple-wear types. A multiple-wear wheel is one that can be reground or machined back into its original contour after it has been worn down in service. The multiple-wear wrought-steel wheel is now the standard passenger-car wheel. Because conditions vary, there are three classes of multiple-wear steel wheels, of varying metallurgical composition and adapted to different operating conditions. For example, one such class is used when loads are light but braking is severe, and high resistance to thermal cracking is needed.

Wheels are pressed on the axle, and turn with it. The part of the axle projecting at each end forms the journal, which turns in a journal box that holds oil and "waste" to lubricate the journals. Resting on the journals are brasses—friction-reducing bearings—which support the weight of the car on the journals. On many passenger cars, these brasses are replaced by roller bearings. Springs absorb shocks, and various snubbing devices reduce the vibration of cars at high speeds.

Developments in tracks, motive power and other plant facilities to promote greater speeds of train operation would be of little avail without a correspondingly developed braking system for trains, because safety demands adequate brake control at all times. The power required to stop a moving train is tremendous. Engineers have calculated that stopping a train running at 60 mi. an hour uses as much power as would be needed to lift the train vertically to a height of 120 ft.

Braking is now performed by means of the automatic air brake. Each car has such brakes, controlled from the engine by varying the air pressure. Compressed air from the locomotive is distributed to reservoirs on each car, through air pipes and hoses which connect all cars. Each car has a "triple" valve, which so controls the air pressure as to set the brakes when there is a reduction in the air pressure from the engine. As long as pressure in the train line is full, usually about 110 lb. per square inch for passenger trains, the valve simply passes air into the reservoir. But when the engineer reduces air pressure, or when pressure in the line drops for any other reason, such as a break in the air line, the valve closes the passage to the reservoir and opens a vent from the reservoir to the brake cylinder. Pressure of the air stored in the reservoir then operates a piston against the brake rigging, which forces the brake shoes against the wheels, and brings the train to a slowdown or a stop.

Automatic slack adjusters on passenger cars keep the slack in the brake rigging uniform throughout the train and thus equalize brake tension, helping to prevent uneven brake applications on the various cars. Wheel-slip protectors and speed-pressure regulators automatically adjust the application of braking force as train speed is reduced. The "decelostat," which electrically regulates brake pressure, permits greater refinement in the proper adjustment of braking force. Wheel-slide controllers on individual axles release and reapply brakes when a pair of wheels is about to slide.

A primary essential in the development of the present coordinated system of nation-wide interchange of cars was the development of a standard coupler between cars which would work with every other coupler in use. The early link-and-pin coupling, in almost universal use in 1880, accomplished this purpose but presented serious safety hazards. Tests of a number of proposed devices to improve this situation were held near Buffalo, N.Y., beginning in 1885 and continuing for two years. These tests resulted in the adoption as standard of a coupling (of which there were various designs) based on the idea of a swinging knuckle and working like the hooked fingers of two hands—the principle still in use. The new coupler closed automatically upon impact and could be released without requiring a man to go between the cars, by use of a safety lever projecting out to the side of the car. Further progress in standardization through the years resulted in adoption in 1911 of a single design of coupler,

with all its parts standard and interchangeable. This design has undergone subsequent improvement, and since 1938 a new tight-lock coupler for passenger cars has been available.

Freight Cars.—Freight cars haul an almost innumerable variety of products, using various types of cars for different kinds of traffic.

The boxcar, of which there are about 740,000 in use (1950), is the most numerous type of freight car. About 685,000 are plain boxcars, or general-service cars, and are equipped with inside linings for both the sides and ends. Other boxcars are specially designed for the movement of special types of freight, such as automobiles and automobile parts. Some boxcars are equipped with special bulkheads and other devices for better handling of less-than-carload merchandise shipments. Still other boxcars are equipped with ventilated side doors and end or side louvers and are used for carrying fruits and vegetables at certain seasons in certain sections of the country.

Inside length of boxcars varies from 36 ft. to 60 ft. 6 in., standard lengths being 40 ft. 6 in. and 50 ft. 6 in. Inside width ranges from 8 ft. 6 in. to 9 ft. 4 in., the standard being 9 ft. 2 in. Height from floor to eaves may be as low as 8 ft. or in some special cases as high as 11 ft., the standard being 10 ft. 6 in. Capacity ranges from 2,900 cu.ft. to 5,900 cu.ft. and load limits from about 80,000 lb. to 120,000 lb.

Another important type of roofed car is the refrigerator car, designed to protect loads against either heat or cold. There are several classes. One large class consists of cars designed for the transportation of fresh fruits and vegetables. Others are designed for transporting meats, dairy products, frozen foods and so on. The improvement of refrigeration equipment and methods is the subject of extensive research by the railroads. This research also extends to protection against low temperatures during winter months.

Principal classes of open-top cars are gondola cars and hopper cars. Gondolas have flat bottoms, with fixed sides varying in height from 2 ft. 6 in. to 4 ft. 8 in. (even 8 ft. in the case of coke cars), and having either fixed ends or drop ends which may be lowered to facilitate loading and unloading. Inside length of "gons" varies from 37 ft. 6 in. to 65 ft., and capacity from 100,000 lb. up to 200,000 lb. Hopper cars have drop bottoms, sloped to be self-unloading. Some hopper cars dump outside the rails, but most dump between the rails, through one to four hoppers. Capacity varies from 100,000 lb. to 220,000 lb. There are also covered hopper cars for bulk commodities, such as cement, which require protection from weather.

The tank car is used for carrying liquids in bulk. It consists of a large tank, sometimes divided into compartments, and sometimes with special linings, mounted on a steel underframe and forming an integral part of the car. Numerous products are carried in such cars, including crude oil and various refined oils, wine, milk, chemicals of many kinds, compressed gases, liquefied petroleum gases and chlorine gas, and a growing list of other liquid or liquefied-gas products.

Most tank cars are owned by companies specializing in their production and rental, and the railroads pay a specified rate per mile for their use. Much the same is true of refrigerator cars.

Other types of freight cars are flatcars and stockcars. Some flatcars have depressed centres, to accommodate loads so high that otherwise they might not clear bridges and other structures; these are called "well" or "depressed centre" cars. Stockcars might be described as boxcars with slatted instead of continuously closed sides, to provide ventilation for animals and help keep them cool in summer. Some are equipped with a second deck, to enable them to handle small animals, such as hogs or sheep, on two levels.

While the variety of cars provides better service to industry, it also increases the complexity of the car-supply and maintenance phases of railway operation. Maintenance problems have been greatly eased, however, by standardizing freight cars from the floor down—the working parts. Wheels to roll the load, axles to hold the wheels, frames and springs to support the body, couplings to connect cars, draught gear to absorb the push-pulls of train and yard movement, brakes to control speed and stops—all have been so standardized that any of these parts can usually be replaced or repaired without regard to distance from the owners' rails or headquarters. This is a result of the development and general adoption by the railroads of a code of rules to govern the interchange of cars and their movement and repair on "foreign" lines (that is, lines other than their owners'), which has been a major factor in the advancement of transportation and industry in the United States. This arrangement makes possible the nation-wide movement of cars, so that from the standpoint of shippers the cars of all railroads comprise one great national pool. At the same time, the railroads also have developed methods whereby each railroad knows the location of each of its cars at all times, and collects an agreed amount per day for the use of its cars from other railroads on whose lines they may be located.

Freight-Car Operating Features.—Many items of the trucks and running gear of passenger cars have their counterparts on freight cars, in some instances with modifications to take account of differences in the characteristics of the two kinds of service. In freight service normal pressure in the air-brake line from the locomotive to the cars approximates 70 lb., compared with 110 lb. in passenger service. It is now possible to follow a normal application of brakes with an emergency application, or to slow down to very low speed, then release the brakes and pick up speed, without bringing the train to a stop, which in earlier days could not be done. The present freight air brake, because of the greater speed with which the application of brakes is transmitted through the length of the train, also makes possible smoother stops.

Back of the coupler of the freight car, and connecting it to the centre sill or principal structural member of the car, is the draught gear—a combination of steel wedges, plates, rings and springs. In a space about two feet long, with a cross section of less than one square foot, the draught gear must absorb the shock of coupling loaded cars, under which it must recoil no more than two and three-fourths inches. Hence, the device has to be strong, rugged, long-lasting to reduce maintenance, and simple to facilitate upkeep and repair. Improvements were under development in 1950 to make this device still more flexible in responding to light blows and yet having greater ability to diminish shock to the car itself and thus avoid damage to goods in transit.

Freight-car trucks also are important to efficient rail service. Lighter weight is a goal gradually being achieved. The two four-wheel trucks which support a car weigh about 14,000 lb., approximating one-third of the total weight of a boxcar. Wheels and axles alone account for about 8,000 lb. of the total. Tubular axles and lighter materials for side frames, bolsters, brake beams and so forth serve to reduce weight.

Truck springs are vital to smooth riding of car body and load. At high speed, the freight-car body moves vertically because of harmonic oscillation and sidewise because of lateral sway. Improved springs and snubbers are means of achieving greater stability. As with draught gear, the problem is one of shock absorption.

Maintenance of Rolling Stock.—With all the mechanical equipment on approximately 42,000 locomotives, 2,000,000 freight cars (counting privately owned and all other units), 44,000 passenger-train cars (including diners, mail and baggage, etc.), plus 120,000 cars for company-service needs, upkeep and repair of rolling stock is a considerable responsibility of the mechanical department.

The operation of locomotive shops involves tasks like those of any heavy manufacturing industry. Powerful cranes and hoists are needed, along with furnaces, grinders, presses, machine tools, steam hammers, punches, shears, pipe forges and cutters, tanks and many other types of tools and equipment.

Besides routine servicing during and after each trip, locomotives are given running repairs and minor adjustments as needed. This work is commonly performed in the roundhouse. In addition, locomotives also are given periodical general overhauls in the "back shop." These overhauls, performed after a prescribed amount of mileage, are classified according to varying degrees of comprehensiveness, scaled according to the service performed since the last overhaul, and hence are often referred to as classi-

fied repairs or back shopping.

A locomotive due for classified repairs usually moves to the back shop directly from road service. In the case of a steam locomotive, fires are dumped, the ashpan cleaned and the boiler "blown down" and drained. Front end, ashpan, and firebox are washed out. Coal on the tender is removed for later use. On a designated track, the locomotive is stripped of fittings and appurtenances—pipes, gauges, mountings, boiler jackets, side rods and so on. Moved thence into the main erecting shop, a giant crane may pick up the entire locomotive and move it to an assigned repair pit.

On the pit, the engine is stripped down to its component parts, and each part is examined. Sandblasting, machining, welding, painting and so on are performed at the proper time and place. Each step is carried out according to a prearranged time schedule. With scientific layout and scheduling of hundreds of individual operations, a locomotive can be almost entirely rebuilt in three weeks.

As diesel locomotives came into more widespread use, specialized facilities were needed to service them. A diesel locomotive terminal provides a wide range of services (some of which also are common to steam locomotives). Routine servicing requires oil storage and dispensing equipment, water-filling connections, sand towers, lubricating equipment, pits for inspection of running gear, and the like. For regular or periodic inspection and running repairs, the terminal shop may have travelling cranes, hoists, jacks, various machine tools, testing equipment, an electrical repair room, facilities for cleaning fuel-injection and other equipment, a lubricating oil reclaimer, battery chargers and perhaps even a machine for washing the outside of the engine.

Practices vary with respect to back shopping or general overhaul of diesel locomotives. Some railroads have no diesel back shops, considering them unnecessary with a well-planned program of parts replacement. Others prefer a system of general repairs at definite periods, as with steam locomotives, and provide extensive back-shopping facilities, often concentrated at one or two points on the railroad. When heavy repairs are needed, either the locomotive is moved to one of these shops or the particular items are sent to the main shop and replaced by others at the regular servicing point. For example, an entire engine can be removed from a diesel locomotive for overhaul and replaced by another, thus keeping the locomotive continuously in service.

Repairs to electric locomotives are handled in much the same manner as repairs to diesels.

Car repair shops are organized much like locomotive shops, carrying on many operations, often simultaneously. For heavy repair or rebuilding programs involving considerable numbers of cars, operations usually are set up on a progressive or assembly line basis, with various stages of the work performed at successive shop stations. Some of these stations are fed parts and materials from subassemblies or other departments of the shop. Power tools and other modern devices are extensively used.

Cars undergoing general overhaul or rebuilding are completely stripped. Rivets and perhaps other items are removed by flame-cutting in a burner shed. Wheels are removed and turned, or rebored. There are straightening stalls for various car parts such as side stakes, centre sills and bulged ends. A fitting-up shop builds up and rivets or welds complete sides for cars. Doors and accompanying parts are assembled. Test racks for air brakes establish whether they are functioning properly. The truck shop makes necessary repairs to truck parts and packs journal boxes. The paint shop applies the railroad's distinctive colours and adds the car number and other information on the sides of the car. Battery chargers and mechanical washers help to condition passenger cars. Numerous testing devices make sure that all work has been accurately and adequately done.

Train, Yard and Station Operations.—Movement of passengers and freight in trains and operation of yards, terminals and stations are responsibilities of the transportation department. This department usually is headed by a general superintendent of transportation, aided by a chief of freight transportation, and his counterpart for passenger service, titles varying among different railroads. Stations and transfer points for L.C.L. (less-than-carload) merchandise, highway transport service, car service, mail service, police protection and labour and wage bureaus are supervised by subordinate officers. The transportation organization on a division includes the train, engine and yard crews and the dispatchers involved in actual movement of cars and engines, and the agents, clerical forces and warehouse forces at stations.

Yards and Terminals.—Yards and terminals are key points of the railroad system. From, to and through them flow cars and trains. In them cars are serviced, assembled and classified, and locomotives are housed and serviced.

Class I line-haul railways operated in 1950 approximately 355,000 mi. of all tracks (excluding trackage rights). About 53,500 mi., or about 1 mi. out of every $6\frac{2}{3}$ mi. of all tracks, were required for yard switching operations. In the industrial east such proportion exceeded 1 mi. out of every 5 mi. This did not include approximately 7,430 mi. of tracks operated by carriers organized exclusively as terminal belt-line and switching railroads.

Classification of Freight Cars.—The principal function of a freight yard is to sort and classify cars for further movement. Inbound trains are broken up and the cars, to the extent necessary, are reclassified and reassembled into groups bound in the same direction, or to the same destination or to the same connecting railroad. Cars terminating locally or for interchange to local connections are sorted out for delivery to their respective destinations in the terminal area, and cars originating locally or received from local connections are distributed to the proper outbound tracks. Most yards of any considerable size also include, or have adjacent, facilities for servicing of, and running repairs to, cars and locomotives.

Classification and distribution of cars is performed by switching engines, in either hump or flat yards. Freight-car movements are made in accordance with a switching list prepared in the yardmaster's office.

The primary distinction between a hump yard and a flat yard is that in the latter the trackage is level, as the name implies, and movements of freight cars are powered in their entirety by switching engines, instead of partly by gravity from the hump. Another distinction is that in a hump yard the movement of cars progresses in a single direction.

In a hump yard, a humping engine slowly moves an entire freight train upgrade to the top of the hump, at constant speed. Working from the switching list, a crew member uncouples one or more cars at the summit, whence gravity carries them into the classification tracks. The selection of tracks is controlled by power switches, operated from one or more control towers at strategic points in the yard. A typical yard may contain 50 or more tracks, depending on type of traffic and number of classifications required.

Car Retarders.—In earlier installations of hump yards, cars moving down the hump to classification tracks were controlled by car riders, to operate the hand brakes and avoid excessive impact. Their sole job was braking; other men were assigned to throwing switches as the cars moved down to the appropriate track. After delivering a car, perhaps at the far end of the yard, these men returned to the hump, either on foot or by riding a motor car. An improvement on this type of operation was the installation of car retarders. The retarder is a braking device, located along the track, which clasps each side of the car wheel at the rim. It is actuated from the control tower. With the combination of retarders and power switches, the tower operators control both the direction and the speed of car movement.

Other Yard Activities.—Classification of freight cars is the principal but not the only element of yard work. Numerous related activities add to the complexity and importance of the yard. Fuelling and watering facilities for locomotives are provided. There may be car or locomotive shops equipped for extensive repairs, or merely a special track for running repairs. Many yards set aside cleaning tracks, where cars containing dunnage or debris are emptied and made ready for reloading. Scales are usually provided for weighing loaded and empty cars. Where perishable traffic is handled, car-icing platforms, an icehouse and associated

trackage may be part of the yard facilities. In a large terminal yard there is also a roundhouse for engine storage and repair. There may be stockyard tracks and sheep barns.

Typically, the complete yard embraces primary elements consisting of a receiving yard, hump tracks, a classification yard and a departure yard, in the order named, with auxiliary features that include car repair tracks, caboose tracks and necessary running or intercommunication tracks. At industrial centres, a major function is the switching of cars in and out of manufacturing establishments; special storage tracks are usually provided for this operation. Team tracks are another usual feature; alongside them are paved or otherwise improved driveways where motor or horse-drawn vehicles can load into or out of the cars.

Blocking Cars in Trains.—In switching freight cars for assembly into outbound trains, efforts are made to assemble cars into "blocks," grouped according to destination. This requires more work at the origin point, but results in a substantial net saving of switch moves for the complete movement. Later switch moves also are saved by arranging cars in trains so that those to be dropped off at intermediate points can be switched out without needless movement—and delay—of other cars. Wherever practical, solid trains are made up, to move through intermediate terminals without breakup.

Yard Communication.—Rapid and effective communication is essential in minimizing waste motion and unproductive time in the operation of a freight classification yard. Telephones, of course, are in general use, but there are many occasions when yard forces are not near a telephone or other fixed communication facility. Consequently, a number of other devices and methods have been developed. Loudspeaker systems are frequently used when rapid instructions are needed. Developments in two-way radio communication opened new possibilities for improved yard efficiency. In switching to and from industries, where engines may be operating several miles from the yard proper, radio reduces time needed for obtaining and executing new or revised instructions.

Other Improvements in Efficiency.—Ordinarily, when a freight train arrives at the receiving track in the yard, the conductor brings the waybills (one for each car, showing origin, destination, commodity, weight, routing, etc.) to the yard office. Alternatively, he may dispatch them through a pneumatic tube. After waybills have been checked, a clerk copies certain of the information for a switch list, or for car cards, depending on local practices. In large yards a photographic process replaces hand copying. While the train is being inspected and the cars are being switched for further outbound movement, a train list is compiled from the waybills for all cars in outbound trains. In many yards an interchange report also must be made for cars delivered to or received from connecting lines. Waybills are arranged in order according to the position of each car in the train, and a "wheel report" or train consist is prepared from them. The conductor then picks up the waybills and wheel report, and the train departs. Alternatively, the wheel report may be prepared by the conductor while the train is en route.

Some roads in areas of heavy traffic have adopted various mechanical systems involving use of punch cards (such as are used in electric tabulating machines) combined with use of printing-telegraph equipment. Waybill data are punched on cards at the originating station or the first yard thus equipped, instead of being transcribed by hand. The cards are then used to reproduce automatically, by printing telegraph, at distant receiving yards and in headquarters car-record bureaus, such information as interchange reports and wheel reports on trains before they arrive. This automatic reproduction reduces delays and eliminates possibilities of error in typing or copying by hand. With such a system, the wheel report can be prepared and transmitted after the train has departed.

By having a printing-telegraph consist of incoming trains before they arrive, the yardmaster can plan in advance the amount and type of work to be done, with a minimum of switch-engine moves and minimum delay to cars. Data from the wheel report are automatically and immediately transmitted to the superintendent of car service at headquarters for record purposes, so that the location of all cars on the line can readily be ascertained.

In addition to greater speed and accuracy, other potential operating benefits include quick, accurate information to show car detention, location of cars by type, turn-around time and so on. Car movements can be better controlled, and cars distributed to loading points with a minimum of avoidable car-days and nonproductive car mileage and train mileage. While installations of this character were largely in the experimental stage as of 1950, with new uses for the punch-card data still being explored, such systems promised considerable increases in economy and efficiency in many situations.

Inspection of Cars.—"Safety first" is a basic tenet in all railroad operations. At virtually all yards and terminals and at all points of interchange between railroads, inspectors check all equipment as trains pull in. These inspectors customarily go up one side and down the other, the length of each train, looking for defects in wheels, axles, brakes, journals or other car parts or in the loadings. Sometimes a shifted load, for example, may make further movement of the car hazardous. Should any unsafe condition be found, the car is marked for removal to the repair (or "rip") track.

In large terminals, cars frequently are inspected as they move at slow speed above sunken pits and past inspection towers, in which inspectors are stationed, flanked by batteries of strong floodlights. Normal activities can be continued while this takes place. Defects that call for switching particular cars out of the train are immediately reported, with a substantial saving in time and handling.

Passenger-Yard Operations.—In large cities, certain of the freight-yard facilities also have their counterparts, as appropriate and needed, for passenger operations. Examples are storage tracks, cleaning tracks and turn-around tracks for passenger cars. Also provided are commissaries, with adjacent tracks, for stocking dining cars. At large stations, terminal facilities often include tracks for loading and unloading mail and express. There are a number of other specialized facilities and activities in individual yards, varying with local conditions and needs.

Railroad Use of Highway Vehicles.—Railroads have extensively availed themselves of the advantages of highway vehicles for certain types of operations, both freight and passenger.

Bus Operations by Railroads.—In many instances, buses provided railroads with an alternative to the dilemma of whether to continue operating passenger trains which did not pay for themselves or to abandon the field entirely.

Motorbus operations in which railroads are engaged are generally carried on (1) by the railroad directly, (2) by a contractor under railroad supervision or (3) by an affiliate or a wholly owned subsidiary of the railroad. Affiliates often are associated with one of the several bus systems which operate on a national basis. By far the greater number of bus operations by railroads have resulted from substitution of bus service for curtailed rail service.

Truck Operations by Railroads.—Railroads operate highway-freight trucks both to improve service and to effect economies by the substitution of truck service for local freight-train service, especially on lines with light traffic. Railroads also use trucks locally for pickup and delivery service for less-than-carload shipments and for transferring such freight between stations, especially in large terminal areas.

Truck operations of railroads usually are carried on (1) by use of existing railroad organizations, (2) by wholly owned subsidiaries of railroads, (3) by contract with the Railway Express Agency, Inc. (which is wholly owned by the railroads), or (4) by use of other contractors under railway supervision.

Directly or through subsidiary companies, the Railway Express agency performed at the end of 1949 intercity truck service supplementing or replacing rail service on about 480 routes with a total of approximately 19,000 route miles. Types of traffic thus moved consisted generally of United States mail, baggage, milk and cream, express, L.C.L. freight and railway supplies. In addition to these operations, the railroads themselves operated, directly or through subsidiary companies, several times as much route mileage of intercity truck service.

The Interstate Commerce act imposes on railroads seeking au-

thority to operate truck or bus service requirements which do not apply to other applicants. In nearly all cases where such authority is granted, it is surrounded by regulatory restrictions not imposed upon other carriers.

Rail-Water Terminals.—As most freight which moves by water also requires rail transportation at one or both ends of its journey, adequate port facilities for interchange of freight between cars and vessels are of great importance. This applies not only to ocean ports but also to rail-water terminals on the Great Lakes and inland waterways. For service of this character, railroads have invested approximately $250,000,000 in piers, wharves, grain elevators, coal dumpers, harbour vessels and other facilities for economical and efficient handling of freight between shore and ship. The so-called "railroad navy" comprises approximately 1,900 units of floating equipment of all kinds, including tugboats, barges, car floats, lighters, floating derricks and so on.

Ordinary merchandise or package freight may be either switched in cars to marginal tracks within reach of ship's tackle, or brought alongside the ship in lighters or car floats, or else unloaded into a wharf warehouse and thence trucked to ship's tackle. For handling exceptionally heavy weights, cranes and floating derricks usually are provided. Conveyor systems, either overhead on rails or using endless belts or rollers, may be utilized for moving freight through warehouses. Small electric or internal-combustion motor trucks, sometimes hauling trailers, also are used in many terminals for expediting such movement. These methods are patterned on those developed by railroads for handling L.C.L. freight through their stations (*see* later section on *Improvements in Handling L.C.L. Shipments*).

Bulk Freight on the Great Lakes.—Large volumes of iron ore, coal and grain are handled in bulk by vessels on the Great Lakes, and virtually all this traffic also receives some rail movement. There is intensive co-ordination of rail and water facilities on the Great Lakes to achieve efficient, economical service. Vessels are specially built for the trade and integrated with terminal facilities likewise specially designed, with provision for ship-to-shore radio communication, to permit loading, unloading and interchange of cargoes with utmost dispatch.

Ore-loading facilities at upper Great Lakes ports consist of docks ranging from 900 ft. to 2,300 ft. in length and from 60 ft. to 80 ft. in height, equipped with bins and pockets into which ore is dumped from specially designed railroad cars. At lower Great Lakes ports, unloading gear consists of electrically operated ore unloaders, equipped with buckets ranging in capacity from 5 tons to 17 tons. Those of the larger type can discharge a 10,000-ton vessel in from three to four hours. As ore is removed from the ship, it is weighed and moved to railroad cars on tracks under the unloading machines, for shipment to interior points.

Loading equipment for coal at Great Lakes ports is usually of the car-dumper type. Loaded cars roll by gravity to a pit, are drawn by cable up to a loading platform, clamped to a cradle, and then raised and inverted, the contents being dumped into a pan, whence the coal travels by telescopic chute into the vessel's hold. Unloading facilities consist of electrically operated travelling bridge cranes, equipped with clamshell buckets with capacity of 5 tons to 12 tons.

Similar facilities also have been provided at many ports to handle coal, phosphate rock, bauxite ore and other bulk materials. As a rule, these facilities, as well as the Great Lakes coal and ore docks, are provided and owned by railroads.

Grain.—Most U.S. ports—ocean and Great Lakes—are equipped with large marine grain elevators. Grain is sucked out of the ship or cars and deposited on conveyors, passing through a drier to bins. Loading of ships or cars is done by gravity, the grain flowing through chutes leading to the hold or car.

Car Ferries.—Ferries to move cars or trains across inland or sheltered bodies of water have been operated by railroads in the United States and elsewhere for many years. Notable North American examples are such services across Lakes Michigan, Erie and Ontario, and the St. Lawrence, Mississippi and Tennessee rivers, and on Chesapeake bay, Puget sound, between Vancouver and Vancouver Island, and around San Francisco bay.

Another development is the operation of ocean car ferries between Florida points and Cuba and between New York city, Havana, New Orleans and Texas City, Texas. The ships used are built to standard international specifications for ocean-going vessels. They are of two principal types. With one type, cars are pushed over floating track connections onto tracks in the hold of the ship, through wide doors at the stern, somewhat in the manner used during World War II for loading trucks and tanks on L.S.T. vessels. With the second type, cars are individually lifted bodily by special cranes and lowered through hatches into position on several decks of tracks in the hold.

Connecting Railroads and Switching Lines.—Adequate rail facilities to service port operations have been provided at all port cities—in almost all cases by railroads. Primarily essential are trunk lines capable of moving the requisite volume of traffic to and from the port. Equally important are belt lines or other rail interconnections among trunk lines serving the port, and yard trackage of adequate capacity for classification and storage of outbound and inbound cargo. Other facilities include many special types to meet corresponding needs, such as bonded warehouses and storage space to accommodate shipments from abroad pending reshipment or payment of import duties.

Co-ordination.—An important element of railway operations is joint use of facilities and co-ordination of services among railroads.

Whereas consolidation may be defined as any form of integration or unification of carrier properties under a single control or management, co-ordination involves joint use or ownership of equipment or facilities, or the joint performance of a service or transportation function, by two or more independent railways. In some instances another agency, such as a terminal company, is especially created to provide joint facilities and perform joint service. More than 200 such terminal companies were in operation at the end of 1948, with a total of approximately 7,400 mi. of tracks, utilizing approximately 1,700 locomotives, 14,000 freight-train cars and 1,000 company-service cars of their own, and representing a total investment in road and equipment of $1,085,000,000.

Through co-ordination and joint use of facilities and services, the many hundreds of railways in the United States, no one of which serves more than a limited area, have been integrated into a truly national transportation system. Such co-ordination and co-operation have been practised ever since tracks of one small railroad first touched those of another and the economies of joint action and use began to be apparent.

Standardization necessary for interchangeable use of equipment and facilities among railroads, and related intercompany arrangements which underlie them, are fundamental to co-ordination. Uniform designs and practices, however, have enabled facilities to be jointly used, or services to be jointly provided, on such a broad scale, and such practices have become so coextensive with the railway industry, that they may not always be recognized as co-ordinated activities. Thus, while co-ordination is as literally present when a western-owned boxcar moves in a freight train in the east, or when a passenger ticket sold and issued in Maine is honoured by the conductor of a train in California, it is nevertheless true that the word is usually confined to such instances as one railroad using tracks or terminals of another, or the pooling of services between certain competitive points.

As railways spread over the United States, much capital investment was avoided, and subsequent maintenance expense saved, by one railroad obtaining trackage rights (*i.e.*, use of an existing line of another railroad) which made it possible to avoid construction of parallel routes. More than 28,000 mi. of trackage in the United States (not counting miles of trackage of joint switching and terminal companies) is used by two or more railroads. Usually, one railroad is an owner and the others tenants, but occasionally two (or more) railroads are common owners of the route, each possessing an undivided share.

Types of Co-ordination.—Just as one railroad uses tracks of another, or two or more own trackage in common, so they also use yard and other facilities through owner-and-tenant arrangements, or by provision of jointly owned properties, which may or may not

entail use of a separate owning (and possibly operating) company.

The most common examples of railway joint facilities are passenger and freight stations used by two or more railroads, of which there are thousands. Joint facilities of this nature vary from the simplest small country stations through every stage of relative development to the most complex terminals in the country, in large metropolitan centres.

This joint use of facilities is more common than the pooling of services, which latter is sometimes done, subject to the specific consent of the Interstate Commerce commission, pursuant to requirements of the Interstate Commerce act. In each such case the participating railroads operate noncompetitively and provide their agreed proportions of the total train service. Revenues and expenses of operation of the pool of trains are apportioned in accordance with terms of the agreement.

Difficulties Met in Co-ordination.—Many conflicting interests must be adjusted satisfactorily for successful accomplishment of most co-ordination undertakings. Co-ordinations must generally obtain approval of regulatory or other public bodies. Political and labour considerations also enter into such proposals.

Railway Research.—*Technological Research.*—Engineering and mechanical research in the railway industry is a continuing activity. Equipment, devices and materials are being daily subjected to the test of actual operation, with new facts being learned about them and about better ways of using them. In addition to this widespread daily routine of applied research on the railroads, numerous research activities of more specialized nature are conducted.

The Association of American Railroads (A.A.R.) makes important contributions to technological advancement within the industry. This voluntary organization of principal railroads in the United States, Canada, Cuba and Mexico maintains a research centre and laboratory in Chicago, Ill., in its own building on the campus of the Illinois Institute of Technology. The bulk of A.A.R. research work is under the direction of committees made up of experienced railroad men.

Subjects embraced in the research work of these groups include: metallurgy in relation to bridges, rails, locomotives and cars; preservation of ties and other timbers against decay and mechanical wear; electrical equipment and methods for air conditioning, communications and signals; design and application of braking devices; standards for testing locomotives and parts; measurement of service stresses in, and improvements in design of, track, bridges and rolling stock and the like. The list could be greatly prolonged, but the foregoing summary is illustrative of one type of railway research.

Yet another type of railway research, directly affecting the field of customer relations, aims toward prevention of loss or damage to shipments, with consequent reduction of claim payments and of annoyance to shippers. Extensive laboratory and road tests are conducted to improve freight-car trucks and springs so that loads may ride more smoothly. Through the A.A.R. the railroads also maintain continuing research having to do with the protective characteristics of various types of freight containers, and of various methods of packing, stowing and bracing shipments.

In addition to this collective research, much technological research of similar or supplementary nature is conducted by individual railroads (several of which have their own laboratory and testing facilities), by groups of railroads working on common problems, and in co-ordination with certain industries; by industries which supply the railroads with equipment of various kinds; and by colleges and other research institutions. Much of this work is co-operative; for example, rail manufacturers, the A.A.R. and the University of Illinois (Urbana) have collaborated in research on rail; a draught-gear laboratory is operated by the A.A.R. at Purdue university, West Lafayette, Ind., in co-operation with that institution; several railroads and coal companies are working toward development of a coal-burning gas-turbine locomotive. Other co-operative research projects include freight cars for high-speed service, various parts and equipment for freight cars and methods of refrigeration. This work is supplemented both by test installations and by close observation of results of actual operation.

Traffic Research and Development.—Of ever-increasing emphasis and importance is the attention given by railroads to traffic and economic research and development. This work is pursued by various methods on different railroads; in some cases by a special department, in others by branches of certain departments working in co-ordination, and in still others by "task groups" organized for specific assignments. Where a separate research department is maintained, its main functions in general are (1) to gather a wide range of facts and statistics pertaining to the railroad's economic climate and traffic performance, so that performance can be measured against known potentials; (2) to conduct exhaustive studies on particular commodities or traffic practices; (3) to undertake specific projects assigned by the department head; and (4) to furnish a wide variety of economic and traffic data to management, including forecasts of business activity.

Many railroads have long maintained separate bureaus or departments charged with fostering industry and agriculture in the railroad's territory. Railroad industrial development activities include: (1) attraction and establishment of new, permanent industries; (2) establishment of new, temporary industries, such as construction projects; (3) retention or expansion of existing industries; and (4) development of raw material resources. Railroads and civic, state and business organizations co-operate in providing complete information concerning available sites, buildings and facts on the economic and civic conditions in their territories. In addition, railroads undertake to develop sidetrack facilities and new structures, as well as to help find new sources of raw materials and new markets for industries. Another vitally important aid is their co-operation in working out rate adjustments to assist industries.

The railroads exert similar efforts to develop agriculture along their lines. The extent of each railroad's program is determined largely by the nature of the territory it serves. In the main, the following activities are embraced in railroad agricultural development: (1) preservation of the resources of agriculture; (2) development of higher-yielding and better-quality crops; (3) improvement of livestock; (4) technological improvements in marketing, processing and distribution; (5) development of new uses of agricultural products by industry; (6) improvements in farm machinery, buildings and equipment; (7) co-operation with educational institutions in the improvement of agricultural methods; and (8) support of land settlement, reclamation and drainage programs.

Procurement and Handling of Freight Traffic.—Freight traffic of the railroads comprises literally every kind of article that moves in commerce. It takes in shipments large or small, of all kinds of commodities, from and to all points. Rail freight traffic is made up of carload (C.L.) and less-than-carload (L.C.L.) shipments. Carload shipments move at lower rates than L.C.L. shipments, one important reason being that the railroad provides loading and unloading services for the latter which are performed by the shipper and receiver of carloads. Another reason is that the heavier weight of carloads makes for lower unit costs of handling. Generally speaking, for every commodity there is a specified minimum carload weight; shipments weighing less than that minimum are charged the L.C.L. rate (unless the shipper prefers to pay for the minimum carload weight at the carload rate).

Rates are usually expressed in cents per 100 lb. or per ton of 2,000 lb., or in some cases, in cents per gross ton of 2,240 lb. Rates per carload also are published on some commodities.

Rail Charges for Freight Movement.—By law, all charges assessed by railroads for movement of freight must be made public, in compilations called tariffs, stated and published in a manner conforming with rules prescribed by federal and state regulatory authorities. Tariffs must be officially filed with regulatory bodies and be available for public inspection. Rates provided are subject to protest by shippers and suspension by the several commissions, they must meet certain standards provided by law and they may not be changed except after public notice for

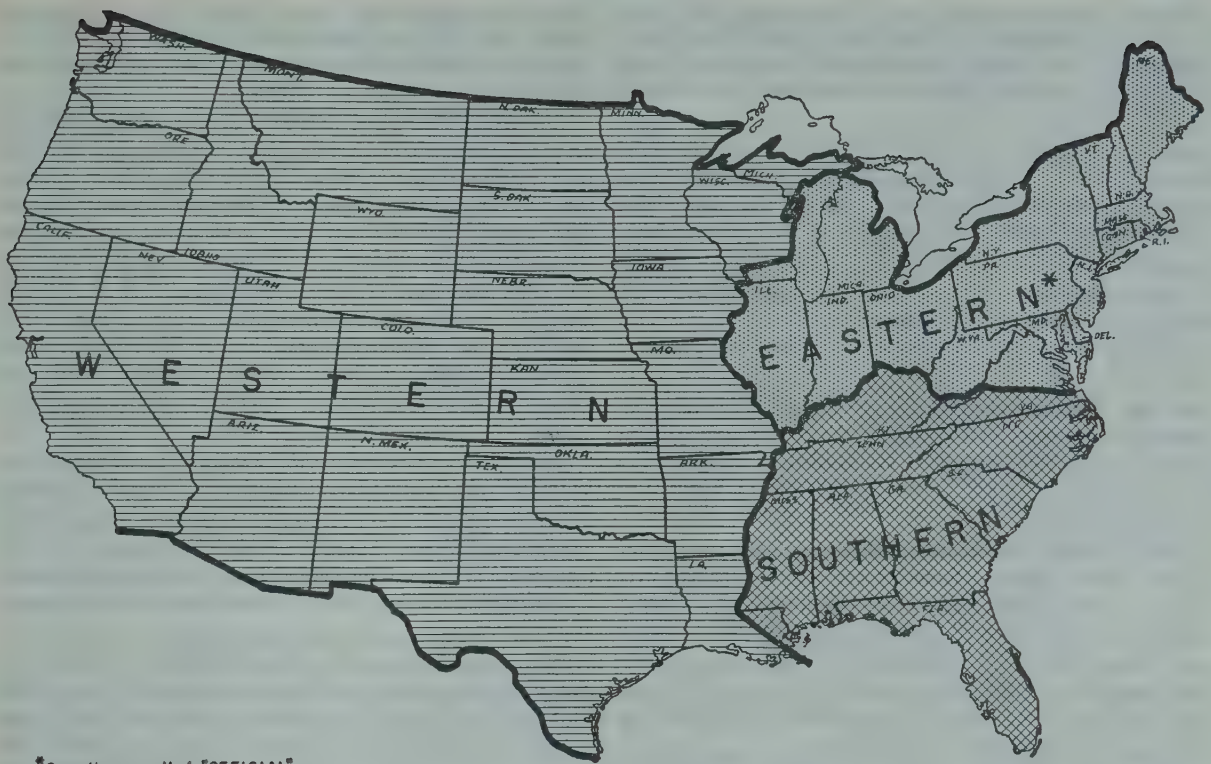


FIG. 4.—RAILROAD FREIGHT CLASSIFICATION TERRITORIES

a prescribed period of time; moreover, railroads in nearly all cases publish rates only after full discussion with shippers and other interested parties. The Interstate Commerce commission and the various states prescribe methods by which shippers may file and pursue complaints against rates. In no industry does the purchaser have a greater voice in determining the price of what he buys than the shipper who purchases railroad transportation.

Rates are in general of three types, according to their method of application. These types are class rates, exceptions to the classification, and commodity rates. Both carload and less-than-carload traffic move on all three types of rates, but the great majority of all carload shipments move on commodity rates, while less-than-carload traffic moves preponderantly on class rates. Carload traffic constitutes nearly 99% of all rail tonnage, and only about 5% of all rail traffic moves on class rates.

Class Rates and Classifications.—Class rates apply to all articles comprised within certain specified classes or groups for rate-making purposes. The system of class rates based upon commodity classifications was devised to enable railroads to comply with their legal obligation to have a published rate available for application to any shipment which might be tendered to them for movement. In some—and probably many—instances, the classification applies to articles of commerce which seldom move in certain parts of the country, or which do not move in any considerable quantity in any part of the country.

Class rates apply between any origin and destination, being scaled within each class broadly (though not exactly) according to mileage. The basis of the system of class rates is the first-class rate. Successive classes bear a descending percentage relationship to first-class, this relationship varying somewhat in different areas of the country.

The rate classifications of various articles are formulated by the railroads through their territorial classification committees, also after and largely as the result of consultations with shippers. They are published in the same manner as tariffs, and are also subject to complaint as to their reasonableness and to investigation and suspension.

Classification and Rate Territories.—There are three major freight-rate classifications. They are called, after the geographical areas in which they apply, the eastern (frequently referred to as the "official" because it was the first territorial classification adopted), the western and the southern classifications. The descriptions of the more than 20,000 articles classified are uniform in the three classifications. However, there have been some differences in classification ratings on the same commodities among the three territories, arising out of variations in transportation and economic conditions. For convenient reference, all three classifications are assembled and published in one volume, called the *Consolidated Freight Classification.* A uniform classification, which allocated commodities into the same classes in all territories, thus replacing the existing three classifications, was nearing completion in 1950. Meanwhile, the Interstate Commerce commission has generally determined which classification shall govern on interterritorial shipments. Sometimes it has required the classification applying in the destination territory to govern, and at other times it has specified one classification to apply in both directions.

Exceptions to the Classification.—For various reasons (including economic development and technological progress) it may become advantageous to transfer commodities from their previous classification and apply rates on a lower basis to stimulate movement. Two methods by which this may be accomplished are to reduce the classification rating or to publish an exception to the classification covering a more limited territory than the classification itself. Rates made by the latter method are termed classification exceptions. Such rates usually are made on the basis of a percentage relationship to the first-class rates.

Commodity Rates.—For commodities which move in substantial volume between fairly well-defined areas of origin and destination, commodity rates, on a still lower basis, are often made. Such rates apply on named commodities between named origins and destinations and are designed more nearly to fit the needs of the traffic than is possible under general classification or classification-exception ratings. Origins and destinations may be either a single

community or a relatively large area, in which latter case the rates are said to be "blanketed" over the area in question. By far the greater part of the country's railway traffic moves on such commodity rates, established with the definite aim of encouraging maximum development of traffic.

In some instances, it has become customary to regard certain rates on a commodity between key points of large movement as the standard or base, with rates for movement to or from other points being related to the base rates. In other instances, rates between the same origin and destination may vary according to the route designated. In such cases the lower rates are called differential rates. All rates thus made, however, must conform to legal requirements of fairness to all concerned, and are by law subject to complaint as to their propriety.

Considerations Which Influence Rates.—The primary aim of the railroads in establishing rates is to have them at a level which will cover the cost of suitably performing the service. At the same time, the level should be that which will best stimulate industry and commerce and encourage the widest movement of traffic. Commercial, and usually competitive, relationships also must be observed in making rates. Thousands of revisions of rates are voluntarily made by railroads each year to take care of changing conditions.

Joint or Interline Rates.—Many shipments move from points on one railroad to points on another railroad, often passing over lines of one or perhaps several intermediate railroads. To provide for such movements, the railroads involved establish through routes with through rates, in which two or more railroads participate. These joint rates, and the division of the revenues therefrom among the participating railroads in the event of failure of the railroads to agree on such division, are under the jurisdiction of the Interstate Commerce commission.

In addition to joint rates established by two or more railroads, there also are joint rates applying between railroads and carriers by highway (see *Railroad Use of Highway Vehicles*) and by water. These joint rates are called rail-truck, rail-barge, rail-ocean, rail-lake or other combinations, the order shown in the name indicating as a rule the order in which the respective carriers share in the movement. Thus, a rail-ocean-rail movement would describe a shipment routed to move by rail from Buffalo, N.Y., to New York city, thence by steamship to Mobile, Ala., and by rail again from there to Birmingham, Ala.

Charges for Accessorial Services.—In addition to providing rates for the movement of shipments between points of origin and destination, the railroads also provide, by published tariffs, rates or charges for what are called accessorial and terminal services. These latter include such services as storage, switching, refrigeration, weighing, and stoppage in transit for various purposes, such as milling in the case of grain or lumber, or compressing in the case of cotton. The transit tariff specifies the conditions under which the commodity may be stopped en route for processing or storing and the extra charges, if any, assessed for the privilege.

Improvements in Carload Freight Service.—Great strides have been made in improvement of the speed and reliability of freight service. Freight schedules have been shortened and time from shipper to consignee reduced by more efficient operating methods. For example, substantial reductions have been made in the amount of time cars spend in terminals, being switched, classified and assembled into or distributed from trains. Through freight trains are operated between important terminals without stops for intermediate yard handling, and many freight trains are operated on fast, regular schedules similar to those applicable for passenger trains, being given distinctive names to identify them and add to their prestige. The car equipment in which freight is handled also has been improved. Illustrative of advances in the efficiency of freight service, the average freight train in 1950 performed two and one-half times as much movement of freight in an hour as it did in 1921.

Supplementing their research work, already outlined, toward prevention of loss and damage to freight in transit, railroads continuously carry on among shippers and their own employees campaigns illustrating proper methods of packing, handling, loading and bracing freight. They also have developed, and are using on a large scale, machines called impact registers which record the degree of any rough handling, and also the time and therefore the approximate place where it occurred.

Many railroads maintain a separate service bureau organization for expediting and directing freight shipments. These bureaus act as intermediaries between shippers and various traffic offices in tracing and expediting, in furnishing special equipment, in effecting diversion and reconsignment, in checking clearances, in handling complaints and delays and in preparing and publishing freight schedules. Because its work is of a combined traffic-operating nature, the service bureau is sometimes operated jointly by the traffic and operating departments. The most characteristic and fundamental feature of every service bureau is its extensive communication network, which reaches into every yard, terminal and office by printing telegraph, telephone, telegraph and mail. Some railroads maintain a separate L.C.L. merchandise service bureau. The largest companies have subbureaus or branch bureaus in regional headquarters.

Handling Merchandise—L.C.L. Traffic.—Merchandise traffic (often referred to as less-than-carload or L.C.L. traffic) refers to small lots of goods moving in quantities of less than a carload, as previously defined. Aside from size of shipments, it differs from carload traffic in that the latter is loaded and unloaded by or at the expense of shipper and consignee, whereas merchandise traffic is usually loaded, unloaded and otherwise handled at the expense of the railroad.

A development in the handling of merchandise traffic is forwarder service. Forwarders specialize in soliciting and assembling merchandise shipments, which they consolidate into carloads (or truckloads) and ship at the carload (or truckload) rate. Their incentive is the difference between the L.C.L. rate which they charge the shipper and the considerably lower carload (or truckload) rate which they pay the carrier for the line-haul transportation of goods. In some cases, however, they also make rail shipments in L.C.L. quantities.

A large share of the merchandise traffic handled by forwarders is shipped by them as carloads over the railroads. To this extent, some part of the decline in railroad merchandise traffic which has taken place is offset by increased rail carload traffic shipped by forwarders. Carload forwarder traffic of the railroads in 1949 was 3,700,000 tons, compared with 12,600,000 tons of L.C.L. traffic originated by the railroads themselves.

Merchandise shipments may reach the custody of the railroad in any of several ways. At many points the shipment may be picked up at the shipper's door by a truck, at the expense of the railroad. In such case the truck may be operated either by the railroad itself, or by an affiliate, or by a local trucking concern operating under contract with the railroad. If the shipper prefers, he may deliver the shipment to the railroad with his own vehicle, in which case he usually receives an allowance from the railroad for performing the service, where such service is in effect, in lieu of having the railroad perform it. Both the pickup by the railroad and the alternate allowance to the shipper are prescribed in published tariffs, and are subject to the shipment moving at a specified minimum rate per 100 lb.

If the shipper has a considerable volume of merchandise traffic, he may prefer to load it (at his own expense) into an empty freight car at his warehouse or plant, to be switched to the railroad freight or transfer station. Such cars are termed "ferry" or "trap" cars. Again, a large shipper may at his option load several lots of merchandise into a car for direct intercity movement. In such cases the railroad either will send a representative to check the contents of the car as loaded, or will accept the shipper's certification as to the contents. In large port cities, such as New York city, a considerable volume of merchandise deliveries to railroads is made by lighters or car floats.

Deliveries of merchandise from railroads to consignees takes place in general by the reverse of procedures just outlined.

Scheduled Merchandise Cars.—As the great bulk of the traffic of a railroad moves in carloads, and railway operations are geared to carloads, methods of handling merchandise traffic in trains

have been largely adapted to fit in with the carload operations with maximum efficiency and economy. Generally speaking, the procedure is for the railroad to consolidate merchandise shipments so far as possible into larger quantities which can be handled the maximum distance in carloads. For this purpose, there are on every railroad numerous points where such consolidation operations are performed. These may be stations with a considerable volume of outbound shipments of merchandise, or they may be other points, called transfer stations, which are strategically situated for the consolidation of merchandise traffic from numerous origins. Between these large stations or transfer points, merchandise cars are scheduled for regular operation, often for moves of many hundreds of miles or even across the continent.

In the case of a small station not loading scheduled merchandise cars in the desired direction, the shipment would be moved by the railroad to the nearest station or transfer point from which such a car is operated. The shipment then will either move directly to its destination or be taken to another station or transfer point which does have a scheduled car to its destination.

If a shipment is destined to a point not the terminus of a scheduled merchandise car, the shipment will be handled in such a car to a nearby scheduled destination. Thence it will move to its ultimate destination either by truck service, which many railroads operate for this purpose, or it may be put with other merchandise shipments for other such small points in a car moving on a local freight train which stops at each station en route. Such a car is known as a way car.

Cars Used for Merchandise.—Generally, railroads use boxcars for handling merchandise freight. Where the volume of traffic needing such protection warrants, scheduled refrigerator cars also are operated. Occasionally, and for appropriate loads, flatcars or gondola cars may be used. Some railroads make use of metal containers into which merchandise shipments may be placed and sealed, for movement without disturbance and with maximum protection of contents; these containers are usually transported on flatcars or gondola cars. A number of railroads use refrigerated containers for handling small lots of perishable merchandise traffic. These containers are equipped with wheels for mobility, and also have special doors. They ordinarily are used only between specified points on the same railroad.

Some railroads use boxcars especially equipped for high-speed operation for the movement of merchandise in passenger-train service, or on passenger-train schedules, between certain points.

Improvements in Handling L.C.L. Shipments.—The railroads promote speed and economy in handling merchandise freight by moving shipments the maximum distance in scheduled cars. Another step is improvement in the layout and equipment of facilities for handling this traffic. Special arrangements at transfer points reduce the time and distance of movement from inbound to outbound cars. Many improvements have also been made in the design and installation of devices for handling freight speedily and efficiently. One such method is by use of pallets or platform trucks on which freight is loaded (or "unitized") so that it may be handled or temporarily stored as a unit, instead of being handled as individual packages. Another method is the use of automotive vehicles in freight stations and between cars. These vehicles are equipped with devices by means of which platform trucks are towed to the desired location, or pallets may be lifted from the floor, transported to cars or storage places, and then stacked, if necessary. The sealed metal containers, previously mentioned, are another step in the direction of minimizing and expediting physical handling of merchandise.

Among further steps for improvement of merchandise service by rail is the operation of high-speed merchandise trains, on special schedules to fit the needs of the traffic. Much progress has been made in development and provision of cars with adjustable blocking devices, to secure the load and minimize damage. Clerical work connected with waybilling and handling this traffic is being lessened and expedited by use of modern office equipment, including photographic devices. Substitution by railroads of truck service for consolidation and distribution of merchandise traffic also will continue, the benefits of such substitution under appropriate conditions having been demonstrated by many railroads.

Passenger Traffic.—Transportation of passengers by rail has been, since the early days of railroad operation, an important service to the public as well as a considerable source of revenue to the carriers.

Prior to the advent of the automobile and the construction of hard-surfaced intercity highways, almost all except local travel overland was by rail. The major portion of common-carrier travel still is rail-borne, but of the total intercity travel—private as well as common-carrier—private automobiles accounted for 85% between 1937 and 1941, when travel conditions were relatively normal. In terms of passenger-miles (*i.e.*, the total of intercity mileages travelled by all passengers by all means of transportation, private and public) between 1920 and 1940, total intercity passenger travel increased more than 460%, but travel by use of common carriers decreased by 20%.

In 1948, compared with 1940, there was a marked return to common carriers. Railroad passenger-miles increased by 78%, while travel by private automobile increased by 21%, between these years. Undoubtedly of much influence in this connection were the many new streamline trains and new and improved types of other passenger equipment installed by railroads when the close of World War II again made such equipment obtainable. However, the private automobile in 1948 accounted for almost five-sixths of the total movement by all carriers.

Table XVI illustrates these trends in travel habits.

TABLE XVI.—*Intercity Traffic*
(In billions of passenger-miles)

	1920	1940	1948
Railroads (except commutation travel)	40.8	19.8	35.3
Buses	—	11.6	23.6
Air lines	—	1.0	5.9
Total	40.8	32.4	64.8
Private automobiles	7.0	238.4	287.4
Grand total	47.8	270.8	352.2

The proportion of their total operating revenues which railroads derived from passenger traffic declined during the years preceding World War II to about 10% on class I railways. In 1949 it was somewhat more than 10%.

Types of Trains.—Passenger service is provided by three types of trains: commutation, local and through. Commutation trains are operated principally within a relatively few large metropolitan areas, for carrying passengers to and from the city for work, shopping and pleasure. The term "commutation" is derived from the reduced-fare, multiple-trip tickets used by most such patrons. Local trains provide service to all or most stations along the railroad. In addition to handling passengers, these trains frequently pick up and deliver mail and express at way stations. Through trains, often called express trains because of their fast schedules, operate between principal cities and make infrequent stops en route. These trains usually consist of equipment especially designed for long trips, such as sleeping cars, lounge and parlour cars, dining cars and, in many cases, specially arranged coaches. Much equipment on such trains has been streamlined. Many passenger trains have distinctive names by which they are widely known. Some of these names are of such long standing that they have become traditional.

Railroads in Relation to Other Carriers.—Types of transportation other than railway service are performed by freight and passenger motor vehicles on highways, vessels operating in coastwise and intercoastal ocean service and on the Great Lakes and inland waterways, aeroplanes and pipe lines.

Tables XVII and XVIII show percentage distribution of commercial intercity freight and passenger traffic among the various types of carriers. Years shown represent the first official compilation of this information by the Interstate Commerce commission (1926), the last peacetime year (1941), the peak of the war effort (1944) and a postwar year (1949).

Use of Public Facilities.—Railroads and pipe lines are the only transport agencies which own substantially all facilities used in producing their service. Carriers by highway, water and air own

TABLE XVII.—*Percentage Distribution of Commercial Intercity Freight Traffic*

	1926	1941	1944	1949
Steam railroads (including mail and express)	76.8	64.3	70.0	61.5
Great Lakes*	14.1	13.9	9.9	11.0
Rivers and canals	1.6	3.6	3.0	4.6
Motor trucks	2.8	7.7	4.6	10.5
Oil pipe lines	4.4	10.4	12.4	12.3
Electric railroads	0.3	0.1	0.1	0.1
Air carriers	—	—	—	—
Total	100.0	100.0	100.0	100.0

*U.S. domestic traffic only.

TABLE XVIII.—*Percentage Distribution of Commercial Intercity Passenger Traffic*

	1926	1941	1944	1949
Steam railroads	75.2	62.0	74.4	54.0
Electric interurban	11.7	2.5	1.6	0.9
Inland waterways*	3.9	3.8	1.7	2.6
Buses	9.2	28.8	20.6	31.9
Air carriers	—	2.9	1.7	10.6
Total	100.0	100.0	100.0	100.0

*Great Lakes, rivers and canals.

their vehicles, and in varying degrees furnish some of their own terminal facilities. However, highways used by highway transport and channels used by water transport are constructed and maintained at public expense, as also are airways, beacons, emergency landing fields and other navigational aids utilized by operators of air transport. Operators of water and air transportation pay nothing toward the cost of waterways (except the Panama canal) and airways they use, and it may be questionable whether tax payments by commercial intercity highway transport operators are fully compensatory.

CANADA

Canada had (in 1948) 41,909 mi. of railway line (exclusive of 339 mi. operated in the United States by Canadian railroads) and 57,005 mi. (including U.S. mileage, which cannot be separated) of all classes of tracks. More than 93% of the mileage was owned or operated by two systems, the Canadian National railways and the Canadian Pacific Railway company. The former, and somewhat the larger, is owned by the government of Canada. Both these systems were truly transcontinental, extending from ocean to ocean. In addition to the two large systems, there were a number of smaller railroads, some of them owned by provincial governments. The total gross investment in Canadian railroads at the end of 1948 was $3,600,000,000.

Table XIX compares principal statistics of Canadian railroads for the last prewar year (1939), the peak wartime year (1944) and a postwar year (1948):

TABLE XIX.—*Statistics of Canadian Railroads*

	1939	1944	1948
Gross revenues (000)	$367,179	$796,637	$875,832
Operating expenses (000)	$304,373	$634,774	$808,126
Operating ratio	82.9%	79.7%	92.3%
Net income (000)	$27,299	$61,692	$2,181
	(Def.)		(Def.)
Employees, number	129,362	175,095	189,963
Average annual compensation	$1,549	$2,125	$2,696
Tons of freight originated (000)*	84,631	155,326	154,933
Revenue ton-miles (000)	31,464,991	65,928,078	59,080,323
Average haul (in miles)	372	424	381
Revenue per ton originated	$3.38	$3.72	$4.51
Revenue per ton-mile (in cents)	.909	.876	1.183
Passengers carried (000)	20,482	60,336	38,280
Passenger-miles (000)	1,751,973	6,873,188	3,477,273
Average trip (in miles)	86	114	91
Revenue per passenger carried	$1.76	$2.18	$2.18
Revenue per passenger-mile (in cents)	2.06	1.92	2.40
Locomotives in service	4,373	4,416	4,521
Freight-train cars in service	160,018	164,067	172,406
Passenger-train cars in service	6,387	6,263	6,099

*Includes receipts from foreign connections.

Freight traffic of Canadian railroads in 1948 was made up, by major groupings, as follows:

	Tons
Products of agriculture	27,656,000
Products of animals	2,890,000
Products of mines	56,733,000
Products of forests	19,442,000
Manufactures and miscellaneous	44,105,000
L.C.L. (merchandise)	4,107,000
Total	154,933,000

The first railroad construction in Canada was in 1835, comprising a 16-mi. line between Laprairie and St. Johns, Que., to facilitate travel between Montreal and New York city. In 1850 there were 66 mi. of railroad in Canada. Subsequent development has been as follows (the figures including a small mileage in the United States which is owned and operated by Canadian railroads):

	Miles of road
1860	2,065
1880	7,194
1900	17,657
1920	38,805
1940	42,565
1948	42,248

The 1948 mileage was located as follows:

Prince Edward Island	286
Nova Scotia	1,396
New Brunswick	1,835
Quebec	4,765
Ontario	10,464
Manitoba	4,836
Saskatchewan	8,738
Alberta	5,643
British Columbia	3,888
Yukon	58
Total in Canada	41,909
Total in United States	339
Grand total	42,248

The foregoing mileages do not include 705 mi. of 3 ft. 6 in. gauge line in Newfoundland, which on April 1, 1949, became a province of Canada. The Newfoundland mileage is now operated by the Canadian National railways.

The first transcontinental line in Canada was the Canadian Pacific railway, completed in 1885. The terms under which British Columbia entered into confederation in 1871 bound the Dominion of Canada to commence a transcontinental railroad within two years and complete it within ten years. Construction as a public work started in 1874 but was not pushed very rapidly. In 1880 the project was taken over by the Canadian Pacific railway under a contract calling for completion by May 1, 1891. Under the contract, the railroad was granted 25,000,000 ac. of land, $25,000,000 and certain other inducements.

A second transcontinental line grew out of the extension of the Grand Trunk railway, chartered in 1852, which about the end of the century extended via Canada from Portland, Me., to Chicago, Ill. Under an agreement in 1903, the government constructed a line from Moncton, N.B., to Winnipeg, Man., which was completed in 1915. Its extension to Prince Rupert, B.C., was completed in 1914, with financial assistance from the government. A third transcontinental line was completed in 1915 by the extension westward to Vancouver and eastward to Montreal of the Canadian Northern railway, which by 1902 had been completed from Winnipeg to Port Arthur, Ont., by several predecessor companies. This construction also had the benefit of government financial assistance.

The hopes of development which had inspired the construction of the second and third transcontinental lines were disappointed in consequence of World War I and its aftermath, and the government had to give financial assistance to these railroads. In 1917 the government acquired the capital stock of the Canadian Northern, and the insolvency in 1919 of the Grand Trunk Pacific led to the acquisition of that railroad and its parent, the Grand Trunk, by the dominion government. The Intercolonial railway, built as a condition of confederation and completed by 1876 from Halifax, N.S., to a point east of Quebec, and the Prince Edward Island railway, opened in 1875, had been owned and operated by the dominion government since their construction. Unification of these various lines into the present Canadian National railways came about in 1923.

The Hudson Bay railway, extending 510 mi. from The Pas, Man., to Churchill, Man., on Hudson bay, constructed by the Canadian government, was completed in 1929. Its purpose was to stimulate development of northern Manitoba, Saskatchewan

and Alberta by providing a shorter and cheaper route for movement of grain. These hopes have not been fully realized, and the line has had operating expenses in excess of revenues in all but one year since it was opened (to 1950). It is operated by the Canadian National for the Canadian government.

In most physical respects, railroads of Canada conform to standards of those of the United States, and there is an extensive and regular movement of locomotives and cars, both freight and passenger, across the border. In fact, the railroads of the two countries operate as a single system so far as their users are concerned. Principal Canadian railroads are members of the Association of American Railroads, and conform in general to A.A.R. standards and specifications of equipment. An important difference between railroads of the two countries is that the two large Canadian systems operate all types of transportation, a privilege denied or severely restricted by law and by administrative rulings in the United States. These Canadian railroads operate, in addition to their rail service, ocean and coastal ships, vessels on inland lakes and rivers, highway transport service, air lines, express companies, telegraph and radio communications, hotels and other commercial enterprises.

The Canadian National-Canadian Pacific act of 1933 directed the two railroads to try to agree on co-operative measures to effect economies and bring about more remunerative operations. Pursuant to this act, many passenger services have been pooled and other types of co-ordination effected.

Regulation of railroads in Canada follows much the same lines as in the United States, although it is not so comprehensive. Responsibility for regulation rests with the Board of Transport Commissioners, organized by statute in 1938, with enlarged responsibilities, as successor to the Board of Railway Commissioners, organized in 1904. It consists of a chief commissioner, an assistant chief commissioner, a deputy chief commissioner and three commissioners. Passenger rates are standard and special. Freight rates are standard, special and competitive. Standard rates are maximum and are the only ones which must be approved by the B.T.C. Special and competitive rates may be applied if the change of rates has been advertised. In 1947 the B.T.C. established a Bureau of Transportation Economics to co-ordinate all economic studies pertaining to air, rail and water.

There is competition with railroads by water carriers and highway carriers. Water carriers operate principally on the Great Lakes and the St. Lawrence river and canal system; otherwise, there is relatively little competition by inland water carriers. An extensive amount of coastwise service is operated on the Pacific coast, partly supported by the national government, but relatively little of this could be considered truly competitive with rail service, because of the geographical situation. There is no federal regulation of highway service, this being left in Canada to the provincial governments. Some of these governments exercise no economic regulation over commercial carriers. In consequence, there is lively competition with the railroads in these provinces, which are the principal centres of industry and population.

Wages for railway employment in Canada are influenced to some extent by those in the United States, but average somewhat lower. During World War II, several cost-of-living bonuses were awarded to workers generally, including railway employees. In 1943 there was a wage increase of 6 cents an hour for railway employees, with further increases of 10 cents an hour in 1946 and 17 cents an hour effective March 1, 1948. Further demands presented by railway employees for a general wage increase and a shorter work week were followed in Aug. 1950 by a nation-wide railroad strike. This was ended only after parliament had passed emergency legislation which called for resumption of negotiations and provided that the workers receive a provisional four-cent-an-hour wage increase.

Freight rates in Canada were unchanged for 26 years prior to 1948. In the aggregate, they average somewhat lower than those of the United States. In large part, this is the result of the Crowsnest Pass agreement of 1897 and the Maritime Freight Rates act of 1927. The Crowsnest Pass agreement was entered into between the Canadian government and the Canadian Pacific Railway company. Under it, the Canadian Pacific railway was granted a subsidy of $3,630,000 to aid in construction of a railway line from Lethbridge, Alta., through the Crowsnest pass to Nelson, B.C. In return, the railroad agreed to make certain reductions in rates on specified commodities. Enacted as a statute, and subsequently amended, the agreement has the present effect of binding that railroad—and, for competitive reasons, the Canadian National as well—to maintain rates at the 1897 level on grain and flour from the prairie provinces (Manitoba, Saskatchewan and Alberta) eastward to Port Arthur and Ft. William, Ont., at the head of Lake Superior, and, in the case of these commodities for export, westward to the ports of Vancouver and Prince Rupert. Under the Maritime Freight Rates act of 1927, the Canadian government ordered the Canadian National to make effective a reduction of 20% on all freight on lines east of Quebec. For competitive reasons, other railroads were allowed to make the same reduction. The difference between normal rates and the reduced rates is made up to the railroads in payments by the Canadian government. These payments average about $3,500,000 yearly.

Wages and materials prices entering into railroad operation, having moved sharply upward during and after World War II in Canada as well as in the United States, and their freight rates having remained unchanged for 26 years prior to 1948, Canadian railroads experienced increasingly difficult financial problems by reason of their greatly increased costs. To cope with these problems, the railroads in Oct. 1946 applied for a general increase of 30% in freight rates, and in March 1948 were granted an increase of 21%, subject to some exceptions. Because of objections to this increase by the prairie and maritime provinces, the Canadian government ordered a general rate investigation by the Board of Transport Commissioners. In addition, the government early in 1949 established a royal commission on transportation, composed of three men and a counsel, to make a general survey of transportation in Canada.

In response to a petition of the railroads in July 1948 for a further general increase of 20% in freight rates, the Board of Transport Commissioners in Sept. 1949 authorized an interim increase of 8%, which in March 1950 was expanded to authorize rates 16% above the July 1948 level. A further increase authorized in May 1950 brought the rate level up to the full 20% increase over the July 1948 level which the railroads had sought.

The Canadian Pacific railway has operated profitably in most years. The contrary is true of the Canadian National, which customarily experiences large deficits, borne by the Canadian government. However, the Canadian Pacific has important advantages of location by reason of its priority of construction. Moreover, the Canadian National is in many respects an instrument of governmental policy as well as a transportation enterprise. Thus, many of its lines have been constructed, and many of its activities are conducted, primarily to aid in developing the territory traversed and in promoting the commerce of Canada.

MEXICO

The common-carrier railroads of Mexico comprise 12,517 mi., of which 11,409 mi. are standard gauge. Substantially all the remainder is three-foot gauge. Much the greatest portion of the total mileage is owned by the federal government.

The nucleus of the Mexican railway system is the government-owned National Railways of Mexico (Ferrocarriles Nacionales de México), acquired partly by purchase and partly by expropriation, beginning in 1937. It comprises a well-integrated system from Matamoros (opposite Brownsville, Tex.) and Ciudad Juárez (opposite El Paso, Tex.) to Suchiate, on the Guatemalan border. Most of this system is in the eastern half of the country, the principal exceptions being lines to Manzanillo, on the Pacific coast, and the transisthmian line of the Tehuantepec National from Puerto México, on the Gulf of Mexico, to Salina Cruz, on the Pacific ocean. The three-foot lines of the National railways are east and southeast of Mexico City, to Puebla and Oaxaca.

Besides the National railways system, the federal government also owns other lines. One is the Kansas City, Mexico and Orient

railway, whose line runs southwestward from Ojinaga (opposite Presidio, Tex.) through Chihuahua to a projected connection with the port of Topolobampo, on the Gulf of California. There is a gap of 199 mi. in this line, between a point 78 mi. northeast of Topolobampo and a point about 190 mi. southwest of Chihuahua. Other government-owned lines not incorporated in the national system include the Mexican Railway company, linking the capital and Veracruz; the Southeastern railway, southeastward from Veracruz; and the Sonora-Baja California railway. The last-named has completed a line 325 mi. long, which directly connects the head of the Gulf of California with San Diego, Calif., on the northwest and with the main rail network of Mexico to the southeastward, via Benjamin Hill, Sonora.

In the western part of the country are the Southern Pacific Railroad of Mexico, the Mexico North-Western railway and some smaller lines, which remain under private ownership. The territory of Quintana Roo and the state of Yucatan also own railway lines within their respective areas. Until 1949 the Yucatan railroad was completely isolated from any other, but the government-owned Southeastern railway extended its line from Veracruz to connect with it.

The main trunk lines of railroad reach the most populous areas and converge on Mexico City. There is direct contact between the capital and the United States via eight border points between Mexicali-Calexico and Nogales, on the west, and Matamoros, on the east. Lines also connect the capital with Suchiate, on the Guatemalan boundary, with seaports on both coasts, and with the most productive industrial, commercial, mining and agricultural regions of the country. There is considerable interconnection of lines, with additional mileage under construction or projected to increase such interconnection.

Table XX shows principal statistics of the National Railways of Mexico for the years 1939, 1944 and 1947.

TABLE XX.—*Statistics of National Railways of Mexico*

	1939	1944	1947
Gross revenues (in thousand pesos)	158,128	297,780	410,707
Operating expenses (in thousand pesos)	135,914	285,980	457,634
Operating ratio	86.0%	96.0%	111.4%
Employees (number)	43,483	51,071	55,686
Average annual compensation (in pesos)	2,057.75	3,307.80	5,549.33
Tons of freight (thousands)	9,819	11,920	13,644
Revenue ton-miles (thousands)	2,807,332	3,982,152	4,199,119
Average haul (in miles)	286	334	308
Revenue per ton (in pesos)	10.96	15.16	20.49
Revenue per ton-mile (in pesos)	.0383	.0454	.0666
Passengers carried (thousands)	17,364	24,839	20,848
Passenger-miles (thousands)	737,752	1,535,942	1,232,079
Average trip (in miles)	42	62	59
Revenue per passenger carried (in pesos)	1.68	2.94	3.50
Revenue per passenger-mile (in pesos)	.0397	.0475	.0593
Locomotives (number)	903	947	1,026
Freight-train cars (number)	14,763	15,681	17,097
Passenger cars (number)	505	491	519

Generally speaking, facilities and rolling stock are of United States origin or pattern. During World War II a United States mission operated in Mexico to assist in rehabilitating about 1,900 mi. of certain key lines so as to facilitate the movement of Mexican materials needed for the war effort. As regards weight of rail, maximum grades and curvature of line, types of locomotives and other rolling stock, and other operating characteristics, the standards of the Mexican railroads on the whole are less advanced than those in the United States.

Oil is the principal locomotive fuel, but much coal and gasoline also are used, and wood on a few small lines. The country has insufficient productive capacity to satisfy its needs for rail, track material and rolling stock, and the United States is the principal source of supply.

Railroads of Mexico are to some extent integrated with those of the United States. Passenger and freight cars of United States railroads are operated to and from points in Mexico. However, Mexican rolling stock does not enter the United States (except within border terminals), freight loads destined to interior points in the U.S. being transshipped at the border. Mexican cars thus unloaded often are reloaded with freight transshipped in the opposite direction.

CENTRAL AMERICA

The six countries of Central America (Canal Zone excluded) have a total of 1,783 mi. of common-carrier railway lines, all of which is narrow gauge, 735 mi. being 3 ft. 6 in. and 1,048 mi. being 3-ft. gauge.

The following table shows location of this mileage:

	Miles and gauge	
	3 ft. 6 in.	3 ft.
Costa Rica	410	—
El Salvador	—	386
Guatemala	—	538
Honduras	88	—
Nicaragua	237	—
Panamá	—	124
Total	735	1,048

Government ownership embraces 562 mi., including all mileage in Honduras, Nicaragua and Panamá and some mileage in all countries except El Salvador. In addition to the common-carrier mileage, there are about 1,250 mi. of 3 ft. 6 in. and 3 ft. private railroads, owned and operated by banana companies.

Except in Guatemala and El Salvador, railroads are isolated and serve only small areas of the country. The Guatemala-Salvador lines form a fairly well-integrated system of three-foot gauge lines. This system extends from the Mexico-Guatemala boundary at Ayutla, Guat., through the length of Guatemala and El Salvador to Cutuco, on the Gulf of Fonseca. Branches connect with four Pacific ports and with the Caribbean port of Puerto Barrios, Guat.

The system connects at Ayutla with the National Railways of Mexico line to Suchiate but, as the latter is standard gauge, freight must be transferred.

The railroads of Costa Rica consist chiefly of an interoceanic route through San José, the capital; the remainder of the country is without railway service, except for local banana lines. In Honduras, railroads serve small areas inland from a few Caribbean ports in the western part of the country, and are used primarily for hauling bananas. The Nicaraguan railroad runs inland a short distance from and paralleling the Pacific coast, linking Managua, the capital, with the Pacific port of Corinto and with Lake Nicaragua. In the republic of Panamá, the only common-carrier railroad serves a small area inland from the Pacific port of David.

All railroads in Central America are of relatively light construction. Virtually all equipment and supplies are imported, principally from the United States.

Oil is the principal locomotive fuel, with some relatively small use of coal and wood. The government railroad in Costa Rica is electrified.

Canal Zone.—The Canal Zone has 51 mi. of interoceanic railroad, five-foot gauge, from Colón to Panamá City, with 112 mi. of terminal and passing tracks. It operates 17 road engines and 12 switch engines, 655 freight cars and 48 passenger cars. The railway properties are an adjunct of the canal and are owned and operated by the United States government, through the Panama Railroad company. This company is supervised by a board of directors under the secretary of the army of the U.S. It has been the policy to elect the governor of the Canal Zone as the president of the railroad company.

CUBA

Railroads of Cuba operated for public service comprise 3,015 mi. of line, of which 2,492 mi. are main line and 523 mi. are branches, with 623 mi. of yard tracks and sidings. Substantially all this mileage is standard gauge, there being a few short narrow-gauge lines. Of the mileage of line, 82% is operated by two companies, of British and United States ownership, and 95% by a total of nine companies. The other 5% of total mileage is divided among 11 companies. The railway mileage extends virtually from end to end of the island, reaching the coast at numerous points, and is well interconnected. Public-service railroads operate approximately 587 steam and 24 electric locomotives, 667 passenger-

train cars and 15,227 freight cars. In the year ended June 30, 1944, these railroads originated 23,000,000 metric tons of freight, of which more than 19,000,000 metric tons was sugar cane and its products. Passengers carried approximated 14,000,000.

In addition to the public-service railroads, sugar mills operate a total of 7,037 mi. of railroad (of which 270 mi. perform public service and are included in the public-service mileage above). Of this total trackage, 4,232 mi. is standard gauge, and substantially all the remainder is 36-in. and 30-in. gauge. Sugar-mill railroads operate approximately 800 locomotives and 33,000 cars of all types.

Through the service operated by ocean car-ferries, freight cars of United States railroads carry loads to and from points on Cuban railroads.

SOUTH AMERICA

The continent of South America has a total of 61,937 mi. of railway line, of which 23,575 mi. is standard- or wide-gauge and 38,362 mi. is narrow-gauge track. All wide-gauge track is 5 ft. 6 in. in Argentina and Chile and 5 ft. 3 in. in Brazil. Narrow-gauge track is principally of metre (39.37 in.) gauge, which amounts to 87% of such mileage. Table XXI shows wide-, standard- and narrow-gauge mileage by countries.

TABLE XXI.—*Miles of Road, South America*

Country	Wide gauge	Standard gauge	Narrow gauge	Total
Argentina	14,881	2,044	9,990	26,915
Brazil	1,288	—	19,969	21,257
Bolivia	—	—	1,692	1,692
Chile	1,798	—	2,820	4,618
Colombia	—	—	1,880	1,880
Ecuador	—	94	562	656
Paraguay	—	274	—	274
Peru	—	1,258	704	1,962
Uruguay	—	1,878	11	1,889
Venezuela	—	—	597	597
French Guiana	—	—	11	11
British Guiana	—	60	19	79
Dutch Guiana (Surinam)	—	—	107	107
Total	17,967	5,608	38,362	61,937

Whereas most of the railway mileage of North America comprises, and to a large extent is operated as, an integrated whole, there is no comparable situation in South America. Indeed, no individual South American country has an integrated railway system that is truly national in comprehensiveness. For the most part, railroads of South America are individual operations, more or less localized, relatively few of the operating companies having any great length of mileage. Many lines run inland for a short distance from a coastal or river port, or connect with a highway. Railway mileage usually is concentrated in relatively small areas of each country.

A trend in South America, especially marked during the decade 1940–50, was toward nationalization of railroads. Argentina and Uruguay were particularly active along this line. There was in 1950 no country in South America in which the government did not own and operate some railroad mileage, and in several countries government ownership was the predominant or only type.

There is little interconnection of lines. Indeed, interconnection in many if not most cases is physically impossible because of differences of gauge. There is a wide variety of gauges, ranging from 5 ft. 6 in. (1.676 m.) down to 23.5 in. (.60 m.). Only Bolivia, Paraguay and Uruguay have all or substantially all their mileage of the same gauge. Differences of gauge mean little so long as lines are isolated, but they become increasingly troublesome and uneconomical as railway development progresses and interconnection and integration are sought.

Equipment of South American railroads also is varied as to both gauge and origin. Virtually all equipment has been purchased abroad, derived variously from England, Belgium, France, Germany, Spain and the United States. This situation complicates maintenance problems. It also handicaps integration of lines, because of diversity of types and parts. Two varieties of telegraph instruments and codes, the Morse and the Spagnoletti, are in use. Lack of standardization extends also to terminology and therefore to statistics as well.

Grades and curves often are severe, partly because of the rugged and difficult topography traversed (especially in the west where mountains rise steeply from the seacoast) and partly because railroads in their developmental stages characteristically sacrifice easy grades and curvatures to economy of construction. The Central Railway of Peru climbs 15,806 ft. from Callao in 108 mi., averaging about 2.8% gradient. The Guayaquil and Quito railway (Ecuador) climbs 9,651 ft. in 49 mi., averaging 3.7% gradient. The former North Central Argentine (now part of the Ferrocarril General Belgrano) railway crosses into Bolivia at an elevation of 11,287 ft. The same railroad's line to the Chilean border rises at one point to 14,520 ft. (The highest point reached by a standard steam railroad in the United States is 11,319 ft., and grades in excess of 2.2% on main lines are uncommon, even in mountainous country.)

Climatic conditions further increase difficulties of railway construction, maintenance and operation. Torrential rains cause landslides, rockslides and washouts, and on some lines the ground becomes so soft during the rainy season that the track will not support locomotives. Deep snows in the mountains are another serious problem, as also are earthquakes in certain localities. These conditions often cause disruptions of service, sometimes of considerable duration, and because of the hazards trains in some localities are operated only in daylight.

Track as a rule is of relatively light construction. Ties generally are of native woods, but some wooden ties are imported, coming from the United States, Australia and elsewhere. Some railroads also use ties made of steel or iron. Most of the rail weighs from 60 lb. to 70 lb. to the yard. Much track is ballasted with earth. Automatic signalling is seldom found, and sometimes there is no central train dispatching, trains proceeding from station to station by telephoning the next station ahead to ascertain if the track is clear.

In keeping with the light track, rolling stock in South America also is relatively small and light. Freight cars often have capacity of 20 tons to 25 tons or less. Some modern passenger equipment is operated on a few lines, and more is being acquired.

A great problem of railway operation throughout South America is procurement of fuel. The continent has little coal, and what there is does not make good locomotive fuel, besides being situated in remote areas. Likewise, domestic oil production is inadequate to supply needs for oil for locomotive fuel, and it also is remotely situated. Some railroads, especially in the north, depend entirely on wood for locomotive fuel. Not only have large areas of country adjacent to railway lines been deforested thereby, but procurement of wood requires the services of a large proportion of available cars and locomotives.

Good ballast also is a problem. In the Argentine pampas there is no rock or wood for many miles, and parts of Brazil and Bolivia also have no rock. Rock and sand sometimes have to be hauled many miles.

Partly because of differences in gauge, relatively few railroad lines cross national boundaries, and there are still fewer transcontinental lines, with through service. A 39-mi. standard-gauge line connects Tacna, Peru, with Arica, Chile. Continuous lines (metre gauge) connect La Paz, Bol., with Arica and Antofagasta, Chile. Another continuous through line (standard gauge) links Buenos Aires and Asunción, the capitals of Argentina and Paraguay. Crossing the Uruguay river on the international railway bridge at Paso de los Libres, a branch of this line also extends to a junction with a metre-gauge Brazilian railroad at Uruguayana, Braz.

Between La Paz and the Peruvian seaport of Mollendo there is a route made up of a Bolivian metre-gauge line to Lake Titicaca, vessels on the lake, and thence a Peruvian standard-gauge line.

A transcontinental route, metre gauge, is available from Buenos Aires to Antofagasta, but it is quite circuitous, involving use of part of the line extending between La Paz and Antofagasta. Use of this route to La Paz also affords access to Mollendo, as above described. However, washouts in the rainy season annually disrupt traffic on the Argentine portion of the route. Another transcontinental metre-gauge route, completed in 1948, connects

Buenos Aires and the Argentine port of Santa Fé, via Salta and Socompa pass (elevation 12,512 ft.), with Antofagasta.

From Buenos Aires and Santa Fé still another metre-gauge line and also a broad-gauge (5 ft. 6 in.) line extend westward to Mendoza, whence another metre-gauge line extends to a connection with a Chilean metre-gauge line, which in turn connects with the main Chilean rail network. This route is subject to interruption by snowslides and floods. It was reopened in 1944 after several years' interruption by flood damage west of Mendoza.

Two other transcontinental routes were under construction in 1950. One involved the completion of about 65 mi. in Chile and 50 mi. in Argentina, south of the line via Mendoza, to connect the principal Argentine and Chilean rail networks through Zapala, Arg., and Lonquimai, Chile, respectively. The other project involved construction to complete a route between the Brazilian port of Santos and the Chilean port of Arica, through Bolivia. Completion of the remaining portion, in eastern Bolivia, involved serious difficulties in terrain and supply.

Other construction projects under way or contemplated included lines in Bolivia connecting with the projected Santos-Arica line (including a connection with the Argentine railway system), lines in Argentina and Uruguay toward their respective borders, a link in Brazil to give that country a continuous north-south metre-gauge line, several branch lines in Chile and lines in other countries to reach ports or link existing lines.

During the 1930s and 1940s there appears to have been a trend in South America toward development of highways instead of railroads. Air transportation also has had considerable development, especially in the north, where large areas have no other means of access.

EASTERN HEMISPHERE

The eastern hemisphere has approximately 433,403 mi. of railroad, distributed as follows:

Continent	Miles
Europe	262,875
Asia	95,588
Africa	43,389
Australasia	31,551
Total	433,403

EUROPE

Of all mileage of railroad in the eastern hemisphere, Europe has 61%, distributed as follows:

Country	Miles
Austria	4,450
Belgium	3,209
Bulgaria	2,224
Czechoslovakia	8,383
Denmark*	2,263
Estonia	911
Finland	3,533
France	49,348
Germany	36,256
Great Britain*	19,863
Greece	1,621
Hungary	5,173
Ireland, Northern*	754
Ireland, Republic of*	2,463
Italy	11,383
Latvia	2,102
Lithuania	1,045
Luxembourg	332
Netherlands	2,114
Norway	2,769
Poland	13,375
Portugal*	2,102
Rumania	7,363
Spain*	10,503
Sweden*	10,518
Switzerland*	3,345
U.S.S.R.*	57,487
Yugoslavia	6,926
Total	262,875

*In view of political and territorial changes, and wartime destruction, it is not possible to include comparative figures more up-to-date than for 1937, except in respect of the countries thus indicated.

Developments in Europe.—Later railway history in Europe falls into three main periods: that terminating with the outbreak of World War II in 1939, the war period itself (1939–45) and the postwar years. Technical developments had been outstanding during the prewar decade, though competition, chiefly from road transport—the private automobile, the intercity and local coach and bus, and the motor truck—had limited the return earned, if any, on capital investment, to meagre rates. International cooperation among the European railways had increased steadily through the activities of the International Union of Railways, with headquarters in Paris; in a wider and more technical sphere, the older International Railway Congress association, centred in Brussels, Belg., had held a meeting at Paris in 1937.

Other international railway bodies, based in Berne, Switz., had done much to assist the flow of international railway traffic. For example, meetings at Berne produced as far back as 1890 the so-called C.I.M. (Convention Internationale sur le Transport des Marchandises), an international arrangement under which goods may be moved by rail across national borders in Europe with a single transport document—the international waybill. From the same source later developed the C.I.V. (Convention Internationale sur le Transport des Voyageurs), a similar agreement relating to international travel. The C.I.M. and C.I.V. conventions are multilateral governmental treaties, forming an extensive codification of international law concerning movement of goods, passengers and baggage by rail under tariff arrangements. They determine the rights and obligations of the railways and their users, regulate the extent of responsibility of railroads taking part in a given movement and contain provisions for settlement of accounts and rights of recourse among participating railroads. Other international arrangements of long standing are the R.I.V. (Regolamento Internazionale Veicoli) and the R.I.C. (Regolamento Internazionale Carrozzi), which are the successors to arrangements dating well back into the 19th century covering international movement and interchange of freight and passenger cars. Similar arrangements provided for annual international passenger timetable conferences, to which was added a similar freight timetable conference.

Another notable trend in Europe was the rapid development of electrified operation. In some respects, this was the counterpart of the trend toward dieselization in the United States. There had been some development of the use of light diesel locomotives for switching in Europe, but operation of diesel locomotives on main lines had not progressed beyond a few experiments. Widespread availability of sources of hydroelectric power in Europe, contrasted with lack of domestic sources of oil, perhaps accounts in large measure for this difference in trend. Electrified traction was increasing in Europe after World War II, even in countries with abundant domestic supplies of coal. The three basic power systems in Europe were 3,000 v. D.C., 1,500 v. D.C. and 15,000 v. A.C., of which the two direct-current systems mentioned were gaining in use. Belgium and Italy used 3,000 v., while France and the Netherlands used 1,500 v. New lines in Spain used 1,500 v., while older lines had 3,000 v.

Railways of Great Britain.—Turning to individual countries one may first consider Great Britain, the only European country (Northern Ireland and the Republic of Ireland excluded) at the outbreak of World War II to rely entirely on privately owned and operated railways.

Growth and Development.—The railway systems of Europe had their earliest beginnings in Great Britain. The commercial success of the Stockton and Darlington and the Liverpool and Manchester railways, opened in 1825 and 1830, led to construction of numerous small railroads, starting in the northeastern counties of England. Gradually, these were consolidated in larger units. Though parliament throughout the 19th century based railway policy mainly on the necessity of keeping competition alive, World War I finally broke down that policy and created a complete reversal of it in the Railways act of 1921. This act forcibly amalgamated practically all the railways into four great systems, in certain cases amalgamating lines which had been refused permission to do so some years before. The four systems were the London Midland and Scottish, the Great Western, the Southern, and the London and North Eastern railways. Other than these four big systems, certain smaller lines were jointly owned by some of them.

In the London area was a group of electrified passenger traffic lines, mainly constructed in tunnels and known collectively as the Underground. There was also the Metropolitan, a line electrified within London itself but still worked by steam traction north of Rickmansworth. In 1933 these, with other public passenger-carrying undertakings in the London area, were amalgamated under the London Passenger Transport board (L.P.T.B.), a public-trust enterprise which purchased the security holdings of the former owners of the component lines.

Lastly there were certain small light railways in various parts of Great Britain, some of a gauge narrower than the standard of 4 ft. 8½ in., notably the Eskdale line in the Lake District, and the Romney, Hythe and Dymchurch line in Kent. In north Wales was the Snowdon Mountain rack railway.

Growth of British railways is seen in the following table of mileage statistics (excluding railways of London Transport):

TABLE XXII.—*Growth of British Railways*

Year	Route miles	Year	Route miles
1825	26	1900	21,855
1844	2,236	1910	23,387
1850	6,635	1920	23,734
1860	10,410	1926	20,395*
1870	15,310	1933	20,251*
1880	17,935	1948	19,853*
1890	20,073		

*Not including Irish Free State.

Since 1890 there have been only comparatively small additions to railway mileage, route mileage taking no account of the presence of second, third or fourth tracks, but widenings have taken place and the figures for track mileage, which measures all tracks and converts them to a basis of one track only, are: in 1913, 36,448 mi.; in 1933 (including sidings), 52,638 mi.; in 1948 (including sidings), 52,592 mi.

Pre-World War II Activities.—The British railway system at the outbreak of World War II consisted of the four large railways already mentioned by name, while the London Passenger Transport board held from 1933 a monopoly of public passenger services in the London area, embracing electric railways (largely in subways or so-called tubes), buses, trolley buses and electric tramways (street railways). The four main-line railways—unlike the French railway situation prior to 1938, when the latter became nationalized—were to some extent competitive on the main traffic routes, such as London-Birmingham, London-Leeds, London-Perth and London-Exeter, but pooling of receipts in such cases tempered the measure of competition. In the London area, all passenger receipts were pooled between the main-line railways and the Passenger Transport board.

Outstanding activities of the individual main-line railways may be summarized briefly. On the Great Western, which had retained its identity for more than a century, a high degree of standardization had been achieved with its locomotive power, culminating, in regard to express locomotives, with the four-cylinder "King" class, which had originally visited the Baltimore, Md., fair in 1927. Retention of the cream and brown livery for passenger equipment emphasized the individuality of the Great Western. A pioneering development on this line was a zonal system of rail and highway co-ordination, whereby much mileage of pickup freight trains was eliminated and a better freight service offered to small consignments, through a system of railhead working served by the railway's own highway vehicles. A unique feature of Great Western practice was the fitting of virtually all main lines with automatic train-control apparatus on the intermittent system, with nearly all locomotives so equipped.

The Southern had developed by 1939 the largest system of suburban electrification in the world, extending over about 600 route miles and stretching from London to such coast towns as Hastings, Brighton and Portsmouth. The operation was wholly by multiple-unit electric trains, using the third-rail system at 660 v.; electric passenger cars numbered about 1,500. The Southern specialized in the use of colour-light automatic signals on extensive mileages of main lines.

The London and North Eastern had become famous for its steam-hauled, limited-train flyers from King's Cross (London) to Newcastle (the "Silver Jubilee"), to Edinburgh (the "Coronation") and to Leeds (the "West Riding"); speeds ranged up to 100 m.p.h. and one of its "Pacific" (4-6-2) locomotives, "Mallard," in 1938 had touched 126 m.p.h., believed to be a world record. The L.N.E.R.'s "Flying Scotsman" provided the longest nonstop daily run in the world, between London and Edinburgh, 392 mi.

On the London Midland and Scottish railway attention may be directed to the scientific research department located at Derby, where was also the residential school for staff training. This company's "Coronation Scot" express between London (Euston station) and Glasgow was its most famous train. Its progressive (assembly line) system for rolling-stock repairs, and for new construction, was a unique feature of European railway practice and development.

Nevertheless, most of the progress to be recorded on the British railways was of necessity on a four-company basis. Typical instances were development of container working, a system by which a vehicle body can be transferred by crane from rail car to motor truck and vice versa. This system had formed an effective method of meeting intensive highway competition, being ideally suited to British rail transport, with its small average consignment of less than six tons, and the retail nature of its short-distance freight traffic, with an average haul of about 70 mi. Approximately 14,000 containers were in service in 1938. Other effective methods of competing with highway transport included the quotation of agreed charges (also in use in Canada), by which the traffic of a large firm, such as Woolworth's, would be held to rail movement with a block payment for all consignments over a period, based on a census of traffic previously handled.

Co-ordination of rail and highway services was probably carried further in Britain than almost anywhere else. On the passenger side, the four railways had, by 1938, invested about £10,000,000 in bus-operating concerns, thus ensuring a measure of co-operation between bus and train travel, in the form of connecting schedules, and the replacement of unremunerative rail mileage by bus routes. On the freight side the railways, besides operating their own horse and motor collection and delivery road vehicles, to the number of nearly 36,000, had also acquired the old-established road concerns, Pickfords, Ltd., and Carter, Paterson and Co., Ltd., at a cost of £3,000,000.

In truth, the British railways were transport concerns, operating not only railways and road vehicles, but also owning some of the country's greatest ports—Southampton, Hull, Cardiff and Newport—as well as steamer services to France, the Netherlands, Belgium and Ireland. They owned extensive canal mileages, and also operated a big chain of hotels, chiefly at railway termini and holiday centres. They also operated internal air services under the name of Railway Air services.

Capital expenditures on the British railways system by 1938 had reached the immense total of almost £1,175,000,000 (exclusive of the L.P.T.B.).

On Sept. 1, 1939, the government assumed wartime control of the British railways and the L.P.T.B. Though arrangements for financial compensation to the companies were changed during the war period, the final agreement embodied an annual rental of approximately £43,000,000 to the four companies and the L.P.T.B. All receipts were credited to a common pool; after meeting current expenditures, the remainder accrued to the government, which, after payment of the annual rental of £43,000,000, obtained a 1941–45 profit of £195,000,000 in the aggregate. However, net revenue in 1946 and 1947 was insufficient to meet the £43,000,000 annual rental, and the balance had to be made good by the government, approximately £11,000,000 in 1946 and £59,000,000 in 1947 (of which latter figure £16,000,000 covered items accruing in earlier years). At the close of 1947, by the provisions of the Transport act, 1947, the British main-line railways and the L.P.T.B. were nationalized.

War Damage.—The British railway system suffered heavily from enemy air attack over the period 1940–45, there being 9,239

incidents reported, but only 662 of these affected traffic facilities for more than one week. Nearly 400 railwaymen were killed by enemy action and 2,444 injured. Illustrative of property damage and destruction, passenger cars demolished numbered 637, and 13,487 were damaged.

Nationalization.—The British Transport act, 1947, was the most important legislation in the railway world for many decades. By its nationalization of the British railways, the United States was left as the sole major country reliant on a privately owned and operated railway system, though the Canadian Pacific still remained such in Canada. Whereas the Railways act, 1921, consolidated the main-line railways into four systems, the Transport act, 1947, not only nationalized the railways, together with their ancillary services—docks, steamers, road vehicles, hotels and canals—but also provided for government ownership of the long-distance highway transport industry and nationalization of canals.

Under this far-reaching act, there was set up the British Transport commission, which in 1949 included five full-time members and one part-time member. Its duties included the provision of an efficient, adequate, economical and properly integrated system of public inland transport and port facilities within Great Britain for passengers and goods. The business of the commission was to be regarded as one undertaking, and it was to be so conducted and such charges levied as would ensure the undertaking paying its way, taking one year with another, after making provision for all charges properly allocated to revenue.

Under the commission there was set up a series of executives. The Railway executive is responsible for the management and working of the main-line railways. Other executives are responsible for London Transport (former L.P.T.B.), Docks and Inland Waterways, Road Passenger, Road Haulage, and Hotels, respectively. The Railway executive consists of a chairman, six functional and two part-time members. The four main-line railways were divided into six regions: Western (former G.W.R.), Southern (former S.R.), London Midland (former L.M.S.R.), Eastern (former L.N.E.R.) and North Eastern (former L.N.E.R.), while the L.M.S. and L.N.E. mileage in Scotland comprised one Scottish region. All equipment was to be relettered "British Railways," with a new and distinctive system of liveries.

Carriages.—All carriages (passenger-train cars) built for long-distance train services in Great Britain are designed to permit travellers to pass from one end of the train to the other, either by means of a side corridor or a centre vestibule. The former are known as compartment-type corridor vehicles, while all dining cars are built to the latter design. Corridor trains permit collection and examination of tickets by railway officials while the journey is in progress, thereby also enabling time at stations to be cut to a minimum, while permitting passengers to distribute themselves more evenly throughout the train. On the other hand, it lowers seating capacity of carriages by at least two seats per compartment, which constitutes a serious consideration in the case of suburban passenger traffic, especially during the hours of peak traffic, or rush hours. Consequently, suburban passenger trains in Europe are sometimes of the noncorridor type, though in certain countries, notably Switzerland, all carriages are vestibuled.

The typical British corridor eight-wheel bogie carriage contains seven first-class compartments or eight third-class compartments, seating respectively 42 and 64 persons on an empty, or "tare," weight of about 30 (long) tons. It usually possesses a lavatory at either end, and is about 60 ft. long by 9 ft. wide, with a height of about 13 ft. from rail level to top of roof centre. Carriages usually possess steel frames and wooden bodies, sometimes metal sheeted, and in some cases a metal roof, although a wooden roof is more common. On continental railways the modern all-steel express-train carriage often weighs 40 tons to 45 tons; a greater degree of safety is claimed for that type of construction, but the all-metal design is usually very much more noisy than the wooden carriage. The noncorridor bogie carriage for British suburban service contains nine or ten compartments, each seating 10 or 12 third-class passengers and 8 first-class passengers, on an empty or tare weight of at least 27 (long) tons. A typical British express train often weighs between 400 and 500 (long) tons empty, exclusive of engine and tender; on the continent a train of similar seating capacity would be heavier because of the continental carriage design. Pullman, dining and sleeping cars are the heaviest cars on European railways.

The screw coupling and side buffer are used on nearly all western European carriages. In Britain automatic couplings of the "buck-eye" type, the two jaws closing when the carriages are pushed together, were standard for long-distance corridor-vestibuled vehicles on the London and North Eastern and the Southern railways and also for Pullman cars. The L.N.E.R. has constructed many "articulated" sets of two, three or five vehicles, the bogie being placed under two vehicles instead of at the ends of each. By this method weight is saved and, it is claimed, less oscillation and smoother running result.

In addition to passenger-carrying vehicles, many other railway vehicles frequently form part of the composition of a passenger train; they consist of vans for luggage and parcels, horse boxes, vans for milk, fruit, theatrical scenery and motor cars. These vehicles are all fitted with vacuum automatic brakes for working on fast passenger trains. Electric multiple-unit cars use the Westinghouse air brake.

Total passenger-train vehicles operating at the end of 1948 approximated 55,700, of which about 40,400 were passenger carriages and 15,300 were nonpassenger vehicles for mail and parcels.

Passenger journeys (passengers handled) in 1948 totalled 996,000,000, transported for a total of 21,259,000,000 passenger-miles. The average journey per passenger was 21.3 mi. and the average revenue per passenger-mile was 1.38*d*.

Wagons.—For the carriage of merchandise and mineral traffic the British railways employ open or covered wagons (freight-train cars), the latter sometimes known as box vans. For general merchandise traffic, shipments often are covered with creosoted tarpaulin sheets, a practice used to any extensive degree only in Great Britain, where use of covered vans is rendered difficult by the large percentage of traffic which has to be handled by crane at the numerous ports. The size of the British railway wagon has grown steadily but slowly as compared with railway wagons elsewhere, but the internal trade of the country is largely retail in its nature, while the average distance travelled by a consignment is comparatively short. The general practice is to offer a frequent railway freight service, as is done with passenger service, often with comparatively light trains. The average weight of paying or net load in a British freight train is about 156 long tons (compared with about 1,000 long tons in the United States).

However, the engine has also to haul the weight of the wagons themselves. Hence, the wagon designer is faced with the problem of constructing a wagon to hold the maximum weight and volume of capacity on the lightest tare, or empty, weight; with increase of wagon capacity the less becomes tare weight per ton of capacity. Thus, a wagon to carry 6 tons may easily weigh 5 tons, but a wagon to carry 20 tons can be constructed to weigh only 10 tons. The high-capacity wagon, as it is called, also occupies less space on sidings, which is very important, but difficulties are experienced on British railways in the use of such wagons by reason of the small clearances for such fixed structures as mine screens and the sharp curves on many sidings.

The average capacity of the railway-owned wagon in Great Britain is almost 13 long tons, varying according to types of cars, though the standard to which all new wagons conform, other than special wagons for rails, boilers, plate glass and so forth, provides for a 12-ton capacity. Policies have been urged which aim at the adoption of a standard wagon of at least 20 tons, which would doubtless result in economies of railway operation, but it is very difficult for the railways to build a type of wagon which the trading community does not desire, and the latter in Great Britain has always insisted upon its preference for the small wagon unit, in view of the retail nature of the country's trade.

Many important developments have taken place in wagon design beyond the steady growth in size. Spring buffers are now universal in Great Britain, as well as on continental railways. Though the latter employ a screw coupling as with passenger trains, the British lines adhere to the "loose-link" coupling which permits easier at-

taching or detaching of extra wagons. This difference is, once again, the result of the short average length of haul on British railways, and the frequency of junctions where trains have to be reformed for different sections of the line. British wagons are fitted with hand brakes which, according to a government order of 1911, must be fitted on both sides of wagons. The modern wagon has almost invariably a metal frame, but the body may be of steel or timber on a metal framework; coal wagons in many countries are now made of metal.

Wagons operating at the end of 1948 totalled 1,180,000, of which about 544,000 formerly were privately owned and 636,000 were owned by the railways prior to nationalization. In addition, there were approximately 25,000 privately owned wagons of special designs, such as tank wagons, which were not nationalized.

Freight originated in 1948 totalled 276,117,000 (long) tons, which were transported for a total of 21,457,000,000 ton-miles. The average haul was 72.1 mi., and the average revenue per ton-mile was 2.04*d*.

The total railway staff at the end of 1948 (including road-haulage employees of railroads) was approximately 649,000.

Locomotives, both freight and passenger, operating on the British railways at the end of 1948 totalled 20,352, of which 67 were diesel and 17 were electric.

Under accounting methods of the British Transport commission, financial results of the railways alone are no longer precisely ascertainable. For the year 1949 operations of the commission as a whole showed a loss of £20,700,000.

Railways of Continental Europe.—*France.*—The first railway in France, opened in 1827 from St. Étienne to Andrézieux, was, like early British lines, mainly for haulage of coal. It used horse traction, and did not carry passengers until 1832; the St. Étienne-Lyon line of 1830 used steam locomotives from its opening. In 1833 the French government began to encourage railway construction, and among earlier lines authorized were those from Paris to St. Germain and Versailles. By 1842 French railways totalled 360 mi. An act of the same year provided for construction of lines which were later to form the great trunk railway routes from Paris to Nancy and Strasbourg; Lyon and Marseilles; Bourges and Toulouse; Tours, Bordeaux and Bayonne; Nantes, Rouen and Le Havre; and, finally, Lille and Belgium. In addition were cross-country routes from Bordeaux to Marseilles, and Dijon to Mulhouse. By Jan. 1, 1852, there had been authorized 3,125 route miles and 2,185 were being operated. Rapid development occurred during the next two decades. Leases granted to private companies to operate railways were to last 99 years, and the companies operating in any one territory were amalgamated to reduce competition. By 1870, 16,685 mi. were authorized, of which 11,250 were being operated—figures which by 1875 had become 21,375 and 13,562 respectively. Soon afterward a state-operated system (in addition to the private companies) was created.

Total mileage of the seven big French railway systems at the end of 1937 was 26,538 mi. These seven were the Paris-Lyon-Méditerranée, the Paris-Orléans, the Midi, the Est and the Nord, which were private companies operating under the terms of a long lease. In addition, there were the État (*i.e.*, the State system) and the Alsace-Lorraine railways, which latter became French national property as a result of World War I. Each system was practically a rail monopoly in its own territory. Additional to the seven large railways was an important mileage of narrow-gauge lines.

At the beginning of 1938, the government took over the lines operated by the private companies and welded them, with its own State railway and the Alsace-Lorraine lines, into the French National railroads (Société Nationale des Chemins de Fer Français, or S.N.C.F.). The reorganized system consisted of five regions: Nord, Est, Ouest (former État railway), Sud-Ouest (former Paris-Orléans-Midi) and the Sud-Est (former Paris-Lyon-Méditerranée). The reorganization had not been completed when war stopped further developments. A new Mediterranean region, based on Marseilles, was set up in 1947.

The railway network suffered material damage in the military campaign of 1940. During the German occupation about 3,400 locomotives and 270,000 wagons, stores, etc., were removed from France. Bridges and other facilities had hardly been repaired when the Allied forces landed in Normandy in June 1944. A key to the success of the Allied campaign had been the paralysis of the railway system of western Europe by air attack, and, on the liberation of Paris, out of more than 40,000 km. (about 25,000 mi.) of line being operated in 1939 only 18,000 km. were then available. France was severed into two parts through the destruction of all rail bridges over the Loire from Roanne to the sea.

The outstanding energy with which the S.N.C.F. tackled the problem of reconstruction is one of the remarkable railway efforts of the century. By May 1946, almost 40,000 km. of line were again in service, while the electrified main lines Paris-Bordeaux-Hendaye, Paris-Le Mans and Paris-Montauban-Cerbère were all working by 1946. By June 1, 1947, 2,468 bridges and viaducts had been reconstructed, 62 tunnels rebuilt and 4,536 km. of line restored. Signalling and telephone wire to a length of 66,000 km. was replaced and 610 signal cabins rebuilt. Out of a total of 17,058 steam locomotives in 1939, only 10,500 were left in Sept. 1944—of these only 3,000 were usable. However, 1,200 steam and 100 diesel locomotives were obtained from the United States and 140 from Canada, while by June 1947, 1,750 locomotives had been recovered from Germany, as were 90,000 wagons.

Prewar standards of speed and comfort had been largely re-established by 1947. As a measure of recovery, in the year 1947 the number of passengers carried was nearly 21% above 1938, passenger-kilometres up by 43%, tons carried up by 6% and net ton-kilometres up by 40%. In addition to reconstruction of the great railway centres and classification yards such as Juvisy, Tours, Orléans and Rouen (Sotteville), major improvements were well under way.

Electrification had been completed by 1950 on lines radiating from Paris to Le Mans, Bordeaux and Toulouse, and the line from Bordeaux through Dax, Tarbes and Toulouse had been electrified as far as Nîmes. In addition, numerous extensions from the latter line toward the Spanish border were electrified. Conversion of the great artery Paris-Dijon-Lyon was expected to be completed by the end of 1952, the Paris-Dijon section being scheduled for earlier completion. Several sections of line in the east of France, including the Culoz-Modane link, also had been electrified.

A scientifically designed basis of freight charges was inaugurated in March 1947, with the older systems of *grande vitesse* and *petite vitesse* being replaced by a *régime acceleré* and a *régime ordinaire*. Many unremunerative branch lines had been closed to passenger traffic, and economies had been effected by the extensive use of diesel rail cars on country services, main and branch line; however, there had been no large-scale development of main-line use of diesels. A postwar feature of interest was the use of oil as fuel on many of the steam locomotives built in the United States.

Germany.—In Dec. 1835 the first German railway was opened between Nuernberg and Furth. The first interstate line was that from Magdeburg, Prussia, to Leipzig, Saxony, opened in 1840, and as early as 1847 there was formed an association of German railway administrations. Strict state control was exercised throughout the period of rapid construction commencing in 1846, and by 1855, 5,410 mi. had been completed. Uniformity of gauge resulted from importation of British locomotives and rolling stock.

An important characteristic of German railways had been, from the first, the large part played by international traffic; a second characteristic had been the great degree of state construction and ownership. The first state line was opened in Brunswick in 1838; by 1855 throughout Germany nearly 50% of the railway mileage was state-owned. The Austro-Prussian War of 1866 strengthened the Prussian railway system, as also did the Franco-German War of 1870. By the latter year, the main trunk network was largely complete, though few branch lines had been constructed. Lines of the French Est railway in Alsace and Lorraine became the property of the German empire in 1871, while 1873 saw the establishment of an imperial railway department.

From 1876 onward, privately owned railways were gradually absorbed by governments, Prussia acquiring the Berlin-Stettin and Cologne-Minden lines, among many others, by an act of 1879. By

1885 private railways in Prussia were practically nonexistent. Bavaria had always favoured state railways and finally bought up the Pfalz railway in 1908. Saxony had adopted the same policy and took over the Leipzig-Dresden line in 1876. In Hesse-Darmstadt, the Hesse-Ludwig railway became state-owned in 1896, the Mecklenburg railways being purchased by the state in 1889. Oldenburg, Württemberg and Baden owned and operated their railways from the first.

The total route mileage in Germany in 1909 was 35,625. In 1920 the various German state railways became the property of the reich, but in 1924, consequent on the recommendation of the Dawes plan, their status was altered to a publicly owned company, so far as operation was concerned, on a lease of 40 years. Under the Hitler regime, control again was assumed by the government. The German railway after 1945 was divided into four sections, corresponding to the four zones of occupation—United States, British, French and Russian. The two former were worked under bizonal control. Little information was definite as regards the soviet zone, but it was known that many double-tracked main lines had been reduced to single track and that electrified mileage had been reduced consequent on removal of apparatus. War destruction and neglect of railroads in Germany would take many years to make good, and progress was slow because of shortage of materials.

Austria.—The Austrian Federal railways, taken over by Germany in 1938, were restored to separate operation in Nov. 1945. The system (as of 1950) was divided into four regions, with regional managements at Vienna, Linz, Villach and Innsbruck, regions approximately corresponding with the respective zones of occupation of U.S., British, French and soviet military forces. The federal ministry of transport in Vienna exercised directing and supervising authority over the entire system. Difficulties occurred in regard to free flow of traffic among different zones of occupation. Because of shortage of coal supplies there was an extensive program of electrification between World Wars I and II, and postwar electrification in the Linz-Villach areas continued slowly.

Other European Railways.—State-owned railway systems exist in the U.S.S.R., Italy, Switzerland and Denmark, dating back to the 1840s; in Sweden, Norway and Portugal, dating back to the 1850s; and in Greece to the 1860s, although state ownership and operation usually came many years after the opening of the first lines. Belgium has a state-owned system, leased for 75 years from 1926 to an operating national company. This small country has the greatest density of railway mileage in relation to area of any country in the world. In Spain, where railways date back to 1848, and in the Netherlands, where they date from 1839, the lines were taken over by those states in 1941 and 1938, respectively. Rumania, Czechoslovakia, Bulgaria and Yugoslavia all own and operate their systems. In the majority of cases small private lines also exist, but they are usually only of local importance.

Belgium.—The Belgian situation following World War II was similar to the French, but on a smaller scale; damage was less in 1940, not quite so grievous in 1944–45, and the efforts of the Belgian National railways (Société Nationale des Chemins de Fer Belges, or S.N.C.B.) were hardly less spirited and energetic than the French in the postwar reconstruction period. By 1947 train services were approaching pre-1939 standard. However, as in France, steep rises in the level of salaries and costs of fuel and stores, coupled with inability to obtain a proportionate increase in the level of charges, prevented the Belgian railways, like the French, from meeting their financial obligations in regard to interest on capital.

Netherlands.—The Netherlands railways suffered grievously from war damage and wanton destruction. Following a strike of railway workers in the Allied interest in Sept. 1944, the northern section of the railway system was systematically demolished by German forces between then and May 1945. Not a single diesel-electric multiple-unit set was left at the liberation, while 99% of the multiple-unit electric cars, 94% of the passenger cars and 84% of the steam locomotives had been removed or destroyed. Of the bridges, 70% were destroyed or damaged, as were 68% of the signal cabins. Postwar reconstruction was rapid and thorough. It also made provision for long-term improvements involving heavier track, extensive conversion to electric traction and the turnover to diesel traction on most of the other lines. The great Moerdijk bridge, 1,100 yd. long, was reopened in Aug. 1946, and 17 other large bridges, including Zaltbommel, had been reconstructed by 1947.

Italy.—The Italian State railways had a somewhat similar postwar problem of destruction and reconstruction to face and met it efficiently. Electrification had been re-established on all the lines previously so equipped by 1948, and further conversions to electric traction were undertaken, as, for example, the Simplon main line between Milan and Domodossola.

Switzerland.—In Switzerland, practically the entire federal railways system had been electrified (as of 1950), and nearly all single-track sections on the Gotthard line had been converted to double track. A complete revision of passenger fares had been carried through, and the freight-rates structure was under review. Shortage of electric energy derived from hydroelectric power had placed a limit at times on train mileage, just as shortage of coal had limited railway services in Britain, France, Spain and many other countries. Lightweight equipment had been developed scientifically by the Swiss railways, and a network of high-speed services introduced. Switzerland was the first country to develop and test a gas-turbine locomotive in main-line service.

Spain.—The Spanish National railways (Red Nacional de los Ferrocarriles Españoles, or R.E.N.F.E.) were formed in 1941 of a consolidation of the Norte, the Madrid, Saragossa and Alicante, and the government-owned Andalusian and Western railways. Conversion to electric traction is a feature of Spanish railway policy, since coal is of poor quality or must be imported, but shortage of materials has delayed progress. Certain cutoff lines were under construction in 1950, and the section Cuenca-Utiel (Madrid-Valencia) was opened in 1947; another line was completed from Zamora to Corunna in 1943.

Sweden.—Swedish State railway progress has been centred primarily on electrification. Nearly all main lines employ electric traction, the electric line from Malmö and Göteborg in the south to the Norwegian frontier near Narvik being one of the world's longest continuous stretches of electrification—2,140 km. Sweden provides another example of the extension of government ownership; many of the privately operated lines have been merged with the state-owned system, a notable instance being that of Göteborg-Gävle traffic group, including the Bergslagens railway, which was absorbed into the state system in 1948.

Norway.—The Norwegian State railways had by 1950 electrified approximately one-sixth of their mileage, and had extensive plans for further electrification, as the country possesses abundant water-power resources. Since World War II, the Sörland railway had been completed, linking Stavanger with Oslo, and the line also had been electrified throughout. The Nörland railway, north from Trondheim, had reached Lonsdal en route to Bodö. Both these lines were of considerable wartime importance during the German occupation, and much work was done on them by the Germans.

U.S.S.R.—The nationalized railways of the U.S.S.R. are said to form the largest single railway system in the world. They are said to be divided into 22 distinct systems administered under a central all-union collegium. The 22 divisions are: Southern, Catherine, South Eastern, Moscow-Kursk and Moscow circuit, Moscow-Kazan, Samara-Zlatoust, Perm, Omsk, Tomsk, Baikal, Ussurisk, South Western, Western, Moscow-Baltic, October, Murmansk, Northern, Ryazan-Uralsk, North Caucasus, West Caucasus, Central Asia and Turksib. Little information of any kind after 1939 was available concerning these railroads. It was known that after World War II there had been considerable development of the trans-Siberian main line in Asia and of alternative routes over certain sections. Various lines near Moscow were said to have been electrified, and a beginning was also said to have been made in the electrification of heavy lines in the Caucasus.

Greece.—In 1920 the government of Greece took over control of three private companies and nationalized them as the Hellenic State railways. Demolitions by the retiring German army late in 1944 placed the entire system out of action except for about 260

mi. War damage on the system was so extensive that many years would be required for restoration to prewar standards.

Baltic and Eastern European Countries.—Little that was definite could be said about the postwar railway situation in the Baltic countries and those of eastern Europe, reliable information from these countries being inadequate.

ASIA

Railway mileage in Asia was approximately as follows in 1950:

Country	Miles
Burma	1,739
Ceylon	913
China	12,960
Formosa	2,440
India and Pakistan	40,861
Indo-China	1,836
Iran	1,533
Iraq	966
Japan*	10,471
Korea	2,101
Malaya	1,068
Manchuria	5,381
Netherlands Indies†	4,536
Palestine	626
Philippine Republic	843
Syria	516
Thailand (Siam)	2,126
Turkey‡	4,672
U.S.S.R. (included in Europe)	—
Total	95,588

*Includes Karafuto (Sakhalin).
†Pre-World War II mileage.
‡Includes 210 mi. in Europe.

Developments in Asia after 1940.—Among notable railway developments in Asia since 1940 may be mentioned the completion during World War II of the coastal railway in Lebanon, from Beirut to Tripoli, thus affording facilities for through-running of standard-gauge trains from Haidar Pasha on the Bosporus to Cairo and the Nile valley. Similarly, completion of the standard-gauge line to Baghdad brought about through-running between the Bosporus and that city. The projected train-ferry service across the Bosporus would make possible through-running from Scotland and London to Cairo and Baghdad, since the cross-channel train ferry between Dover and Dunkirk was restarted in 1947. The trans-Iranian railway was completed prior to the outbreak of World War II.

Railways of Asiatic Regions.—*India.*—India possesses an extensive railway system, mainly constructed to 5 ft. 6 in. and metre gauges. Railways are divided into three classes based upon gross earnings, similar to the method used in the United States. There are 13 class I lines with gross revenues of Rs. 5,000,000 or more per annum, of which the largest are the Great Indian Peninsula, the East Indian, the Bombay, Baroda and Central India, the North Western, the Oudh Tirhut, the Bengal-Nagpur, the Bengal and Assam (changed in 1945 to Bengal Assam railway), the South Indian and the Madras and Southern Mahratta. Some of the Indian lines formerly were privately owned and operated, and others were state-owned but privately operated under contracts; however, the state has gradually taken full control of principal lines. Remaining railroads of private ownership and operation are mainly small lines, of mostly local importance.

A major railway event was a result of the partition of India into Pakistan and India, which disrupted the North Western railway system, requiring redistribution of railway mileage north of Calcutta. The former Bengal Assam railway was divided into the Assam railway in India and the Eastern Bengal in Pakistan.

China.—Ranking next to India in point of railway mileage is China (including Manchuria and Formosa). Numerous lines were constructed in China while the country was at war. China's railway history dates from 1876, when the first line, built by foreign capital, was opened; as soon as the money had been repaid the Chinese tore up the rails. Except about 1,900 mi. on Formosa, lines are under either national or provincial ownership. Most Chinese mileage is standard gauge.

After the surrender of Japan in 1945, Manchuria was restored to China, and its railways were placed under a special commissioner, for rehabilitation. The lines are principally standard gauge, the Japanese having converted former narrow-gauge lines in south Manchuria to standard gauge and re-equipped them with rolling stock chiefly of U.S. design and construction.

Formosa (or Taiwan) also was restored to China after the close of World War II. The provincial government operates about 560 mi. of 3 ft. 6 in. and 2 ft. 6 in. gauge lines.

Japan.—Japan ranks third as to railroads among Asiatic countries, with a state-owned and operated system of 3 ft. 6 in. gauge, approximating (pre-World War II) 10,500 mi. The first section was opened in 1872, but by 1887 only 240 mi. of railway had been constructed. In 1906, when route mileage was almost 4,800, a railway nationalization bill was passed and nearly £50,000,000 paid for more than 2,800 mi. A feature of the Japanese railway system is the use of ferry steamers for connecting up the islands over which the railway system extends; some of these steamers are train ferries. There is also a railway tunnel, about 2.2 mi. long, connecting the islands of Honshu and Kyushu.

Turkey.—Turkish railroads date from the completion in 1896 of a line from a point opposite Istanbul to Ankara and Konia. They are state-owned, existing private railways having been nationalized beginning in 1934, and are mainly standard gauge. Between World Wars I and II, the Turkish republic undertook an extensive construction program, adding approximately 2,100 mi. to the system. After World War II an extensive program of rehabilitation and modernization was undertaken, in furtherance of which the aid of U.S. consultants was enlisted.

Other.—Railroads of the Netherlands Indies were badly damaged under Japanese occupation during World War II. Standard-gauge lines were broken up or converted to narrow-gauge lines, and large quantities of materials and rolling stock were transferred by the Japanese to other occupied territories. The state railways of Thailand are metre gauge, converted from standard gauge; the first line was opened in 1893. The state railways of Iran are of recent construction, dating from about 1938. Because of topographical conditions, some of this construction ranks among the most difficult and costly in the world.

AFRICA

Railway mileage in Africa was approximately as follows in 1950:

	Miles
Abyssinia (Ethiopia)	487
Algeria	2,786
Belgian colonies	2,919
British possessions	8,518
Egypt	4,023
Former Italian colonies	411
French territories	3,897
Morocco	1,063
Portuguese colonies	2,700
Spanish Morocco	19
Sudan	2,013
Tunis	1,273
Union of South Africa	13,280
Total	43,389

Developments in Africa after 1940.—Among major railway developments in Africa after 1940 was the rapid development of diesel traction on the North African coast. This seemed likely to result in steady replacement of steam locomotives in Algeria and possibly Morocco. On the west coast, the narrow-gauge Nigerian railways were hard put to it to handle the groundnut (peanut) crop, which is of immense importance to Europe's food resources, and consistent efforts were being made to develop this traffic in East Africa. There, the Kenya and Uganda railway system had been merged with the neighbouring Tanganyika railways to form the new East African Railways system, as from May 1948. The trend to government ownership was evidenced in Rhodesia, where the company-owned and managed Rhodesian railways were taken over in 1947.

Much attention had been given to standardization of gauges in Africa, and later equipment for some of the metre-gauge systems had been so designed as to allow conversion to 3 ft. 6 in. in the future. A feature of African railway practice had been the growing use of the Garrett type of locomotive, especially suited for heavy haulage on light rails and tracks.

Railways of African Regions.—The largest railway system in Africa is that of the South African Railways and Harbours administration, a government-owned and operated system of 3 ft. 6 in. gauge in the Union of South Africa. In 1860 a standard-gauge (4 ft. 8½ in.) line was opened at Natal, followed by a line of similar gauge between Capetown and Wellington. By 1881 the gauge had been changed to 3 ft. 6 in., and Cape Colony and Natal had commenced state ownership. Kimberley could be reached by rail in 1885 and Bloemfontein in 1890, the Orange Free State taking control of this section in 1897, the year when the railway first reached Bulawayo (in Rhodesia). When the railways were amalgamated under the Union government, in 1910, the mileage amounted to more than 7,000, which had increased to 9,600 in 1920.

The South African Railways and Harbours has become one of the most extensive railway administrations in the world. It is almost unique in operating not only the railway system but the main harbours of the country, much of the highway transport, and even the air services, domestic and international. Construction of locomotives and rolling stock was being undertaken in South Africa, and electrified mileage had been extended, especially in the Johannesburg area. With revenue totalling in 1946–47 £(S.A.)75,000,000 per annum, the 3 ft. 6 in. gauge S.A.R. had a route mileage of close to 13,300, of which 584 mi. were electrified, and owned about 2,300 steam and 200 electric locomotives, with 65,000 freight cars. Even so, the traffic offering was handled only with great difficulty.

The Rhodesia railways, 2,445 mi. of 3 ft. 6 in. gauge owned and controlled by the Southern Rhodesia government, operate lines from Bulawayo northwestward through Victoria Falls and Broken Hill, to the Belgian Congo border, and northeastward through Salisbury to Umtali, connecting there with the former Beira railway to reach the

port of Beira in Portuguese East Africa. The Beira railway was purchased by the Portuguese government in 1949, but was temporarily worked by the Rhodesia railways. Altogether, Portuguese East Africa has 1,091 mi. of railroads, nearly all 3 ft. 6 in. gauge. From Beira there runs north the 3 ft. 6 in. gauge Trans-Zambesia railway, terminating at Murraça on the Zambezi, where commences the Central Africa railway. This line crosses the Zambezi river on one of the world's longest railway bridges, and connects with the more important Shiré Highlands line at Port Herald, Nyas. Both these lines are 3 ft. 6 in. gauge, and the latter runs through Blantyre in Nyasaland and terminates at Domira bay on the west shore of Lake Nyasa; thus, there is through rail connection from Capetown to the lake itself. North of Nyasaland run the metre-gauge Tanganyika railways, westward from Dar es Salaam to Kigoma and Mwanza; a further line runs westward from Tanga to Arusha. Near Moshi connection is made with the Kenya and Uganda railway; this latter line, of metre gauge and more than 1,600 route miles long, is based on Mombasa, Kenya, and penetrates to Kisumu, Kenya, on Lake Victoria, with important branches and lake, river and motor services. Northward to El Obeid, in the Sudan, there is no railway connection, thus frustrating present realization of the long-desired Cape-to-Cairo railroad.

The Sudan system, of 2,013 mi. of 3 ft. 6 in. gauge, stretches from El Obeid north through Khartoum to Wadi Halfa, whence Nile steamers connect with the Egyptian railways near Aswan. Sudan railway branches extend to Kareima, Kassala, Port Sudan and Suakin.

The metre-gauge Franco-Ethiopian line runs inland from Jibuti, Fr. Somlnd., to Addis Ababa, Aby. The three segments of lines in the former Italian colonies of Libya and Eritrea total 411 mi. of .95-m. gauge.

In North Africa, Egypt has more than 4,000 mi. of railroads, of which 607 mi. is a system of 2 ft. 6 in. lines serving villages of the Nile delta. The Egyptian state railways system comprises about 3,000 mi. of standard-gauge line and 121 mi. of 2 ft. 6 in. line serving the western oases. The first railroad on the African continent was a line started in 1852 between Alexandria and Cairo, of which the first section was opened in 1854.

The Algerian railway system of 2,786 mi. has about half its mileage of standard gauge (with 102 mi. electrified), the remainder being 2 ft. 6 in. and metre gauge. The system is operated for the country by a special department. The railroads of Tunis are partly government-owned and partly company-owned. There are 315 mi. of standard-gauge line, the remainder being metre gauge. Moroccan railroads, all of standard gauge, are company-owned and -operated.

In the French territories of West Africa, metre-gauge lines extend from the ocean ports of Dakar, Konakry, Abidjan, Cotonou and Lomé principally to inland points on the Niger river. Another metre-gauge line runs inland from Duala, in the Cameroun. From Pointe Noire, in French Equatorial Africa, a short 3 ft. 6 in. gauge line runs to Brazzaville, near the mouth of the Congo.

The 3 ft. 6 in. Nigerian railway system, comprising 1,900 mi., runs inland from Lagos and Port Harcourt to Nguru, connected by water with Lake Tchad, and Kaura Namoda, on a tributary of the Niger river. Other railroads in British West Africa extend inland from Freetown (Sierra Leone) with 2 ft. 6 in. gauge, and from Takoradi and Accra (Gold Coast) with 3 ft. 6 in. gauge.

The 2,900 mi. of line in the Belgian Congo were mostly developed as the result of the great copper deposits in the Katanga district. They are principally 3 ft. 6 in. gauge, with some 2-ft. and metre gauge. A 3 ft. 6 in. line in the Belgian Congo, having connection with the Benguela line, in Portuguese West Africa, also runs northward from Ndola, on the Rhodesian frontier, to Port Francqui (on a tributary of the Congo river). Isolated metre-gauge railroads, linking water routes, serve Stanleyville and Albertville, and a 3 ft. 6 in. gauge line runs inland from Matadi to Leopoldville, on the Congo river.

The Benguela railway, 3 ft. 6 in. gauge, in Angola (Portuguese West Africa), also owes its existence to the copper deposits in the Belgian Congo, affording a much shorter haul for the copper to England than the former route via Beira (Portuguese East Africa). Besides the Benguela line, there are also in Angola shorter lines running inland from the ocean ports of Loanda (metre gauge) and Pôrto Anboim and Mossâmedes (.60 m.).

The French islands of Madagascar and Réunion have 530 mi. and 78 mi., respectively, of metre-gauge railroads, and there are 106 mi. of standard-gauge line on the British island of Mauritius.

AUSTRALASIA

Railway mileage in Australasia in 1950 was approximately as follows:

	Miles
Australian commonwealth government*	2,201
Queensland	6,630
New South Wales	6,194
Victoria	4,756
South Australia	2,547
Western Australia	4,911
Tasmania	780
New Zealand	3,532
Total	31,551

*Includes mileage in South and Western Australia, Northern Territory, New South Wales and Australian Capital Territory.

Australasia's railroads date from 1854, when there was opened for operation the section between Flinders St., Melbourne, and Port Melbourne, now part of the Victorian government system. Portions of lines were opened in New South Wales in 1855 and in South Australia in 1856. Practically all mileage in Australasia is state-owned and operated, the principal exceptions being two lines in Western Australia totalling somewhat more than 525 mi.

The commonwealth government's Trans-Australian (standard-gauge) line has what is said to be the longest stretch of straight track in the world. Crossing the Nullarbor plain in Western and South Australia, the line runs for more than 300 mi. without a curve.

Through movements in Australia are hampered by the use of three gauges on the railroads. Of the commonwealth government lines, about half are standard gauge and half are 3 ft. 6 in. gauge. Queensland lines are 3 ft. 6 in., those of New South Wales are standard gauge, while Victoria has the 5 ft. 3 in. gauge. Lines in South Australia are 5 ft. 3 in. and 3 ft. 6 in. Western Australia has the 3 ft. 6 in. gauge, as also have Tasmania and New Zealand. Small mileages of other narrow gauges also are found.

A courageous plan was prepared by Sir Harold Clapp, former chief commissioner of the Victorian railways, aiming at standardization of gauges of the various state-owned railway systems of Australia. Much preliminary work was accomplished to achieve throughout the continent the standard (4 ft. 8½ in.) gauge used by the commonwealth Trans-Australian and New South Wales government railways. The task and the cost would be immense, as Victoria uses the 5 ft. 3 in. gauge while both the Queensland and Western Australian railways are 3 ft. 6 in. gauge. There would be striking defense, commercial and economic advantages from unification, but the raising of necessary capital and the shortage of labour create severe practical difficulties.

In New Zealand, the policy has been to link up previously existing isolated sections of line with main systems in the North and South Islands, a program almost completed. The New Zealand government railways have gone far in developing co-ordination of rail and highway services, but even so the financial situation, with increased wages and costs for fuel and stores, has outweighed the rising revenue from record traffics.

Nearly all the Australasian railways had, in general, failed to earn interest on their capital expenditure. Shortage of coal had hit these systems hard; some were experimenting with oil fuel, and the Victorian railways were making extensive tests with pulverized coal as fuel. Air competition was proving severe in the case of long-distance interstate movements.

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(J. H. PAR.; L. J. K.; R. S. H.; C. E. R. S.)

RAILWAYS, TUBE. The term "tube railways" is applied generally in Great Britain to deep-level underground railways constructed with a metallic lining and usually of round section. For the construction and the ventilation of the tube, *see* the article TUNNEL. The tube railway is a form of subway. The latter is discussed under TUNNEL. (*See* also TRAMWAYS.)

Stations are constructed, as a rule, by building a tunnel of twice the dimensions of the running tunnels. The station tunnel is sufficiently large to accommodate the platform as well as the track. Tube railways are generally operated at about 600 v., direct current being fed to the conductor rails from substations. The substations are usually of the rotary converter type. High-tension current is supplied from a central power station. From the substations also run cables supplying current for station lighting, elevators, escalators and pumps.

In the London area, metropolitan and district lines are shallow subsurface railways; the other underground lines, also part of the London Transport, and the Southern region line from Waterloo to the city are tube railways proper.

RAIN: *see* RAINFALL; METEOROLOGY.

RAINBOW, formerly known as the iris, the coloured rings seen in the heavens when the light from the sun or moon shines on falling rain; on a smaller scale they may be observed when sunshine falls on the spray of a waterfall or fountain. The bows assume the form of concentric circular arcs, having their common centre on the line joining the eye of the observer to the sun. Generally only one bow is clearly seen; this is known as the primary rainbow; it has an angular radius of about 42°, and exhibits a fine display of the colours of the spectrum, being red on the outside and violet on the inside. Sometimes an outer bow, the secondary rainbow, is observed; this is much fainter than the primary bow, and it exhibits the same play of colours, with the important distinction that the order is reversed, the red being inside and the violet outside. Its angular radius is about 54°.

Among the Greeks and Romans various speculations as to the cause of the bow were indulged in; Aristotle, in his *Meteors*, erroneously ascribes it to the reflection of the sun's rays by the rain; Seneca adopted the same view. The introduction of the idea that the phenomenon was caused by refraction is to be assigned to Vitellio.

The most valuable of all the earlier contributions to the scientific explanation of rainbows is undoubtedly a treatise by Marco Antonio de Dominis (1566–1624), archbishop of Spalato. This work, *De radiis visus et lucis in vitris perspectivis et iride*, published at Venice in 1611 by J. Bartolus, although written about 20 years previously, contains a chapter entitled "Vera iridis tota generatio explicatur," in which it is shown how the primary bow is formed by two refractions and one reflection, and the secondary bow by two refractions and two reflections. René Descartes strengthened these views, both by experiments and geometrical investigations, in his *Meteors* (Leyden, 1637). Descartes could advance no satisfactory explanation of the chromatic displays; this was effected by Sir Isaac Newton. (*See* Newton's *Opticks*, book i, part 2, prop. 9.)

The geometrical theory, which formed the basis of the investigations of Descartes and Newton, afforded no explanation of the supernumerary bows, and about a century elapsed before an explanation was forthcoming. This was given by Thomas Young, who, in the Bakerian lecture delivered before the Royal society on Nov. 24, 1803, applied his principle of the interference of light to this phenomenon.

His not wholly satisfactory explanation was mathematically examined in 1835 by Richard Potter (*Camb. Phil. Trans.* 6, 141 [1838]), who, while improving the theory, left a more complete solution to be made in 1838 by Sir George Biddell Airy (*Camb. Phil. Trans.* 6, 379 [1838]).

Geometrical Theory.—The geometrical theory first requires a consideration of the path of a ray of light falling upon a transparent sphere. Of the total amount of light falling on such a sphere, part is reflected or scattered at the incident surface, so rendering the drop visible, while a part will enter the drop. Confining our attention to a ray entering in a principal plane, we will determine its deviation (*i.e.*, the angle between its directions of incidence and emergence) after one, two, three or more internal reflections. Let EA be a ray incident at an angle i (fig. 1); let AD be the refracted ray, and r the angle of refraction. Then the deviation experienced by the ray at A is $i-r$. If the ray suffers one internal reflection at D, then it is readily seen that, if DB be the path of the reflected ray, the angle ADB equals $2r$; *i.e.*, the deviation of the ray at D is $\pi-2r$. At B, where the ray leaves the drop, the deviation is the same as at A; viz., $i-r$. The total deviation of the ray is consequently given by $D=2(i-r)+\pi-2r$.

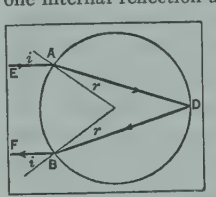

FIG. 1

Similarly it may be shown that each internal reflection introduces a supplementary deviation of $\pi-2r$; hence, if the ray be reflected n times, the total deviation will be $D=2(i-r)+n(\pi-2r)$.

The deviation is thus seen to vary with the angle of incidence; and by considering a set of parallel rays passing through the same principal plane of the sphere and incident at all angles, it can be readily shown that more rays will pass in the neighbourhood of the position of minimum deviation than in any other position. (*See* REFRACTION.) The drop will consequently be more intensely illuminated when viewed along these directions of minimum deviation, and since it is these rays with which we are primarily concerned, we shall proceed to the determination of these directions.

Since the angles of incidence and refraction are connected by the relation $\sin i=\mu \sin r$ (Snell's law), μ being the index of refraction of the medium, then the problem may be stated as follows: to determine the value of the angle i which makes $D=2(i-r)+n(\pi-2r)$ a maximum or minimum, in which i and r are connected by the relation $\sin i=\mu \sin r$, μ being a constant. By applying the method of the differential calculus, we obtain $\cos i=\sqrt{\{(\mu^2-1)/(n^2+2n)\}}$ as the required value; it may be readily shown either geometrically or analytically that this is a minimum. For the angle i to be real, $\cos i$ must be a fraction; that is, $n^2+2n>\mu^2-1$, or $(n+1)^2>\mu^2$. Since the value of μ for water is about $\frac{4}{3}$, it follows that n must be at least unity for a rainbow to be formed; there is obviously no theoretical limit to the value of n, and hence rainbows of higher orders are possible.

So far we have only considered rays of homogeneous light, and it remains to investigate how lights of varying refrangibilities will be transmitted. It can be shown, by the methods of the differential calculus or geometrically, that the deviation increases with the refractive index, the angle of incidence remaining constant. Taking the refractive index of water for the red rays as $\frac{108}{81}$ and for the violet rays as $\frac{109}{81}$ we can calculate the following values for the minimum deviations corresponding to certain

assigned values of n.

n	Red	Violet
1	$\pi - 42°.1$	$\pi - 40°.22$
2	$2\pi - 129°.2$	$2\pi - 125°.48$
3	$3\pi - 231°.4$	$3\pi - 227°.08$
4	$4\pi - 317°.07$	$4\pi - 310°.07$

To this point we have only considered rays passing through a principal section of the drop; in nature, however, the rays impinge at every point of the surface facing the sun. It may be readily deduced that the directions of minimum deviation for a pencil of parallel rays lie on the surface of cones, the semivertical angles of which are equal to the values given in the above table. Thus, rays suffering one internal reflection will all lie within a cone of about 42°; in this direction the illumination will be most intense; within the cone the illumination will be fainter, while, outside of it, no light will be transmitted to the eye.

Fig. 2 represents sections of the drop and the cones containing the minimum deviation rays after 1, 2, 3 and 4 reflections; the order of the colours is shown by the letters R (red) and V (violet). It is apparent, therefore, that all drops transmitting intense light after one internal reflection to the eye will lie on the surfaces of cones having the eye for their common vertex, the line joining the eye to the sun for their axis, and their semivertical angles equal to about 41° for the violet rays and 43° for the red rays. The observer will, therefore, see a coloured band, about 2° in width, and coloured violet inside and red outside. Within the band, the illumination will be faint; outside the band there will be perceptible darkening until the second bow comes into view. Similarly, drops transmitting rays after two internal reflections will be situated on covertical and coaxial cones, of which the semivertical angles are 51° for the red rays and 54° for the violet. Outside the cone of 54° there will be faint illumination; within it no secondary rays will be transmitted to the eye. We thus see that the order of colours in the secondary bow is the reverse of that in the primary; the secondary is half as broad again (3°), and is much fainter, because of the longer path of the ray in the drop, and the increased dispersion.

Similarly, the third, fourth and higher orders of bows may be investigated. The third and fourth bows are situated between the observer and the sun, and hence, to see them, the observer must face the sun when looking at the water drops which produce the bows. But the illumination of the bow is so weakened by the repeated reflections, and the light of the sun is generally so bright, that these bows are rarely, if ever, observed except in artificial rainbows. The same remarks apply to the fifth bow, which differs from the third and fourth in being situated in the same part of the sky as the primary and secondary bows, being just above the secondary.

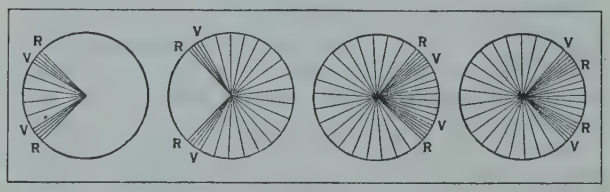

FIG. 2

Physical Theory.—Usually the most conspicuous colour in the principal rainbow is the red; but wide variations are noted from one bow to another, not only in the brightness and purity of the different colours, but also in their angular width. This is not in accordance with the elementary theory, which would require all rainbows to be similar in the distribution of colours as well as in their relative intensity. The fuller treatment of the theory which is based on the undulatory theory of light will be found in J. M. Pernter and F. Exner's *Meteorologische Optik*, or in W. J. Humphreys' *Physics of the Air*. It can be shown that the phenomena depend in a very marked way on the size of the water drops, and that the width of the coloured bands increases as the size of the drop decreases. The elementary theory leads to the result that there is a direction of maximum illumination along the direction of minimum deviation, but the more detailed theory leads to the result that there are other directions along which there is considerable illumination. The subsidiary maxima account for the spurious bows, whose distance from the main bow is greater for small drops than for larger drops. The actual primary rainbow observed is thus the effect of the superposition of a number of bows. If the red of the second bow falls upon the green of the first, the result is to give a bow with an abnormally wide yellow band, since red and green lights when mixed form yellow. This is a very common type of bow, one showing mainly red and yellow, with little or no green or blue. If the drops are smaller the red of the second bow may fall within the blue of the first bow, so that we should then see a second bow (spurious bow) within the first. The phenomena are further complicated by the variation in the size of raindrops within the cloud. Since the smaller drops occur in the upper levels, the spurious bow is generally observable only near the top of the bow.

With very small drops, whose diameter is 0.1 mm. or less, the colours become superimposed, and the rainbow becomes almost a pure white. This type of rainbow, sometimes known as Ulloa's ring or as a fogbow, is seen distinctly only when the observer is very near the cloud which produces it.

The centre of a rainbow is at the same angular distance below the horizon as the sun is above the horizon. Rainbows can be formed by light coming from the reflection of sunlight in a water surface. The observer then sees more than a semicircle of this rainbow, the centre being above the horizon; and he will at the same time see the rainbow formed in the usual way by direct rays from the sun. The two rainbows intersect, and are commonly referred to as intersecting rainbows.

Rainbows can also be formed by moonlight, but the colours are then very faint and difficult to distinguish.

The physical theory of rainbows is given in R. W. Wood, *Optics;* T. Preston, *Theory of Light,* 5th ed. (1928); W. J. Humphreys, *Physics of the Air,* 2nd ed. (1929); J. M. Pernter and F. Exner, *Meteorologische Optik.* (D. BRU.)

RAINBOW TROUT (*Salmo irideus*): *see* SALMONIDAE.

RAINER, ARCHDUKE OF AUSTRIA (1827–1913), was born on Jan. 11, 1827. His father, Rainer, the eighth son of the emperor Leopold II and of his consort Maria Luisa of Spain, was born in Florence in 1783, and from 1818 to 1848 was viceroy of the kingdom of Lombardo-Venetia; his mother was the princess Elizabeth, sister of Charles Albert, king of Sardinia. The archduke was in 1857 placed at the head of the permanent Imperial council organized in 1851, which stood immediately under the emperor and had among its functions the preparation of laws. His experience in this office convinced him that the transition to a constitutional form of government on a liberal and centralized basis was necessary. In 1860 he conducted the negotiations for a strengthened Imperial council; in 1861 he was associated with the promulgation of the charter of the constitution of Feb. 26, 1861, elaborated by the liberal A. von Schmerling administration. In the same year he became curator of the Academy of Sciences. In 1865 he retired from public affairs. In 1872 he was appointed to the supreme command of the newly established Austrian *Landwehr*, to the organization of which he devoted many years. The archduke purchased the papyrus discovered at Fayum, which was called, after him, the Rainer papyrus. He married in 1852 Marie Caroline, daughter of the archduke Charles, the victor of Aspern, but died childless on Feb. 27, 1913.

RAINFALL occurs when active lifting of moist air brings expansional cooling to below the saturation or dewpoint temperatures and causes the cloud droplets to grow to a size where they must fall to earth. The capacity of air for moisture is determined solely by its temperature. Radiation, conduction and mixing are relatively inefficient atmospheric cooling processes producing the less spectacular forms of condensation such as dew, frost, fog and drizzle. Air cooled by lifting may be internally stable and require forced lifting, such as produced by mountains, or it may be potentially unstable and require only an initial impulse to

establish free convection. Rain drops have limited fall-velocities and may be deposited some distance downwind from their point of formation but, in general, rates of precipitation are closely related to rates of condensation. Both are limited by the initial moisture charge and the extent and rate of lifting. Rapid and extensive lifting by free convection in unstable air masses produces the intense rainfalls associated with showers and, in the warmer, more humid air masses, thundershowers.

Passive lifting processes are represented by air gliding upward over mountain slopes or over wedges of cooler air. Active processes are represented by free convection, underrunning by cooler wedges of air, and large-scale dynamic convergence or net horizontal inflow of air at lower levels. The last is the most effective natural lifting process since large masses of air are forced upward to seek escape by divergent flow at a higher level. Any or all of the passive or active lifting processes may operate on stable or unstable air within the life cycle of one major rainstorm. Orographic lifting of stable air gliding upward over gently sloping cooler wedges of air produces the typical winter rains which are uniformly light, steady and extensive. The flash floods of southeastern Texas represent the other extreme, in that highly unstable and very moist maritime air is lifted by the combined effects of horizontal convergence and upglide over cooler continental air and orographic lifting up the Balcones escarpment.

Forced lifting of maritime westerlies produces more than 100 in. of rainfall a year on many windward points on western mountain ranges, leaving the leeward continental areas with 10 in. or less per year. Rainfall is greatest on windward coastal slopes, near tropical waters and in areas of marked cyclonic activity. Rainfall is least near the centre of continents, in colder higher latitudes, leeward of mountain ranges and within areas of persistent anticyclonic activity. Mt. Waialeale, Hawaii, with a 20-yr. average of 460 in. from tropical easterlies is the wettest known point. The nearest competitor is Cherrapunji, Assam, with an annual average of 426 in. from the moist tropical monsoon. Less than 10 in. and more than 60 in. per year represent approximate extremes of rainfall for all of the continents. Rainfall is slight in the central regions of the subtropical anticyclones, which are therefore the desert regions of the earth. In parts of the desert no appreciable rain has ever been observed. Over most of Europe, South America, eastern North America and central

	London	Paris	Berlin	Rome	Moscow	Tokyo	Bombay	New York	Capetown	Sydney
Jan.	1.9	1.5	1.5	3.2	1.1	2.2	0.1	3.3	0.7	3.7
Feb.	1.7	1.2	1.3	2.7	0.9	2.8	0.0	3.3	0.6	4.2
March	1.8	1.6	1.7	2.9	1.2	4.4	0.1	3.4	0.9	4.8
April	1.5	1.7	1.4	2.6	1.5	4.9	0.0	3.3	1.9	5.6
May	1.8	2.1	2.0	2.2	1.9	5.7	0.7	3.5	3.8	5.1
June	2.0	2.3	2.0	1.5	2.0	6.5	20.6	3.5	4.5	4.8
July	2.4	2.2	3.1	0.7	2.8	5.3	27.3	4.1	3.7	4.8
Aug.	2.2	2.2	2.2	1.0	2.9	5.7	16.0	4.3	3.4	3.0
Sept.	1.8	2.0	1.8	2.5	2.2	8.7	11.8	3.4	2.3	2.9
Oct.	2.6	2.3	1.8	5.0	1.4	7.4	2.4	3.4	1.6	3.2
Nov.	2.4	1.8	1.6	4.4	1.6	4.2	0.4	3.3	1.1	2.8
Dec.	2.4	1.7	1.7	3.9	1.5	2.1	0.0	3.3	0.8	2.9
Year	24.5	22.6	22.2	32.7	21.0	59.9	79.4	42.1	25.3	47.9
Days of rain	167	162	152	102		147		123	104	156
Days of snow	13	14	34	2		16		20	0	0

Africa the annual rainfall exceeds 20 in., while over most of Asia, excluding India, Tibet and China, the annual rainfall is less than 20 in., being less than 10 in. in a long tongue extending from Arabia across to northeast Mongolia. The central regions of Australia, most of northern and a part of southwest Africa, portions of the intermontane area of the United States, portions of the west-central coast and southern interior regions of South America also have less than 10 in. of rain in the year. Portions of the west coast of Africa, between the equator and 10° N., a strip of the west coast of India, parts of Assam, a coastal strip of Burma, windward mountain slopes in the temperate latitudes of North and South America, and many isolated tropical stations average more than 100 in. of rain in the year. Rainfall intensities greater than 1 in. in five minutes, 4 in. in one hour or 20 in. per day are quite rare but these intensities on occasion have been more than doubled for the respective durations.

Average annual rainfall plus melted snow water is given in the table for some of the chief cities of the world. Data for other places will be found in standard textbooks on climatology. *See* W. G. Kendrew, *Climates of the Continents* (Oxford, 1937); U.S. Department of Agriculture, *Climate and Man* (1941). Detailed rainfall data for specific areas is best obtained by inquiry directed to any of the more prominent national meteorological services. (A. K. S.)

RAINIER, MOUNT, a peak of the Cascade range in Pierce county, Wash., about 60 mi. from Seattle, and 50 mi. from Tacoma. It is about 14,408 ft. above sea level, the third highest peak in the United States, excluding Alaska. Rainier, as were the other peaks of the Cascade range, was built up by successive layers of material (chiefly andesite) thrown out of its crater. The volcano has long been extinct, but small craters still give forth steam and sulphurous fumes. Its base is set in the green of the Puget sound forest and its snowy cone rises 10,000 ft. Along its sides are 28 glaciers and a number of permanent ice fields, the largest in the United States, which extend down the scarred slopes to the forests, below which they give rise to dashing streams. Beautiful subalpine wild-flower fields follow the receding snow in summer.

Mt. Rainier was first discovered by George Vancouver, who, disregarding the Indian name "Tacoma," named the peak in honour of Adm. Peter Rainier of the royal navy. The first successful ascent was made in 1870 by Gen. Hazard Stevens and P. V. van Trump.

Mt. Rainier national park (241,219.92 ac. in area) was set aside by the U.S. government to preserve the wild mountain scenery in its natural beauties and to make the mountain accessible to the public. Entrances to the park can be reached from Seattle or Tacoma in a few hours by automobile or railway.

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RAINIS, JÓZSEF: *see* PLIEKSANS, JAN.

RAINPROOF FABRICS. Rainproof fabrics can be divided into two general classes—apparel fabrics and nonapparel fabrics. Included in the first group are fabrics used in raincoats, slickers, umbrellas, etc. Among those in the second group are fabrics employed in making tents, tarpaulins, etc. Rainproof fabrics may be actually waterproof or merely water-repellent. Waterproof fabrics are impervious to water, the interstices or pores in the cloth being completely covered or filled by the waterproofing agent or sufficiently stopped up that water will not pass through them at the maximum pressure to which the fabric is exposed under conditions of use.

Water-repellent fabrics, on the other hand, are not impervious to water, the repellent effect being obtained not by closing or materially reducing the size of the interstices or pores, but by treating the cloth with a compound which increases the surface tension between the fibres and the water and thus makes it more difficult for the water to penetrate into and through the fabric.

Thus, a raincoat made from a lightweight water-repellent fabric may withstand a light shower, but not a heavy, driving rain. The degree of water repellency depends on the type and twist of yarn, weight and closeness of weave and efficacy of the water-repellent compound. In general, heavy, closely woven fabrics are more water-repellent than are light, loosely woven fabrics.

Other important applications of waterproof and water-repellent fabrics, in addition to those mentioned above, include shower-bath curtains, spotproof table covers and sheetings for hospital use. Fabrics which are both waterproof and chemical-resistant find use in such applications as protective clothing for workers engaged in the handling of chemicals. Fabrics which are both waterproof and gasproof or airtight are employed in the aeronautical industry and as a protection against noxious gases.

Many different processes are employed for rendering fabrics waterproof or water-repellent. In general, truly waterproof fab-

rics are obtained by impregnating or coating the cloth with rubber, synthetic rubber, pyroxylin (cellulose nitrate solution), cellulose acetate, linseed oil, tar or synthetic resins. Various degrees of water repellency can be imparted to fabrics by treating them with such materials as aluminum acetate, paraffin wax emulsions, metallic soaps, cuprammonium solution or quaternary ammonium compounds.

Raincoats are made from cotton, silk, rayon or wool fabrics which have been rendered rainproof or showerproof by any one of several processes. One of the earliest methods employed was that invented by Charles Macintosh, which made use of rubber as a waterproofing agent; raincoats made from cloth treated in this way were known as mackintoshes. Oilskins are made by applying boiled linseed oil, together with a suitable drier and pigments to give the desired colour, to lightweight or mediumweight cotton fabrics. Silk fabrics treated in a similar manner, and known as oiled silk fabrics, are being rapidly superseded for use as raincoats by silk or rayon fabrics which have been waterproofed by treatment with a vinyl resin lacquer or another synthetic resin. Another type of waterproof raincoating is made by rubberizing cotton fabrics.

Water-repellent fabrics employed for raincoats are usually made from cotton or wool. One of the best-known methods is to treat the fabric in solution of aluminum acetate and then in a soap solution or an emulsion containing soap and paraffin or Japan wax. Another method makes use of a water-repellent agent consisting essentially of a solution of aluminum acetate containing paraffin wax in colloidal dispersion. Still another process employs long-chain quaternary ammonium compounds that actually combine with the fibre to form a durable, water-repellent coating.

Mixtures of various materials are employed for coating canvas, duck and other heavy cotton fabrics used for tents, tarpaulins, etc. Among these are included asphalt, paraffin, tar, beeswax and lead oleate. An effective method for waterproofing cotton fabrics, which also renders the fabric mildew-resistant, makes use of cuprammonium solution.

See H. P. Pearson, *Waterproofing Textile Fabrics* (1924); S. Mierzinski, *The Waterproofing of Fabrics,* trans. by A. Morris and H. Robson, 3rd ed. rev. by H. B. Stocks (1921). (W. W. Ch.)

RAIN TREE (*Pithecellobium saman*), a tropical South American tree, so called from the fact that the ejection of juice by cicadas (*q.v.*) upon it causes it to appear to be always raining under its branches. *Andira inermis,* which belongs to the same family (Leguminosae), is also called rain tree for the same reason.

RAIPUR, a town and former district of India in the Chhattisgarh (*q.v.*) division of the Central Provinces. The town is 188 mi. E. of Nagpur and has a station on the Bengal-Nagpur railway. There are ruins of an immense fort with many tanks and old temples. The town and civil station is situated on a red laterite plain and the climate is extremely hot. Besides the usual institutions at the headquarters of a division and district, there is the Rajkumar college, where the sons of the chiefs of Chhattisgarh, as well as of chiefs of Orissa, are educated under a European principal. The college also admits sons of the greater landholders. Pop. of the town (1941) 63,465.

The District of Raipur, area 8,205 sq.mi., pop. (1941) 1,516,686, occupied the south and centre of the Chhattisgarh rice plain (*see* Chhattisgarh). The district was traversed by the Bengal-Nagpur railway from Bombay to Calcutta, and numerous roads were constructed in the famines. Raipur is connected by rail with Vizianagram on the east coast section of the Bengal-Nagpur railway and from there with the port of Vizagapatam.

RAIS (or Retz), **GILLES DE** (1404–1440), marshal of France, the central figure of a 15th-century *cause célèbre,* was the son of Guy de Montmorency-Laval, the adopted son and heir of Jeanne de Rais, and of Marie de Craon. He was born at Machecoul in Sept. or Oct. 1404 and was brought up by his grandfather, Jean de Craon. Chief among his great possessions was the barony of Rais (erected in the 16th century into the peerage-duchy of Retz), south of the Loire, on the marches of Brittany. He joined the Montforts, supporting John V of Brittany against the house of Penthièvre. He helped to release Duke John from Oliver of Blois, count of Penthièvre, and was rewarded by extensive grants of land, subsequently commuted by the Breton parliament for money payments. In 1420 he married Catherine of Thouars, a great heiress in Brittany, Vendée and Poitou. In 1426 he raised seven companies of men-at-arms and, under Richemont (Richmond) (*see* Arthur III of Brittany), began active warfare against the English. He accompanied Joan of Arc to Orléans, fighting by her side there and afterward at Jargeau and Patay. He had advocated further measures against the English on the Loire before carrying out the coronation of Charles VII at Reims. On July 17, 1429, he was made marshal of France at Reims. In the winter of 1430 he was in Normandy at Louviers, perhaps with a view to the release of Joan, then a prisoner at Rouen. His military career ended in 1436. He expended great sums in the king's service and maintained a court more suited to royal than baronial rank. He was a munificent patron of literature and of music, and his library contained many valuable works, he himself being a skilled illuminator and binder. At the chief festivals he gave performances of mysteries and moralities, and it has been asserted that the *Mystère de la Passion,* acted at Angers in 1420, was staged by him in honour of his own marriage. The original draft of the *Mystery of Orleans* was probably written under his direction. He ran into financial difficulties and began to sell his estates for small sums, providing his heirs with material for many lawsuits. Among those who profited by his prodigality were the duke of Brittany and his chancellor, Jean de Malestroit, bishop of Nantes; but in 1436 his kinsfolk appealed to Charles VII, who proclaimed further sales to be illegal. John V refused to acknowledge the king's right to promulgate such a decree in Brittany and replied by making Gilles de Rais lieutenant of Brittany and by acknowledging him as a brother-in-arms.

Gilles hoped to redeem his fortunes by alchemy and also spent large sums on necromancers, seeking to guarantee himself from evil consequences by extravagant charity and splendid celebration of the rites of the church. The abominable practices of which he was really guilty seem to have escaped the notice of his equals or superiors, though suspected by the peasantry. His wife left him in 1434–35; and when his brother René de la Suze seized Champtocé, family considerations no doubt imposed silence. His servants kidnapped children, generally boys, whom he tortured and murdered. The number of his victims was stated in the ecclesiastical trial to have been 140. In 1440 he came into conflict with the church by an act of violence which involved sacrilege and infringement of clerical immunity and in the autumn he was arrested and cited before the bishop of Nantes on various charges, the chief of which were heresy and murder. With the latter count the ecclesiastical court was incompetent to deal, and Gilles refused to accept its jurisdiction (Oct. 8). Terrified by excommunication, however, he secured absolution by confession.

A parallel inquiry was made by Pierre de l'Hôpital, president of the Breton parliament, by whose sentence he was hanged (not burned alive as is sometimes stated) on Oct. 26, 1440, with two of his accomplices. In view of his confessions his guilt seems certain, but the irregularities of the proceedings, the fact that his chief accomplices went unpunished, taken together with the financial interest of John V in his ruin, have left a certain mystery over the trial. His name is connected with the tale of Bluebeard (*q.v.*) in local tradition at Machecoul, Tiffauges, Pornic and Chéméré. The records of the trial are preserved in the Bibliothèque Nationale in Paris, at Nantes and elsewhere.

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RAISIN, the name given to the dried fruits of certain varieties of the grapevine, which grow principally in the warm climate of central California and the Mediterranean coasts. Leading countries of production are the United States, Turkey, Australia, Iran, Greece and Spain. Dried grapes, or raisins, are rich in fruit sugar, which acts as a natural preservative of the product, and are of great antiquity as a human food (Numbers vi, 3; I Samuel xxv, 18). "Raisins of the sun" are obtained by letting the fruit

remain on the vines after it has come to maturity, where there is sufficient sunshine and heat in the autumn, till the clusters dry on the stalks. The more usual process, however, is to cut the fully ripened clusters and expose them, spread out, for several days in the rays of the sun. In unfavourable weather, they may be dried in a heated chamber, but are then inferior in quality. Sun-drying may be hastened by first dipping the grapes in a soda or lye bath to puncture the skin, but this process is not generally followed in growing areas that afford a drying season free from rainfall, such as the interior valleys of California. Some varieties are dried and retained on their stems and sent into the market as clusters for table use, but the greater part are separated from their stems in the process of drying and cleaning.

Raisins are of three types: (1) large seeded raisins made from the Muscat of Alexandria variety of grape, or Gordo Blanco, called Malagas in general world commerce and muscats in California; (2) small seedless raisins made from the Sultanina grape, called sultanas in most parts of Europe and Thompson seedless in California; (3) very small seedless raisins made from a black grape known in most countries as the Black Corinth. In commerce they appear as Zante currants or Greek currants.

There are also miscellaneous varieties of grapes dried in some countries, especially in those bordering on the eastern end of the Mediterranean, which are inferior as raisins and are termed "dried grapes."

Malaga-type raisins of commerce come chiefly from the provinces of Malaga, Valencia and Alicante in Spain, and from California and Australia. The variety grown in California, called the muscat, is sweet and extensively used in desserts. It is packed for household purposes by the removal of seeds by automatic machinery, and so processed that the raisins can be separated easily as they come from the box.

Sultana-type raisins are cultivated extensively in California, Smyrna and Australia. Those grown in Smyrna are soda-dipped in the curing process, having a golden-yellow colour and a thin, translucent skin. Those grown in Australia are also usually dipped in the curing process, but those grown in California are exclusively sun-dried except for a limited quantity intended principally for certain portions of the export market.

Zante currants are grown in small quantities in a number of countries, but the principal world supply comes from Greece and Australia.

After 1918 world demand for raisins shifted from seeded to seedless varieties. Seedless varieties are successfully cultivated in California and in Australia, and the United States and Australia are large exporters. Almost all the raisins grown in the United States are produced in the San Joaquin valley of California within a radius of 100 mi. of the city of Fresno. Approximately 10,000 growers are engaged in the production of raisins in this district, and the processing of these raisins centres in Fresno, where there is the largest dried fruit plant in the world. (W. N. K.)

RAJAH, a Hindu title for a chief, or prince, derived from the same root as the Latin *rex*. Other forms are rao, rana and rawal, while chiefs of high rank are styled maharaja, maharao and maharana.

The Hindustani form is rai, and the title of the Hindu emperor of Vijayanagar in south India was raya.

RAJAHMUNDRY, a town of India, in the East Godavari district of Madras. Pop. (1941) 74,564. It is a growing place on the left bank of the river Godavari, at the head of the delta, 360 mi. N. of Madras, and has a station on the East Coast railway, which is there carried across the river by a bridge of 56 spans.

Tradition divides the merit of founding Rajahmundry between the Orissa and Chalukya princes. In 1470 it was wrested from Orissa by the Mohammedans, but early in the 16th century it was retaken by Krishna Raja. It continued under Hindu rule till 1572, when it yielded to the Mohammedans of the Deccan under Rafat Khan. It passed into the possession of the French in 1753, but they were driven out by the British in 1758.

RAJASTHANI LANGUAGE, the language of Rajasthan of Rajputana, an Indo-Aryan vernacular closely related to Gujarati (*q.v.*). It is spoken in Rajputana and the adjoining parts of central India, and has several dialects, the principal of which are Jaipuri, Marwari, Mewati and Malvi. Harauti, an important variety of Jaipuri, is spoken in the states of Kota and Bundi.

See vol. ix of the *Linguistic Survey of India* for a full account; *see* also GUJARATI.

RAJGARH, a former Indian state in the Bhopal agency of central India. Area, 926 sq.mi. Pop. (1941) 148,609. The chief, who had the title of rajah and a salute of 11 guns, was a Rajput of the Ponwar clan. This state and Narsingarh were the result of a partition in the 17th century. It afterward became tributary to Scindia, but fell under the general settlement of Malwa in 1818. It was merged with the state of Madhya Bharat in 1948. The town of Rajgarh had a population of 7,638 in 1941.

RAJGIR HILLS, a range of hills in former British India, in the south of the Patna district of Bihar. They form part of a range, extending northeast from near Bodh-Gaya for 40 mi., and at one place rise to 1,462 ft., but elsewhere seldom exceed 1,000 ft. in height. The hills in Patna district consist of two parallel ridges. In the valley between, south of the village of Rajgir, was built the old city of Rajagriha, "the royal residence." Legend ascribes it to Jarasandha, king of Magadha (south Bihar), who had his capital at Giribraja, "the city of hills." The outer fortifications can be traced on the crests of the hills over a distance of more than 25 mi.; they are 17½ ft. thick, built of massive undressed stones without mortar. According to Sir John Marshall, we can assign these ruins only to "some uncertain age before the dawn of history and rank them, as their stupendousness entitles them to be ranked, among the greatest wonders which primeval man has bequeathed to us." The remains of New Rajagriha, the reputed capital of Bimbisara (*c.* 520–490 B.C.), lie two-thirds of a mile north of the valley.

The Rajgir hills are associated with the life of Buddha, who often taught there. Chhatagiri is the old Gridhrakuta, or vulture's peak, which was one of his favourite resorts. One of the towers on the Baibhar hill (Vaibhargiri) has been identified as the Pipara stone house in which Buddha lived. The Sattapanni, the cave in which after his death the council of his disciples was held to record the tenets of the faith, has been identified with different sites on this hill and with the Soubhandar cave at its foot; the latter is now believed to have been excavated by Jains in the 3rd or 4th century A.D. A brick mound, topped by a Jain shrine, stands in the centre of the valley. Rajgir is a place of pilgrimage. There are modern Jain temples built on the hills round the valley. There are also hot springs in the valleys surrounded by Hindu shrines.

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RAJKOT, a town in India, in Saurashtra state. Situated in the middle of the peninsula of Kathiawar, it is a railway centre and formerly included an area known as the Civil station, leased to the British government for the headquarters of the Western India States agency.

The Civil station contained the Rajkumar college, the first of the several schools of its type to be established in India for the education of the cadets of the ruling families of the states. The former princely state of Rajkot, which merged with Saurashtra in 1948, had an area of 282 sq.mi. and pop. (1941) of 102,951; the town (1941) 52,178.

RAJMAHAL, a former capital of Bengal, India, now a village in the district of the Santal Parganas, situated on the right bank of the Ganges, where that river makes a turn to the south. Pop. (1941) 4,676.

Rajmahal was chosen for his capital by Man Singh, Akbar's governor, in 1595–96, but in 1608 the seat of government was transferred to Dacca. It was again made the seat of government by the prince Shah Shuja in 1639, and was a second time superseded by Dacca 20 years later.

Even in 1665 Manucci found that it had fallen into ruin, being full of dilapidated palaces, great fallen mansions and neglected gardens. A pavilion called the Sangi Dalan is all that survives of Shah Shuja's palace. Rajmahal has given its name to a range of

hills, comprising an area of about 2,000 sq.mi., which rise to a height of about 2,000 ft. They are inhabited by an aboriginal race known as Maler (the Malli of Megasthenes) or Sauria Paharias; *i.e.*, "hillmen." The valleys are inhabited and cultivated by the Santals, a different aboriginal race.

RAJPIPLA, formerly one of the Gujarat states in India, occupying a hilly tract between the rivers Narbada and Tapti; area 1,515 sq.mi.; incorporated into the Broach district of Bombay in 1949. Pop. (1941) 249,032. The soil is fertile, cotton being the chief crop, and there are teak forests in the hills. A light railway, constructed at the cost of the state, connects Rajpipla with Anklesvar in Broach district. The old fort of Rajpipla, in the hills, is now deserted. The modern city of Rajpipla is situated on the river Karjan, 32 mi. from Surat. Pop. (1941) 15,855.

RAJPUT, the generic term for a number of castes, which gives Rajputana (*q.v.*) its name and is widely spread over the rest of northern India. Claiming to have replaced the ancient Kshattriyas (*q.v.*), the Rajputs are a dominant, fighting, landowning class. Of Indo-Aryan type, they have been also recruited from earlier ethnic elements which rose to power and from invading races, notably the Huns. As a body they are physically robust, brave and chivalrous, cherishing the feudal spirit and traditions. Pride of birth makes them punctilious in questions of honour, but poor cultivators when in reduced circumstances. They still hold somewhat aloof from the civil professions, regarding military service as their proper *métier*.

Rajput history is a bardic adaptation of myth to courtly adulation. It asserts that to their two original races, the Solar and the Lunar, were added four, the Agnikula, "fire sprung," purified by Brahmans in the great *agnikunda*, "fire pit," on Mt. Abu to fight the Daityas, "Titans." Being interpreted, this must mean that the four clans were Brahmanized, or Hinduized, to suppress some anti-Brahmanical people or foreign foes. The four were the Chalukya, modern Solanki, a Sanskritized patronymic of Chalkya, a dynasty in the Deccan, but immigrant from Kashmir and probably Gurjara by race; the Pratihara, now Parihar, "durward," known to be Gurjaras; the Pramara, now Panwar; and Chahamana, now Chauhan. These became eponyms of leading Rajput tribes, and the legend traced their origin to Rudra, Brahma, Indra and Vishnu. Folk etymology also derived Chahamana from Chaturbhuja, "four-armed." From these, by some incoherent process, were derived 36 "royal races," never the same in any two versions of their names, but in some including the Jat, Hun, Ahir and Bar-Gujar clans.

To these must be added clans like Chandel, doubtless of Gond origin. Below them were ranged the 84 mercantile tribes, chiefly of Rajput origin, in whom we may see the Bhatias and recall the ancient Vaisyas.

RAJPUTANA was the name formerly given to a group of Indian states under the political charge of an agent to the governor general of India, lying between lat. 23° and 30° N. and between long. 69° 30′ and 75° 15′ E. By a series of constitutional changes in 1948–49, the states of Alwar, Banswara, Bharatpur, Bikaner, Bundi, Dholpur, Dungarpur, Jaipur, Jaisalmer, Jhalawar, Jodhpur, Karauli, Kotah, Partabgarh, Shahpura, Tonk and Udaipur (Mewar) were formed into the united state of Rajasthan, as a unit of the Union of India. In Jan. 1950 part of Sirohi was added. Rajasthan had an area of 128,424 sq.mi. in 1951 and a population (1951) of 15,297,979, compared with the former Rajputana's area of 132,559 sq.mi. and population (1941) of 13,670,208 (13,282,105 being in the areas taken into Rajasthan). The difference arises from the incorporation into the province of Bombay of the small states of Danta, Sirohi and Palanpur. All the Rajputana states were under Rajput rulers, except Tonk, which was Mohammedan, and Bharatpur and Dholpur, which were Jat.

Within the geographical area of Rajputana or Rajasthan is the chief commissioner's province of Ajmere-Merwara, with an area of 2,425 sq.mi. and a population of 692,506 in 1951.

Jaipur was made provisional capital of Rajasthan. Its population was 175,810 in 1941 and 291,183 in 1951.

As constituted at mid-20th century, Rajasthan was bounded on the west by the Pakistan provinces of Sind and West Punjab; on the north by Delhi, the Patiala and East Punjab States Union, and East Punjab; on the east by the United Provinces (Uttar Pradesh) and the United State of Madhya Bharat; and on the south by the province of Bombay.

Physical Features.—The Aravalli range of mountains intersects the country from southwest to northeast. About three-fifths of Rajputana lies northwest of the range and comprises the states of Bikaner, Jaisalmer and Jodhpur. With the exception of the districts of Jodhpur which lie immediately below the Aravallis, this division is sandy, ill-watered and unproductive, improving gradually from a desert in the northwest and west to comparatively fertile land in the east. The country to the east and southeast of the Aravallis includes fertile lands, hill ranges and long stretches of forest, where fuel and fodder are abundant. The chief rivers are the Luni, the Chambal and the Banas. The Chambal rises in the highlands of the Vindhyas and discharges itself into the Jumna after a course of 560 mi. There are several important artificial lakes, constructed for storing water. The only basin of any extent is the Sambhar salt lake, of about 50 mi. in circuit.

From the geological point of view, the country may be divided into three regions—the central and largest, comprising the whole width of the Aravalli system, formed of very old submetamorphic and gneissic rocks; an eastern region, with a sharply defined boundary, along which the most ancient formations are abruptly replaced by the great basin of the Vindhyan strata or are overlaid by the still more extensive spread of the Deccan trap, forming the plateau of Malwa; and a western region, of ill-defined margin, in which, besides some rocks of undetermined age, it is more or less known or suspected that Tertiary and Secondary strata stretch across from Sind, beneath the sands of the desert, toward the flanks of the Aravallis. Rajputana produces a variety of metals. Ore of cobalt and zinc blende are peculiar to it. Copper and lead are found in several parts of the Aravalli range and of the minor ridges in Alwar and Shaikhawati, and iron ores abound in several areas. Alum and blue vitriol (sulphate of copper) are manufactured from decomposed schists at Khetri in Shaikhawati.

The climate over the whole of Rajputana is very dry and hot during the summer, whereas in the winter it is much colder in the north than in the lower districts, with hard frost and ice on the Bikaner borders. The rainfall is unequally distributed.

Social Structure and Occupations.—The territory was called Rajputana because it was politically possessed by Rajputs (*see* RAJPUT). The whole number of this race was only about 620,000 at the beginning of the 20th century, and nowhere did they form a majority of the whole population in a state; but they are strongest, numerically, in the northern areas and in Udaipur. The Brahmans rank first; with them may be classed the Bhats, the keepers of secular tradition and of the genealogies. Next come the mercantile castes, mostly belonging to the Jain sect; these are followed by the powerful cultivating tribes, such as the Jats and Gujars, and then come the so-called aboriginal tribes, chief of whom are the Minas, Bhils and Meos. Rajasthani (and its dialects) is the chief language, being spoken by more than 70% of the population.

The mass of the people are occupied in agriculture. The chief manufactures are cotton and woollen goods, carvings in ivory and working in metals, etc., all of which handicrafts are chiefly carried on in the eastern states. The system of agriculture is very simple; in the country west of the Aravallis only one crop is raised in the year, while in other parts south and east of the Aravallis two crops are raised annually, and various kinds of cereals, pulses and fibres are grown.

History.—Before the invasion of upper India by the Mohammedans, Rajputana was subject for the most part to two or three powerful tribal dynasties. Chief of these were the Rahtors, who ruled at Kanauj; the Chauhans of Ajmer; the Solankis of Anhilwara, in Gujarat; the Gehlots with the Sisodhyia sept, which remained in Mewar or Udaipur; and the Kachwaha clan, which remained in Jaipur. These tribal dynasties of Rajputs were gradually supplanted by the Moslem invaders of the 11th century and weakened by internal feuds. The clans were finally either conquered, overawed or conciliated by Jalal Ud-Din Mohammed Akbar—all except the distant Sisodhyia clan, which, however, submitted to Jahangir in 1616. The Marathas, having been called in by the Rahtors to aid them, took possession of Ajmer about 1756; thenceforward Rajputana became involved in the general disorganization of India. By the end of the 18th century nearly the whole of Rajputana had been virtually subdued by the Marathas. On the outbreak of the Pindari War in 1817, the British government offered its protection. The Pindaris were put down, Amir Khan sub-

mitting and signing a treaty which constituted him the first ruler of the existing state of Tonk. By the end of 1818 similar treaties had been executed by the other Rajput states with the paramount power. The political history of Rajputana then became comparatively uneventful. The great storm of the mutiny of 1857 was short, as most of the rajahs remained loyal.

Rajputana is of great archaeological interest, possessing some fine religious buildings in ruins and others in excellent preservation. Among the latter are the mosques at Ajmer and the temples on Abu. But the most characteristic features of architecture in the country are shown in the forts and palaces of the chiefs.

RAJSHAHI, a district, division and town of India, in the province of Bengal. The administrative headquarters are at Rajshahi, formerly called Rampur Boalia, pop. (1941) 40,778. Area of district 2,526 sq.mi.; pop. (1941) 1,571,750. Rajshahi comprises an alluvial plain seamed with old river-beds and studded with marshes, but on the north and west a slightly elevated country is found in the Barind. Rice is the staple crop, with pulses, oil-seeds and jute. Indigo has disappeared and the silk industry is moribund. The hemp grown on a small tract in the north of the district supplies all the *ganja* that is consumed in Bengal. The district is traversed from south to north by the main line of the Eastern Bengal state railway. The town is 28 mi. by road from the Nator station of the Eastern Bengal state railway and has a steamer station on the Ganges. It also has a government college and the museum of the Varendra Research society.

The DIVISION OF RAJSHAHI is coextensive with northern Bengal, from the Ganges to the mountains. It comprises the districts of Rajshahi, Dinajpur, Jalpaiguri, Malda, Darjeeling, Rangpur, Bogra and Pabna. Area, 19,642 sq.mi. Pop. (1941) 12,040,465.

RÁKÓCZY, the name of a noble Hungarian family, which in the 10th century was settled in the county of Zemplén, members of which played an important part in the history of Hungary during the 17th century.

GEORGE I., prince of Transylvania (1591–1648), who began his career as governor of Onod, was the youngest son of Sigismund Rákóczy (1544–1608), who was for a short time prince of Transylvania. He took a leading part in the rebellion of Bethlen Garbo, who made him commandant of Kassa, and was elected prince of Transylvania by the diet of Segesvár on Nov. 26, 1630. He followed Bethlen's national Hungarian policy, allied himself with Gustavus Adolphus of Sweden and on Feb 2, 1644, with the consent of the Pope, declared war on the Emperor Ferdinand III., drove him out of most of Hungary, and forced him to conclude the Peace of Linz (Sept. 16, 1645), which accorded full religious liberty to the Magyars, and ceded to Rákóczy the fortress of Regéc and the Tokaj district. On the death of Wladislaus IV. (1648) Rákóczy aimed at the Polish throne also, but died before he could accomplish his design. His capital, Gyula Fehérvár, was a great Protestant resort and asylum.

See Sándor Szilagyi, *The Rákóczy Family in the 18th Century* (Hung.) (Pest, 1861).

GEORGE II., prince of Transylvania (1621–1660), was the eldest son of George I. and Susannah Lorántffy. He was elected prince of Transylvania during his father's lifetime (Feb. 19, 1642), and married (Feb. 3, 1643), Sophia Báthory. On ascending the throne (Oct. 11, 1648), he hoped to realize his father's Polish ambitions, and he allied himself, in 1649, with the Cossack hetman, Bogdan Chmielnicki, and the hospodars of Moldavia and Wallachia In 1657, as the ally of Gustavus Adolphus, he led his allies against the Polish king, John Casimir, took Cracow and entered Warsaw with the Swedes; but the moment his allies withdrew the whole scheme collapsed, and it was only on the most humiliating terms that the Poles finally allowed him to return to Transylvania. Here (Nov. 3, 1657) the diet, at the command of the Porte, deposed him for undertaking an unauthorized war, but in January 1658 he was reinstated by the Medgyes Diet. Again he was deposed by the grand vizier, and again reinstated. The Turks again invaded Transylvania, and Rákóczy died at Nagyvárad of the wounds received at the battle of Gyula (May 1660).

See Imre Bethlen, *Life and Times of George Rákóczy II.* (Hung.) (Nagy-Enyed, 1829); *Life* (Hung.) in Sándor Szilagyi's *Hungarian Historical Biographies* (Budapest, 1891).

FRANCIS I., prince of Transylvania (1645–1676), was the only son of George Rákóczy II. and Sophia Báthory. He was elected prince of Transylvania during his father's lifetime (Feb. 18, 1652), but lost both crown and father at the same time, and withdrew to the family estates, where, at Patak and Makovica, he kept a splendid court. His mother converted him to Catholicism, and on March 1, 1666 he married Helen Zrinyi. In 1670 he was implicated in the Zrinyi-Frangepán conspiracy, and only saved his life by the interposition of the Jesuits on the payment of an enormous ransom.

See Sándor Szilagyi, *The Rákóczy Family in the 17th Century* (Hung.) (Pest, 1861).

FRANCIS II., prince of Transylvania (1676–1735), was born at Borsi, Zemplén, on March 2, 1676. Having lost his father during infancy, he was educated under the guardianship of his mother, Heleń Zrinyi, in an ultra-patriotic Magyar environment, though the Emperor Leopold I. claimed a share in his tutelage. In 1682 his mother married Imre Thököly, through whose speculations Rákóczy lost the greater part of his estates. As a child of eleven he witnessed the heroic defence by his mother of his ancestral castle of Munkács against Count Antonio Caraffa (d 1693). On its surrender (Jan. 7, 1688) the child was transferred to Vienna that he might be isolated from the Hungarian nation and brought up as an Austrian magnate. Cardinal Kollonics, the sworn enemy of Magyar separatism, now became his governor, and sent him to the Jesuit college at Neuhaus in Bohemia. In 1690 he completed his course at Prague, and in 1694 he married Maria Amelia of Hesse-Rheinfels, and lived for the next few years on his Hungarian estates. Rákóczy's birth, rank, wealth and brilliant qualities made him the natural leader of the Magyar nation. On the eve of the war of the Spanish Succession Rákóczy, with some other magnates, entered into correspondence with Louis XIV. for assistance through one Longueval, a Belgian general in the Austrian service. Longueval betrayed his trust, and Rákóczy was arrested and imprisoned at Eperjes. His wife saved him from certain death by enabling him to escape to Poland in the uniform of a dragoon officer. On June 18, 1703 he openly took up arms against the emperor; but the Magyar gentry stood aloof, and his ill-supported peasant levies (the Kuruczes) were repeatedly scattered. He had, indeed, some initial success; but the battle of Blenheim made any direct help from France impossible, and on June 13, 1704 his little army of 7,000 men was routed by the imperialists at Koronco and subsequently at Nagyszombat. Want of arms, money, native officers and infantry, made, indeed, any permanent success in the open field impossible; yet he drilled his army into some degree of efficiency, and even after the rout of Pudmerics (Aug. 11, 1705), disposed of 100,000 men.

Rákóczy, who had already been elected Prince of Transylvania (July 6, 1704), now surrounded himself with a council of state of 24 members. But his efforts to secure toleration for his Calvinist followers alienated the pope, who dissuaded Louis XIV. from assisting him. Peace negotiations with the emperor during 1705 came to nothing, the latter refusing to acknowledge the independence of Transylvania, while France would not recognize the rebels officially till they had formally proclaimed the deposition of the Habsburgs, which last desperate measure was actually accomplished by the Onod diet on June 13, 1707. This measure, however, alienated both the emperor's foreign allies and the majority of the Magyar gentry, while, after all, Louis XIV sent no effective help. On Aug. 3, 1708 Rákóczy was heavily defeated at Trencsen (Trenčin), and again at Romhány (Jan. 22, 1710). A desperate effort to secure the help of Peter the Great also failing, Rákóczy quitted his country for ever on Feb. 21, 1711, refusing to accept the general amnesty conceded after the peace of Szatmár. (*See* HUNGARY, *History*.) He lived for a time in France on the bounty of Louis XIV., finally entering the Carmelite Order. In 1717, with forty comrades, he volunteered to assist the Turks against the Austrians, but his services were not utilized. He lived for the rest of his life at Rodostó, where he died on April 8, 1735.

See *Autobiography of Prince Francis Rákóczy* (Hung.) (Miskolcz, 1903); E Jurkovich, *The Liberation Wars of Prince Francis Rákóczy*

(Hung.) (Beszterczebánya, 1903); S. Endrödi, *Kurucz Notes, 1700–1720* (Hung.) (Budapest, 1897).

RAKOVSKY, CHRISTIAN GEORGIEVICH (1873–), Russian politician and diplomat, of Bulgarian descent and Rumanian nationality, was born on Aug. 13, 1873 at Kotel, Bulgaria. His father's home in the Dobruja passed after the Russo-Turkish war to Rumania, and the family became Rumanian. Rakovsky's Bulgarian ancestors, especially his grandfather, had organized risings against the Turkish rule, and the revolutionary traditions of the family were revived in Christian Rakovsky. In 1890 on account of his socialist activities all appointments in Bulgarian schools were closed to him. He therefore went to Geneva, where he joined the international social democratic student movement, and came in contact with Plekhanov and other Russian social democrats; and also to Germany, where he met Liebknecht. He was expelled from Prussia in 1894; went to France, where he graduated as a doctor of medicine at Montpellier, and wrote his thesis on *The Etiology of Criminality and Degeneration* (1897). Returning to Bulgaria, he recommenced revolutionary activities, and in *Russia in the East* (1898) denounced Tsarist politics. In 1900 he served as an officer in the Rumanian army. During the peasant riots of 1907 he was expelled from Rumania, his title to Rumanian citizenship not being considered adequate, and his civil rights were only restored in 1912. The five years of Rakovsky's exile were interrupted by illicit homecomings and consequent labour troubles.

After Rumania entered the World War Rakovsky was arrested and imprisoned in various places, and finally at Jassy, whence he was released by the Russians on May 1, 1917. After the Soviets came into power in November he became a member of the central executive committee of the Union, and in 1919 he became a member of the central committee of the Communist party. Rakovsky was well known as a writer on political and economic subjects under the pen name of "Insarov," and a number of his books were written and published in Russia (*Modern France*, 1900; *Metternich and His Time*, etc.).

Rakovsky's diplomatic career began with his appointment as head of the delegation entrusted with the peace negotiations with the Ukrainian central rada. In 1919 he was appointed president of the soviet of people's commissars of the Ukraine, and in 1922 represented Russia at the conference of Genoa. In 1924 he was the Soviet chargé d'affaires in London, and in 1926–27 he was Soviet ambassador to France. His support of Trotsky led, in 1928, to his expulsion from the Communist party and exile to Stalingrad. He was re-admitted in 1934, and was a departmental chief in the Commissariat of Health until 1937, when he was dismissed. He was among the 21 members of the "Right Trotskyist *bloc*" arrested in Feb. and tried in March 1938. Rakovsky was sentenced to 20 years' imprisonment.

RALEIGH, SIR WALTER (*c.* 1552–1618), British explorer, was born about 1552, the son of Walter Raleigh, of Fardell, and Catherine, daughter of Sir Philip Champernown of Modbury. He was born at the farmhouse of Hayes near Budleigh Salterton Bay. In 1568 he was entered as a commoner of Oriel College, Oxford. In 1569 he followed his cousin Henry Champernown, who took over a body of English volunteers to serve with the French Huguenots and was perhaps present at the battle of Jarnac (Mar. 13, 1569). Nothing is known with certainty of his life until February, 1575, when he was resident in the Temple. In June 1578 his half-brother Sir Humphrey Gilbert obtained a patent for six years authorizing him to take possession of "any remote barbarous and heathen lands not possessed by any Christian prince or people." During 1578 Gilbert led a piratical expedition against the Spaniards. Raleigh accompanied his half-brother as captain of the "Falcon," and was perhaps with him in an unsuccessful voyage in 1579. In 1580 Raleigh was twice arrested for duels, and he attached himself to the earl of Leicester, and to the earl of Oxford. Late in 1580 he was serving as captain of a company of foot in Munster. He took an active part in suppressing the rebellion of the Desmonds; he advocated a ruthless policy against the Irish, and recommended assassination as a means of getting rid of their leaders.

In December 1581 he was sent home with despatches and his great fortune dates from his arrival at court, where he was already known through his correspondence with Walsingham. He had corresponded with Walsingham for some time. It is possible that Raleigh did throw his mantle on the ground to help the queen to walk dry-shod over a puddle, and that he scribbled verses with a diamond on a pane of glass to attract her attention. His tall and handsome person, his caressing manners and his quick wit certainly pleased the queen, and the stories in Sir Robert Naunton's *Fragmenta Regalia* and in Fuller's *Worthies* represent at least the mythical truth as to his rise into favour. The rewards showered on him were out of all proportion to his services in Ireland. In February 1583 he accompanied the duke of Anjou to Flanders. In 1583 he received the grant of Durham House, Strand, and in the same year the queen's influence secured him two beneficial leases from All Souls, Oxford, which he sold to his advantage, and a patent to grant licences to "vintners"—that is, tavern keepers, which he subleased. In 1584 he had a licence for exporting woollen cloths. He was knighted in 1584. In 1585 he succeeded the earl of Bedford as Warden of the Stannaries. Raleigh made a good use of his new powers in the mining districts of the west. He reduced the old customs to order, and showed himself fair to the workers. In 1586 he was given 40,000 acres of the forfeited lands of the Desmonds, on the Blackwater in Ireland. He planted English settlers, and introduced the potato and tobacco. In 1587 he received a grant of part of Babington's forfeited land.

Raleigh was now at the height of his favour; Queen Elizabeth always had several favourites at once, lest any one might be supposed to influence her. She treated Raleigh exclusively as a court favourite, but never gave him any great office, nor admitted him to the council. Even his post of captain of the Guard, given in 1587, was mainly ornamental. The patent given to his half-brother Sir Humphrey Gilbert ran out in 1584. To avert this loss Raleigh, partly out of his own pocket, provided the means for the expedition to Newfoundland in 1583, in which Gilbert died. The patent was renewed in Raleigh's favour in March 1584.

Raleigh now began the series of ventures in the colonization of Virginia. His patent gave him and his heirs the proprietary right over all territory they occupied on payment of one-fifth of the produce of all mines of precious metals to the crown. In April 1584 Raleigh sent out two captains, Philip Amadas and Arthur Barlowe, on a voyage of exploration. They sailed by the Canaries to Florida, and followed the coast of North America as far as the inlet between Albemarle and Pamlico sounds in modern North Carolina. The name of Virginia was given to a vast and undefined territory, but none of Raleigh's captains or settlers reached the state of Virginia. In the same year he became M.P. for Devonshire. His first body of settlers, sent out in 1585 under Sir Richard Grenville, landed on what is now Roanoke Island in North Carolina. The settlers got on bad terms with the natives, and deserted the colony when Drake visited the coast in 1586. Attempts at colonization at the same place in 1586 and 1587 failed (*see* NORTH CAROLINA), and in 1589 Raleigh resigned his rights to a company of merchants, preserving to himself a rent, and a fifth of whatever gold might be discovered.

After 1587 Sir Walter Raleigh's position as favourite was challenged by the earl of Essex. (*See* ESSEX, 2ND EARL OF.) In 1588 he was in eclipse. He was in Ireland for part of the year with Sir R. Grenville, and as vice-admiral of Devon looked after the coast-defences and militia levy of the county. In 1589 he was again in Ireland, visiting Edmund Spenser at Kilcolman. It was by Raleigh's help that Spenser obtained a pension, and royal aid to publish the first three books of the *Faerie Queen*. In 1589 Raleigh accompanied the expedition to the coast of Portugal which failed to raise a revolt against Philip II. In 1591 he was at the last moment forbidden to take part in the voyage to the Azores, being replaced by his cousin Sir R. Grenville. In 1592 he was again at sea with an expedition to intercept the Spanish trade, but was recalled by the queen, having seduced one of her maids of honour, Elizabeth Throgmorton. Raleigh denied the stories in a letter to Robert Cecil. On his return he was put into the Tower, and if he was not already married was married there. To placate

the queen he made a fantastic display of despair at the loss of her favour. The maids of honour could not marry without the queen's consent, which Elizabeth was always reluctant to give and would be particularly unwilling to give when the husband was an old favourite of her own. Raleigh proved a good husband and his wife was devoted to him through life. He superintended the distribution of the booty from the Portuguese carrack "Madre de Dios." He had provided large sums for the expedition, but the queen left him barely enough to cover his expenses.

Raleigh now retired to an estate at Sherborne in Dorsetshire, which he had extorted from the bishop of Salisbury by unscrupulous use of the royal influence. A son was born to him here in 1593. But a retired life did not suit Raleigh, and in 1595 he sailed on a voyage of exploration to the coast of South America. The object was undoubtedly to find gold mines, and Raleigh had heard the wild stories of El Dorado. His account of his voyage, *The Discoverie of Guiana*, published on his return, is brilliant, but contains much manifest romance and was received with incredulity. He was now the most unpopular man in England for his greed, arrogance and scepticism in religion. In 1590 he was named with Marlowe and others as an atheist. The share he took in the capture of Cadiz in 1596, where he was wounded, was followed by a return to favour, and he was apparently reconciled to Essex, whom he accompanied to the Azores in 1597. This co-operation led to a renewal of the quarrel, and Raleigh became still more unpopular. In 1600 he obtained the governorship of Jersey, and in 1601 took a part in suppressing the rebellion of Essex, at whose execution he presided as captain of the Guard. In 1600 he sat as member for Penzance in Elizabeth's last parliament. He was a steady friend of religious toleration, and a bold critic of the fiscal and agrarian legislation of the time.

James I., who regarded Essex as his partisan, had been prejudiced, and Raleigh's desire for war with Spain was against James's peace policy. Raleigh sold his Irish estates to Richard Boyle in 1602. He was expelled from Durham House, which was reclaimed by the bishop, dismissed from the captaincy of the Guard, deprived of his monopolies and of the government of Jersey. He was concerned in the complication of conspiracies of the first months of James's reign, and was committed to the Tower on July 19, 1603. Here he tried to stab himself, but only inflicted a small wound. His trial at Winchester, November 1603, was conducted with outrageous unfairness, and his gallant bearing in face of the brutality of the Attorney-General, Sir Edward Coke, turned public opinion in his favour. Raleigh was probably cognizant of the conspiracies, though the evidence against him was insufficient to prove his guilt. Much was kept back by the council, and the jury was influenced by knowing that the council thought him guilty.

The sentence of death passed on Raleigh was not carried out, but he was sent to the Tower, where he remained till March 19, 1616. His estate of Sherborne, which he had transferred to his son, was taken by the king. A sum of £8,000 offered in compensation was only paid in part. Raleigh's confinement was easy, and he turned to chemical experiments and literature. He had been known as a minor poet, and in prison he composed the only volume of his vast *History of the World* published. He invented an elixir, a very formidable quack stimulant. Hope of release never deserted him, and he secured his freedom in a way discreditable to all concerned. He promised the king to find a gold mine in Guiana without entrenching on a Spanish possession. It must have been obvious that this was impossible, and the Spanish ambassador, Gondomar, warned the king that the Spaniards had settlements on the coast. The king, who was in need of money, replied that if Raleigh was guilty of piracy he should be executed on his return. Raleigh gave promises he obviously knew he could not keep and sailed on March 17, 1617, relying on the chapter of accidents, and on vague intrigues he had entered into in Savoy and France. The ill-equipped expedition reached the mouth of the Orinoco on Dec. 31, 1617. Raleigh was ill with fever, and remained at Trinidad. He sent five small vessels up the Orinoco under Lawrence Keymis, with whom went his son Walter and a nephew. The expedition found a Spanish settlement on the way to the supposed mine, and a fight ensued in which Sir Walter's son and several Spaniards were killed. Keymis returned to Sir Walter with the news of his son's death and his own utter ruin, and killed himself as a result of Raleigh's reproaches. After a miserable scene of recriminations and mutiny, the expedition returned home. Raleigh was arrested, and in pursuance of the king's promise to Gondomar was executed under his old sentence on Oct. 29, 1618. When he knew his end to be inevitable he died with serenity and dignity. His wife survived him, and he left a son, Carew Raleigh. His enmity to Spain made him a popular hero.

AUTHORITIES.—An edition of his *Works* in eight volumes was published in London in 1829. It contains a *Life* by Oldys and Birch, written with all the knowledge then available. A *Life of Sir Walter Raleigh* (1806, 2nd ed.) was much used by Southey in his biography of Sir Walter Raleigh in vol. iv. of *The British Admirals* in the *Cabinet Cyclopaedia* (1837). Two biographies appeared simultaneously, *Life of Sir Walter Raleigh* by J. A. Saint John, and *Life of Sir Walter Raleigh* by E. Edwards (1868). E. Edwards's work is in two volumes, of which the second contains the correspondence, and is still the best authority. Smaller lives, which in some cases contain new matter, are those by E. W. Gosse, "Raleigh" in *English Worthies* (1886); W. Stebbing, *Sir W. Raleigh* (1891 and 1899); Martin Hume, *Sir Walter Raleigh* (1897); H. de Selincourt, *Great Ralegh* (1908); and M. Waldman, *Sir Walter Raleigh* (1928). For special episodes *see* Sir John Pope Hennessy, *Sir Walter Raleigh in Ireland* (1883), and T. N. Brushfield, *Raleghana* (Ashburton, 1896). Two separate editions of Raleigh's poems have been published, *Poems, with biography and critical introduction* by Sir F. Brydges (London, 1813), and *Poems of Raleigh with those of Sir H. Wotton, etc.*, edited by J. Hannah (London, 1892). S. R. Gardiner made a careful examination of the events of Raleigh's life after 1603 in his *History of England from the Accession of James I. to the Outbreak of the Civil War* (1883–84). *See* also C. H. Firth, *Sir Walter Raleigh's History of the World* (1918); and L. Cust, *Portraits of Sir Walter Raleigh* (1920).

RALEIGH (raw'lĭ), **SIR WALTER** (1861–1922), English man of letters, born on Sept. 6, 1861, in London, was educated at University college, London, and King's college, Cambridge. He was professor of modern literature at University college, Liverpool, and professor of English literature at Glasgow. In 1904 he was appointed professor of English literature at Oxford. He was knighted in 1911, and elected to a fellowship at Merton college in 1914. He died on May 13, 1922.

Raleigh was a good critic, and a stimulating teacher. He was not bound by the accepted judgments on individual writers, but brought a fresh and original mind to bear on literature. He did as much as any man of his time to break with what may be called the "dry-as-dust" school. His publications include *The English Novel* (1894), *Style* (1897), *Wordsworth* (1903), *The English Voyagers* (1904), *Shakespeare* (1907), *Six Essays on Johnson* (1910), *Romance* (1917), and many essays on literary subjects.

RALEIGH, the capital of North Carolina, U.S.A., and also the county seat of Wake county; in the heart of the eastern part of the state, on federal highways 1 and 70, and served by the Norfolk Southern, the Seaboard Air Line and the Southern railways. Pop. (1950) 65,679. The city has an altitude of 360 ft. and an area of 12.5 sq.mi. In the centre, on the highest ground, is the beautiful Capitol park of 4 ac. The present capitol building (completed 1840) of granite from a near-by quarry owned by the state, has a Doric portico and an octagonal dome. In the immediate neighbourhood are the state supreme court, the State Office building, the Justice building, the State Law library, the State museum, the Administration building, the Agricultural building and the highway commission; and not far away is the governor's mansion (1889), set in 4 ac. of grounds. In Pullen park is the house in which Andrew Johnson was born. Among the numerous antebellum mansions still standing is that of Joel Lane (1760), from whom in 1792 the state purchased the site of the city. Most of the state institutions are located at Raleigh: the hospital for the insane and epileptics (established in 1856, through the efforts of Dorothea Lynde Dix), the prison (1869), the schools for the white blind (1845) and the Negro deaf and blind (1867), the Confederate soldiers' home (1891) and the laboratory of hygiene. Raleigh is an educational centre, with about 5,000 students in the colleges and other schools under private auspices. The North Carolina State College of Agriculture

and Engineering (1887) with affiliated experimental farms, occupies 486 ac. in the western part of the city. Meredith college for women (Baptist, 1891) moved in 1924 to a suburban campus of 130 ac. Shaw university (Baptist, 1865) and St. Augustine's college (Protestant Episcopal, 1867) are two of the oldest institutions in the south for the higher education of Negroes. Wake Forest college (Baptist, 1833) is 17 mi. N. Raleigh has a large wholesale and retail trade. Raleigh is fast becoming a town of diversified industries. Some of the products manufactured in Raleigh include cotton, rayon and worsted cloth, venetian blinds, awnings, automobile seat covers, high-grade furniture, fertilizers, vegetable oils, patent medicines, steel products, concrete products and all kinds of food and dairy products. Raleigh is a trade centre of eastern North Carolina and at mid-century contained more than 700 retail stores. Five insurance companies have their home offices there. The assessed valuation of property at mid-20th century was about $100,000,000.

In 1787 the state convention decreed that there should be a "fixed and unalterable seat of government," and that it should be named in honour of Sir Walter Raleigh; in 1788 the site (Wake Court House) was chosen; in 1792 the land was bought and the city was laid out, with wide streets and large public squares; and in 1793 it was incorporated. Gen. William Sherman's army passed through Raleigh on April 13, 1865.

RALPH (d. 1122), archbishop of Canterbury, called Ralph de Turbine, or Ralph d'Escures from his father's estate of Escures, near Séez in Normandy, entered the abbey of St. Martin at Séez in 1079, and ten years later became abbot of this house. After Anselm's death in April 1109 Ralph acted as administrator of the see of Canterbury until April 1114, when he himself was chosen archbishop at Windsor. Claiming authority in Wales and Scotland, he refused to consecrate Thurstan as archbishop of York because the latter prelate declined to profess obedience to the archbishop of Canterbury. This step involved him in a quarrel with the papacy, and he visited Rome, but was unable to obtain an interview with pope Paschal II., who had left the city. In spite of peremptory orders from Paschal's successors, Gelasius II. and Calixtus II., the archbishop still refused to consecrate Thurstan, and the dispute was unsettled when he died on Oct. 20, 1122.

RALPH OF COGGESHALL (d. after 1227), English chronicler, was at first a monk and afterwards sixth abbot (1207–1218) of Coggeshall, an Essex foundation of the Cistercian order. Ralph himself tells us these facts; and that his resignation of the abbacy was made against the wishes of the brethren, in consequence of his bad health. He took up and continued a *Chronicon Anglicanum* belonging to his house; the original work begins at 1066, his own share at 1187. He hoped to reach the year 1227, but his autograph copy breaks off three years earlier. The tone of the chronicle is usually dispassionate; but the original text contained some personal strictures upon Prince John, which are reproduced in Roger of Wendover. He wrote a continuation of Niger's chronicle, extending from 1162 to 1178 (printed in R. Anstruther's edition of Niger, London, 1851), and short annals from 1066 to 1223.

The autograph manuscript of the *Chronicon Anglicanum* is to be found in the British Museum (Cotton, Vespasian D. X.). The same volume contains the continuation of Ralph Niger. The *Chronicon Terrae Sanctae*, formerly attributed to Ralph, is by another hand; it was among the sources on which he drew for the *Chronicon Anglicanum*. The so-called *Libellus de motibus anglicanis sub rege Johanne* (printed by Martene and Durand, *Ampl. Collectio*, v. pp. 871–882) is merely an excerpt from the *Chronicon Anglicanum*. This latter work was edited for the Rolls series in 1875 by J. Stevenson.

RAM. A male sheep, one kept for breeding purposes in domestication and not castrated, as opposed to the castrated wether. (*See* SHEEP.) For the ram as one of the signs of the zodiac, *see* ARIES. The word may be connected with O.Nor. *ramme*, strong, or with Skt. *ram*, to sport. The butting propensities of the ram have given rise to the many transferred senses of the word, chief and earliest of which is that of a battering implement used before the days of cannon for beating in the gates and breaching the walls of fortified places. (*See* BATTERING RAM.) Many technical uses of the term have been developed from this, *e.g.*, the weight of a pile-driving machine, the piston of a hydraulic press and other machines or portions of machines worked by water power. (*See* HYDRAULIC MACHINERY.) The ancient war-vessels were fitted with a beak (Lat. *rostrum*, Gr. ἔκβολον), projecting from the bows, and used to ram or crush in the sides of an opposing vessel; for the development of this in the modern battleship *see* SHIP.

RAMA, an almost extinct Indian tribe who live on Rama key in Bluefields lagoon on the east coast of Nicaragua. Formerly they occupied the north bank of the San Juan river. Linguistically the Rama are allied to the Chibchan peoples of South America. Their material culture suggests a South American connection.

See C. de Kalb, *Bibliography of the Mosquito Coast of Nicaragua* (Bulletin of the American Geographical Society, vol. xxvi. No. 2, 1894); D. E. Harrower, *Rama, Mosquito, and Sumu of Nicaragua* (Indian Notes, vol. ii., 1925).

RAMADĀN (rah-mah-dahn′), the Muslim month in which absolute fasting from dawn to sunset is required. The law is based on Qur'ān ii. 179–184, and is as follows: A fast has always been a part of religion. In Islām it falls in this month because in it the Qur'ān was revealed, and it is holier than the others. It begins when the new moon is actually seen, and lasts until sight of the next new moon; it extends each day from the time when a white thread can be distinguished from a black one and until nightfall; it is absolute in that time as to food, drink, women. The sick and those on a journey may be excused, but should fast thereafter an equivalent number of days. The last ten days of the month are regarded as especially sacred; in the course of them falls the "Night of Decree," or "of Power" (Qur'ān xc. 1), but its exact date is not known. Fasting in Ramadān is reckoned one of the five pillars, or absolute requirements, of Islām. It is followed by the Lesser Festival, the first three days of the month Shawwāl (*see* BAIRAM).

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RAMADI, a town in Iraq in 33° 30′ N. 43° 30′ E. about 80 m. by road from Baghdad. The town lies on both sides of the Euphrates, which is here crossed by a bridge of boats, and in the 20th century became of some importance as an airport and as the point at which the overland mail leaves the cultivated area and starts its journey over the desert.

RAMAN EFFECT. When a beam of monochromatic light passes through a transparent substance a certain amount of light is scattered from the path of the original beam which is of greater wave-length than the incident light. This effect was discovered by Raman in 1928, and is known by his name. It must be distinguished from the Tyndall effect and from ordinary fluorescence. In the Tyndall cone (*see* COLLOIDS) the scattered light is of exactly the same wave-length as the primary beam, supposing monochromatic light to be used: if mixed light is used each wave-length is scattered without change of frequency, but the fact that the short wave-lengths are scattered in greater intensity than the longer wave-lengths leads to an apparent modification of colour. With fluorescence the light scattered in all directions is, except in a few exceptional cases, of wave-length greater than that of the primary beam (*see* FLUORESCENCE AND PHOSPHORESCENCE, where the exceptions to Stokes' law are discussed), but this wave-length is characteristic of the particular fluorescent substance, and does not change with the wave-length of the incident light, so long as this is short enough to excite fluorescence at all. The Raman effect is distinguished by the fact that the frequency of the scattered light changes with that of the primary beam, the *difference of frequency* between the primary beam and the scattered light being independent of the frequency of the primary beam. Thus, with the light from a mercury arc as the exciting radiation, each strong line is accompanied by a group of scattered lines, the frequency intervals from the primary line being the same within each group. Further, certain classes of chemical substances, such as different organic liquids each containing the same chemical group (*e.g.*, the CH group), give in the scattered light

groups of lines whose frequency intervals from the primary line are the same for all substances of the class, but these intervals vary from substance to substance in other cases. The Raman radiation resembles the Tyndall scattered light in that it is, in general, strongly polarised.

The effect is observed by illuminating pure dust-free liquids with an intense beam of light containing approximately monochromatic radiations, *e.g.*, the light from a mercury vapour lamp, and photographing the scattered light from a direction more or less at right angles to the original beam. The magnitude of the shift is of the order of 100 Angstrom units: it is not a question of a minute modification of frequency. The scattered light always contains the original frequency in comparatively great intensity, the modified lines often requiring a long exposure.

The interpretation of the effect is a matter of great theoretical importance. On the quantum theory of radiation (*see* QUANTUM THEORY) a certain quantum of energy $h\nu$ is to be attributed to the incident radiation, and a quantum of energy $h\nu'$ to the scattered radiation, h being Planck's constant and ν and ν' the respective frequencies. The difference $h(\nu-\nu')$ must be absorbed by the molecule in some quantum change, and the order of magnitude of this difference corresponds to an infra-red frequency. There is strong support for the view that the energy communicated to the molecule appears as energy of vibration of the nuclei of certain atoms in it, that is, the distance between the nuclei of these atoms varies periodically, the energy of the oscillations being governed by quantum conditions. Thus, associated with the strong mercury line 4,358A in the incident light, there is a scattered line at 5,000A with organic compounds containing the CH group: the difference of wave-number is $10^8\left(\frac{1}{4358}-\frac{1}{5000}\right)=2946\text{cm.}^{-1}$, which corresponds to an infra-red line at 3·4μ. Such a line is present in the infra-red spectra of these compounds, and is attributed to nuclear oscillation. (*See* BAND SPECTRUM.) Other scattered lines lead to other infra-red frequencies characteristic of the molecules in question. The Raman effect thus furnishes spectroscopy with a new and very powerful weapon for investigating the infra-red spectra of determined molecules without the very troublesome technique of infra-red measurements. In the case of complicated molecules the vibrations can be traced to simple groups within them, as exemplified by the CH group.

Besides the lines of lower frequency than the exciting light a few lines are found in the scattered light which have a higher frequency, and thus correspond to a contribution of energy by the molecule to the quantum of energy of the incident light. Such lines find a natural explanation in the existence of molecules which, as regards the nuclear vibrations, are in one of the excited quantum states of higher energy: a quantum jump to a state of lower energy occurring in conjunction with the scattering process provides the necessary increment of energy to the scattered quant.

The Raman effect shows an interesting similarity to the Compton effect (*q.v.*). In the Compton effect the incident light-quant communicates part of its energy to a free, or loosely bound, electron, which energy appears as kinetic energy of this electron, the light quant of diminished energy being scattered as radiation of greater wave-length than that of the incident quant. The Compton effect is observed with hard X-rays, the magnitude to be anticipated for the effect with optical frequencies being too small for experimental observation. In the Raman effect the incident radiation sacrifices part of its energy in an interaction with matter, and reappears as a radiation of diminished frequency, just as in the Compton effect, but the energy lost as radiation appears as energy of molecular vibration instead of as kinetic energy of an electron.

BIBLIOGRAPHY.—The discovery of the effect was first announced by C. V. Raman in the *Indian Journal of Physics*, ii., 387, 1928, and by Raman and K. S. Krishnan in *Nature*, CXXI., 501, 1928. Other papers on the subject are: Raman and Krishnan, *Indian Joural of Physics*, II., 399, 1928; Cabannes and Daure, *Comptes Rendus de l'Académie des Sciences*, CLXXXVI. 1533, 1928; G. Rogard, *Comptes Rendus*, CLXXXVI., 1107, 1928; P. Pringsheim, *Die Naturwissenschaften*, XVI., 597, 1928; R. W. Wood, *Philosophical Magazine*, VI., 729, 1928.

(E. N. DA C. A.)

RAMANUJAN, SRINIVASA (1887–1920), Indian mathematician, whose correct name was Srinivasa Ramanuja Tyengar, was born at Erode, southern India, on Dec. 22, 1887. He was educated at the Town High school and at the Government college at Kumbakonan. He obtained a scholarship from the University of Madras, but after his marriage, in 1909, became a clerk in the Madras Port Trust. Correspondence with Prof. G. H. Hardy, of Cambridge, led to his obtaining a further scholarship from Madras university, and an exhibition from Trinity college, Cambridge. In spite of religious difficulties arising from the fact that he was a Brahmin, he came to England in April 1914, where Hardy, by private teaching, helped to provide the necessary mathematical background for his original work. His mathematical work is on the theory of numbers, theory of partitions and the theory of continued fractions. He became ill in 1917, returned to India in 1919, when he resumed some of his mathematical work, but died on April 26, 1920, at Kumbakonan. He was elected F.R.S. in 1918 and fellow of Trinity college later in the same year.

Most of his papers, edited by G. H. Hardy, P. V. Seshu Aiyar and B. M. Wilson, were published under the title of *Collected Papers of Srinivasa Ramanujan* (1927). *See* also obituary notice, with a list of Ramanujan's papers, by G. H. Hardy, in *Proceedings of the Royal Society*, vol. xcix. (1921).

RAMANUJAS, followers of Ramanuja, a southern Brahmin of the 12th century. Sri Vaishnavas, as they are usually called, worship Vishnu (Narayana) with his consort Sri or Lakshmi (the goddess of beauty and fortune), or their incarnations Rama with Sita and Krishna with Rukmini. Ramanuja's doctrine is essentially based on the tenets of an old Vaishnava sect, the Bhagavatas or Pancharatras, who worshipped the Supreme Being under the name of Vasudeva (later identified with Krishna, as the son of Vasudeva). They have shrines at Srirangam near Trichinopoly, Mailkote in Mysore, Dvaraka (the city of Krishna) on the Kathiawar coast, and Jagannath in Orissa; all of them decorated with Vishnu's emblems, the tulasi plant and salagram stone. Whilst Sankara's mendicant followers were prohibited to touch fire and had to subsist entirely on the charity of Brahman householders, Ramanuja, on the contrary, not only allowed his followers to use fire, but strictly forbade their eating any food cooked, or even seen, by a stranger. On the speculative side, Ramanuja met Sankara's strictly monistic theory by another, recognizing Vishnu as identical with Brahma, the Supreme Spirit animating the material world as well as the individual souls which have become estranged from God through unbelief, and can only attain again conscious union with him through devotion or love (*bhakti*). His tenets are expounded in various works, especially in his commentaries on the Vedantasutras and the Bhagavadgita. The followers of Ramanuja have split into two sects, a northern one, recognizing the Vedas as their chief authority, and a southern one, basing their tenets on the Nalayir, a Tamil work of the Upanishad order. (*See* RAMATS.)

See E. Thurston, *Tribes and Castes of India*, s.v.

RAMATS, a numerous north Indian sect (*Ramanandis* or *Ramavats*). Its founder, Ramananda, flourished in the latter part of the 14th century, according to tradition.

He was originally a Sri-Vaishnava monk, who, having come under the suspicion of laxity in observing the strict rules of food during his peregrinations, and having been ordered by his superior (Mahant) to take his meals apart from his brethren, left the monastery in a huff and set up a schismatic math of his own at Benares. The main distinctive features of their creed consist in their making Rama and Sita, either singly or conjointly, the chief objects of their adoration, instead of Vishnu and Lakshmi, and their attaching little or no importance to the observance of privacy in the cooking and eating of their food. Their mendicant members, usually known as Vairagis, are, like the general body of the sect, drawn from all castes without distinction. Thus, the founder's twelve chief disciples include, besides Brahmans, a weaver, a currier, a Rajput, a Jat and a barber —for, they argue, seeing that Bhagavan, the Holy One (Vishnu), became incarnate even in animal form, a Bhakta (believer) may be born even in the lowest of castes. Ramananda's teaching was thus of a popular character. The Bhakta-malā and other authoritative writings of the sect are composed in the popular dialects.

A follower of this creed was the poet Tulsidas, the author of the Hindi version of the Ramayana. (*See* RAMANUJAS.)

RAMBAUD, ALFRED NICOLAS (1842–1905), French historian, was born at Besançon on July 2, 1842. After studying at the École normale supérieure, he completed his studies in Germany. He was appointed *répétiteur* at the École des Hautes Études on its foundation in 1868. His earlier historical work was done in Byzantine and Russian history. Probably his study of Russia was motived partly by his sense of the desirability of a Franco-Russian entente. Rambaud was *chef de cabinet* to Jules Ferry (1879–81), and in 1883 became professor of contemporary history at the Sorbonne.

He now wrote his *Histoire de la civilisation française* (2 vol., 1885, 1887; 9th ed., 1901) and his *Histoire de la civilisation contemporaine en France* (1888; new ed. entirely revised, 1906), and undertook the general editorship of the *Histoire générale du IVe siècle jusqu'à nos jours.* The plan of this great work had been drawn up with the aid of Ernest Lavisse, but the entire supervision of its execution was carried out by Rambaud. Rambaud held the position of minister of Public Instruction from 1896 to 1898, and sought to carry on the educational work of Jules Ferry. He died in Paris on Nov. 10, 1905.

See the notices by E. Lavisse in the *Revue de Paris* for January 15th, 1906, and G. Monod in the *Revue historique* (vol. xc., pp. 344–348).

RAMBOUILLET, CATHERINE DE VIVONNE, MARQUISE DE (1588–1665), French *salonnière,* was the daughter and heiress of Jean de Vivonne, marquis of Pisani, and Giulia Savelli. She was married at twelve to Charles d'Angennes, vidame of Le Mans, and afterwards marquis of Rambouillet. The young marquise found the coarseness and intrigue that then reigned in the French court little to her taste, and after the birth of her eldest daughter, Julie d'Angennes, in 1607, she began to gather round her the circle afterwards so famous. She established herself at the Hôtel Pisani, called later the Hôtel de Rambouillet. Almost all the more remarkable personages in French society and French literature frequented it, especially during the second quarter of the 17th century. Madame de Rambouillet's natural abilities had been carefully trained, but were not extraordinary. She had genuine kindness and a lack of prejudice that enabled her to entertain on the same footing princes and princesses of the blood royal, and men of letters, while among her intimate friends was the beautiful Angélique Paulet. The respect paid to ability in her salon effected a great advancement in the position of French men of letters. The almost uniform excellence of the memoirs and letters of the period may be traced largely to the development of conversation as a fine art at the Hôtel de Rambouillet, and the consequent establishment of a standard of clear and adequate expression. Mme. de Rambouillet was known as the "incomparable Arthénice," the name being an anagram for Catherine, devised by Malherbe and Racan. Among the famous incidents in the story of the Hôtel are the sonnet war between the Uranistes and the Jobistes—partisans of two famous sonnets by Voiture and Benserade—and the composition by all the famous poets of the day of the *Guirlande de Julie,* a collection of poems on different flowers, addressed in 1641 to Julie d'Angennes, afterwards duchesse de Montausier. Julie herself was responsible for a good deal of the preciosity for which the Hôtel was later ridiculed.

The *Précieuses,* who are usually associated with Molière's avowed caricatures and with the extravagances of Mlle. de Scudéry, but whose name, it must be remembered, Madame de Sévigné herself was proud to bear—insisted on a ceremonious gallantry from their suitors and friends, though it seems from the account given by Tallemant des Réaux that practical jokes of a mild kind were by no means excluded from the Hôtel de Rambouillet. They especially favoured an elaborate and quintessenced kind of colloquial and literary expression, imitated from Marini and Gongora, and then fashionable throughout Europe. Molière's attack was probably levelled not at the Hôtel de Rambouillet itself, but at the numerous coteries which in the course of years had sprung up in imitation of it. But the satire did in truth touch the originators as well as the imitators,—the former more closely perhaps than they perceived. The Hôtel de Rambouillet continued open till the death of its mistress, on Dec. 2, 1665, but the troubles of the Fronde diminished its influence.

The chief original authorities respecting Madame de Rambouillet and her set are Tallemant des Réaux in his *Historiettes,* and Antoine Baudeau de Somaize in his *Grand Dictionnaire des Précieuses* (1660). Many modern writers have treated the subject, notably Victor Cousin, *La Société française au xviie siècle* (2 vols., 1856), and C. L. Livet, *Précieux et Précieuses . . .* (1859). There is an admirable edition (1875) of the *Guirlande de Julie* by O. Uzanne.

RAMBOUILLET, a town of France, capital of an arrondissement in the department of Seine-et-Oise, 30 mi. S.W. of Paris on the railway to Chartres. Pop. (1946) 7,169. Rambouillet derives its interest from the associations connected with the ancient château. Originally a royal domain, the lands of Rambouillet passed in the 14th century to the D'Angennes family, who held them for 300 years and built the château. Francis I died there in 1547; and Charles IX and Catherine de Medici found a refuge there in the Wars of Religion, as Henry III did after them. The title became a marquisate in 1612, and a dukedom under Louis XIV. It was here that in 1830 Charles X signed his abdication. The shooting of the famous coverts of Rambouillet was reserved for French presidents of the republic.

RAMEAU, JEAN PHILIPPE (1683–1764), French musical theorist and composer, was born at Dijon, the son of an organist, on Oct. 23, 1683. His father wished him to study law, but the boy's head was full of music, which he could only pursue in haphazard fashion. In 1701 his father sent him to Milan to break off a foolish love-match. But he learned little in Italy, and soon returned in company with a wandering theatrical manager, for whom he played the second violin. He next settled in Paris, where he published his *Premier livre de pièces de clavecin,* in 1706. He succeeded his father as organist of Notre Dame, Dijon, in 1709, and in 1714 removed to Lyons, where he was organist at the Jacobins. In 1715 he was organist at Clermont-Ferrand and working on his *Traité de l'harmonie.* There he remained until 1722. He studied the writings of Zarlino, Descartes and other theorists.

Rameau's keen insight into the constitution of certain chords, which in early life he had studied only by ear, enabled him to propound a series of hypotheses, many of which are now accepted. While the older contrapuntists were perfectly satisfied with the laws which regulated the melodious involutions of their vocal and instrumental parts, Rameau demonstrated the possibility of building up a natural harmony upon a fundamental bass, and of using that harmony as an authority for the enactment of whatever laws might be considered necessary for the guidance either of the contrapuntist or the less ambitious general composer. And in this he first explained the distinction between two styles, which have been called the "horizontal and vertical systems," the "horizontal system" being that by which the older contrapuntists regulated the onward motion of their several parts, and the "vertical system" being that which is built up perpendicularly from the bass. From fundamental harmonies he passed to inverted chords, to which he was the first to call attention; and the value of this discovery fully compensates for his erroneous theory concerning the chords of the eleventh and the great (Angl. "added") sixth. (*See* HARMONY.)

Rameau first set forth his new theory in his *Traité de l'harmonie* (Paris, 1722), and followed it up in his *Nouveau système* (1726), *Génération harmonique* (1737), *Démonstration* (1750) and *Nouvelles réflexions* (1752). After his return to Paris in 1722 he produced some light dramatic pieces, and then showed his real powers in his opera, *Hippolyte et Aricie,* founded on Racine's *Phèdre* and produced at the Académie in 1733.

Rameau wrote more than 20 operas, the most successful of which were *Dardanus, Castor et Pollux, Les Indes galantes* and *La princesse de Navarre.* Honours were showered upon him. He died in Paris on Sept. 12, 1764. Rameau was undoubtedly the greatest French musician of his day.

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RAMEK, RUDOLF (1881–1940), Austrian statesman, was born at Teschen on April 12, 1881, and served in the Austrian army in World War I. A member of the Christian Socialist party, he was state secretary for justice in the Karl Renner cabinet (1919) and minister of the interior in the Michael Mayr cabinet (1921).

He formed a coalition government in Nov. 1924. The chief problems before him were the strengthening of the federal principle and the completion of the Austrian reconstruction scheme under the League of Nations. Involved in controversy with Benito Mussolini over the latter's reference to "carrying the Italian standard if necessary beyond the Brenner," he obtained an explanation, and the incident was regarded as closed; but in Austria he was criticized as having been too lukewarm in his defense of Tirolese interests.

The fall of his government on Oct. 15, 1926, was immediately caused by his refusal of any increase of pay to civil servants. He retired from politics, but was arrested by the nazis after the *Anschluss* and died in Salzburg in 1940.

RAMESES or **RAMESSES** (Gen. xlvii, 11; Exod. xii, 37; Num. xxxiii, 3), or, with a slight change in the vowel points, RAAMSES (Exod. i, 11), the name of a district and town in Lower Egypt, is notable as affording the mainstay of the current theory that King Rameses II was the Pharaoh of the oppression and his successor Merneptah the Pharaoh of the exodus. The first three passages cited above are all by the priestly (postexile) author and go together. Jacob is settled by his son Joseph in the land of Rameses and from the same Rameses the exodus naturally takes place. The older narrative speaks not of the land of Rameses but of the land of Goshen; it seems probable, therefore, that the later author interprets an obsolete term by one current in his own day, just as the Septuagint in Gen. xlvi, 28, names instead of Goshen Heroopolis and the land of Rameses. Heroopolis lay on the canal connecting the Nile and the Red sea, and not far from the head of the latter, so that the land of Rameses must be sought in Wadi Tumilat near the line of the modern fresh-water canal. In Exod. i, 11, again, the store-cities or arsenals which the Hebrews built for Pharaoh are specified as Pithom and Raamses, to which the Septuagint adds Heliopolis. Pithom also takes us to the Wadi Tumilat. It is possible that these names were added by a writer who knew what fortified places were in his own time to be seen in Wadi Tumilat, for the form of the story of the Hebrews in Egypt is throughout deficient in precise geographical data. The postexile or priestly author indeed gives a detailed route for the exodus (which is lacking in the older story), but he, we know, was a student of geography and might supplement tradition by what he could gather from traders as to the caravan routes.

It appears, however, from remains and inscriptions that Rameses II did build in Wadi Tumilat, especially at Tell Maskhuta, which Lepsius therefore identified with the Raamses of Exodus. But Naville's excavations found that the ruins were those of Pithom and that Pithom was identical with the later Heroopolis. Petrie found sculptures of the age of Rameses II at Tel Rotab, in the Wadi Tumilat west of Pithom, and concludes that this was Rameses. The biblical city is probably one of those named Prameses, "House of Ramesses," in the Egyptian texts.

RAMESWARAM, a town of India, in the Ramnad district of Madras, on an island in Palk straits and on the line of the South Indian railway from Madura. It has one of the most venerable Hindu shrines, founded, according to tradition, by Rama himself, and the resort of thousands of pilgrims.

RAMIE, RHEA or CHINA GRASS, the product of species of the genus *Boehmeria,* a member of the family Urticaceae and nearly allied to the stinging nettle genus (*Urtica*), from which, however, it differs in absence of stinging hairs. Some confusion has arisen in the use of the various terms ramie, rhea and China grass. "Ramie" is generally used by English-speaking people to designate the plant *Boehmeria nivea,* with leaves snow-white on the under surface, and also the fibre obtained from this plant. The name is of East Indian or Malay origin and is said to have been used originally to designate *Boehmeria nivea tenacissima,* a tropical form with thin leaves, green on both surfaces. "Rhea" is used in India to designate both forms, but more especially the introduced form with leaves white on the under side, known elsewhere as ramie. Formerly in the London fibre market the name "ramie" was used to designate the fibre from China and Japan, and the name "rhea" for the fibre from all other sources. China grass is the hand-cleaned but not degummed fibre as it comes on the market. The name has been incorrectly used to designate the plant.

B. nivea is a shrubby plant with the growth of the common nettle but without stinging hairs, sending up each season a number of straight shoots from a perennial underground rootstock. The plant leaves resemble the nettle in their shape and serrated margin, but their backs are clothed with a downy substance and have a silvery appearance. The minute greenish-brown flowers are closely arranged along a slender axis. This variety has been cultivated by the Chinese for many years, and the fibre has been used more or less as a substitute for linen. Ramie is grown commercially in China, Formosa, Japan and the Philippines. It has been grown experimentally in most temperate and subtropical countries throughout the world. About 1855 ramie was first introduced into the United States, and shortly thereafter it found its way into a number of Central American countries. A number of attempts have been made to start a ramie industry in the United States, Central America and South America, but no industry has developed.

In the United States experiments have been conducted along the South Atlantic coast and the Gulf of Mexico coast and in California by individuals, by state agricultural experiment stations and by the United States department of agriculture. The most extensive plantings have been made by companies interested in testing new machines and methods of preparation. Between 1935 and 1943 the acreage of ramie in the U.S. varied from approximately 100 to 300 ac., but only a few tons of ramie fibre were prepared. It is questionable if ramie can be grown and prepared in countries having high labour wage scales to compete with fibre prepared with the cheap labour of the orient.

Cultivation.—The plant, which attains a height of from 3 to 8 ft., is grown from seed, cuttings or layers, or by division of the roots. From two to four crops per season may be obtained on suitable ground, each crop yielding up to four tons or more of green moist stems per acre. The yield of crude China grass fibre is approximately 2½% of the green plant material as cut in harvesting. When proper attention is given to the choice of ground, and to planting, there is not much difficulty in raising a good crop; the trouble arises in the extraction of the fibre.

The stems when ripe are cut down, and after the leaves and small branches have been removed, the outer cover and the layers of fibre are stripped off in the form of ribbons. These ribbons contain the bark, the fibre and a quantity of very adhesive gum. The Chinese remove this bark and as much of the gum as possible before the plant has dried. When it has dried this fibre is called China grass. This hand process is naturally slow and tedious.

Properties.—The fibre possesses some very valuable properties; it is not only much stronger than any other known fibre, but almost equals some kinds of silk in its brilliance. Its lustre is about equal to that of mercerized cotton but much inferior to that of artificial silk. Ramie successfully resists atmospheric changes, is easily dyed and is little affected by moisture. On the other hand, articles manufactured from it have not, because of their hairy character, the same smart appearance as those made from flax. Although the fibre is in some cases 12 in. long, it varies considerably in length, and this handicaps the operations of preparing and spinning. It is impossible to make perfect yarns from fibres of various lengths; hence it is necessary either to separate the fibres into reasonable groups or to cut them into satisfactory lengths.

Manufacture.—In general, after decortication, the first process is that of degumming. This is usually done by immersing the fibre in a hot caustic soda or patented chemical solution. After the gum is removed, the material is lifted out, the alkali or chemical neutralized and the fibre thoroughly washed. The bulk of the water may be removed by a hydro-extractor, and the fibre

is then dried. To facilitate the subsequent process, the fibre may be softened by passing it through a machine fitted with fluted rollers. Then follow the operations of dressing, roving, wet spinning and doubling, and finally the twisted thread may be passed through a flame to remove superfluous hairs.

Ramie has been in the past used for gas mantles, for which it is particularly well adapted, for paper-making, ropes, linens, nets, underwear, and for canvas and several other fabrics. If only a good dependable supply of clean uniform low valued fibre could be obtained, there is not much doubt but that manufacturers and machine-makers would quickly provide means for utilizing it on an extensive scale. (B. B. R.)

RAMILLIES, a village of Belgium, in the province of Brabant, 13 miles N. by E. of Namur, between the sources of the Little Gheete and of the Mehaigne. It is famous for the victory of the Allies under the duke of Marlborough over the French commanded by Marshal Villeroi on May 12–23, 1706 in the War of the Spanish Succession (*q.v.*). The position of the French on the high ground about Ramillies was marked by the villages of Autréglise (Anderkirch) on the left, Offuz on the left centre, Ramillies on the right centre and Taviers on the right close to the river Mehaigne. In front of the last was a smaller village, Franquenay, which was held as an advanced post. Between these *points d'appui* the ground was mostly open upland, and the position as a whole was defective in so far that the villages were barely within cannon-shot of each other. It was particularly strong on the flanks, which were protected by the marshy beds of the Mehaigne and the Little Gheete. Ramillies stands almost on the watershed of these adjacent valleys, and here Marlborough decided to deliver his main attack. The forces were about equal, and were at first equally distributed along the whole line of each army. Marlborough's local concentration of force at the spot where the attack was to be pressed home was made not before, but after the action had opened. Villeroi's left wing of cavalry and infantry was secure—and at the same time immobilized—behind the upper course of the Little Gheete, and the French commander allowed himself to be imposed upon by a demonstration in this quarter, convinced perhaps by the presence of the British contingent that a serious attack was intended. The morning was spent in arraying the lines of battle, and it was about 1.30 when the cannonade opened. Soon the first lines of infantry of the Allied centre and left (Dutch) opened the attacks on Franquenay and Taviers and on Ramillies, and, when after a severe struggle Taviers fell into the hands of the Dutch, their commander, Marshal Overkirk, led forward the whole of the left wing cavalry and fiercely engaged the French cavalry opposed to it.

The ground was open, both parties had placed the greater part of their horse on this side, and it was only after a severe and prolonged engagement (in which Marlborough himself took part like a trooper and was unhorsed) that the Allies were definitely victorious, thanks to the arrival of a force of cavalry brought over from the Allied right wing. Meanwhile the principal attack on Ramillies had been successfully pressed home, the necessary concentration of force being secured by secretly and skilfully withdrawing some British battalions from the right wing. While Villeroi was trying to bring up supports from the left to take part in the cavalry battle, the French in Ramillies were driven out into the open, where the Allied cavalry, having now gained the upper hand, rode down many battalions. Most of the French cavalry from the other wing, having to force its way through the baggage trains of the army (these had been placed too near the fighting lines), arrived too late, and once Ramillies had fallen the whole line of the Allies gradually took up the offensive. It was not long before the French line was rolled up from right to left, and the retreat of the French was only effected in considerable confusion. Then followed for once a relentless pursuit, carried on by the British cavalry (which had scarcely been engaged) to Louvain, 20m. from the field of battle. Marlborough's unequalled tactical skill and judgment thus sufficed not merely to win the battle, but to win it with so large a margin of force unexpended that the fruits of his victory could be gathered. The French army lost, in killed, wounded and missing, some 15,000 men, the Allies (amongst whom the Dutch had borne the brunt of the fighting) scarcely one-third as many.

RAM MOHAN ROY (1774–1833), Indian religious reformer, and founder of the Brahma Samaj (*q.v.*) or Theistic Church, was born at Radhanagar, in the district of Hugli, Bengal, in May 1774. He was the son of a small landowner, and in his early life acquired a knowledge of Persian, Arabic and Sanskrit, besides his own vernacular, Bengali. At the age of sixteen he first assailed idolatry in his Bengali work, entitled *The Idolatrous Religious System of the Hindus.* This gave offence to his orthodox father, and Ram Mohan left home and spent some years in travel. He was a clerk in the British service from 1800 to 1814, when he settled in Calcutta to devote himself to religious reform. Ram Mohan wrote Bengali works on the Vedanta philosophy, translated some of the *Upanishads,* and on Jan. 23, 1830, definitely established the Brahma Samaj "for the worship and adoration of the Eternal, Unsearchable, Immutable Being who is the Author and Preserver of the Universe." In 1830 the emperor of Delhi bestowed on Ram Mohan the title of raja, and sent him to England as his agent. He presented petitions to the House of Commons in support of the abolition of the suttee rite. He died on Sept. 27, 1833.

RAMNAD, a town and district of Madras, British India, at the base of the spit of land that projects towards the island of Pamban in Palk strait. The town, pop. (1941) 18,152, is the residence of a raja of old family, head of the Maravar caste, whose title is setupathi, or lord of Adam's Bridge. It is a desolate and generally barren tract, traversed by the South Indian railway. The district has an area of 4,851 sq.mi., and a pop. (1941) of 1,979,643. Fishing is carried on.

RÂMNICU SĂRAT, the capital of the department of Râmnicu Sărat, Rumania; on the railway from Buzau to Focşani, and on the left bank of the Râmnicu, a tributary of the Sereth. Pop. (1930) 15,013, about 1,500 being Jews. The town rises from a marshy plain, east of the Carpathians, and west of the cornlands of southern Moldavia. Râmnicu Sărat was the scene of battles between the Moldavians and the Walachians in 1434 and 1573, and between the Walachians and Turks in 1634. Here also, in 1789, an Austro-Russian army defeated the Turks. In 1854 the town was almost destroyed by fire and was rebuilt.

RÂMNICU-VÂLCEA, an episcopal city and the capital of the department of Vâlcea, Rumania; situated at the foot of the Carpathians, on the right bank of the river Olt, and on the railway from Caracal to Sibin. Pop. (1930) 15,162, including many "Saxons." The district contains the famous monasteries of Arnota, Bistrita, Cotia and Moret. Besides wine, fruit, grain and timber, the surrounding uplands yield petroleum and salt. Within a few miles are the thermal springs of Olănestzi and Calimanesti and the salt mines of Ocnele Mari, with deposits estimated at 330 million tons. The city is said to be the ancient Castra Traiana.

RAMÓN Y CAJAL, SANTIAGO (1852–1934), Spanish histologist, was born May 1, 1852, at Petilla de Aragon (Pamplona). He graduated at the University of Saragossa, and went in 1881 as professor to the University of Valencia, and in 1886 to Barcelona, publishing in 1889 his first important work (*Elementos de Histologia normal y de Técnica Micrográfica*). In that year he discovered "the laws which govern the morphology and the connections of the nerve cells in the grey substance." In 1890 and 1891 he discovered the primary changes of the neurin, and the genetic unity of the nerve fibres and the protoplasmic appendices. During this period also he discovered the axis cylinder of the fibres of the cerebellum and their continuity with the parallel fibrillae of the molecular covering, formulated the principle of the dynamic polarisation of the neurins, aided by Van Gehuchten, and worked upon the analysis of the sympathetic ganglia. In 1892 he took the chair of normal histology and pathological anatomy in the University of Madrid. In 1894, on the invitation of the Royal Society of London, he developed systematically his views on morphology and connections of the nervous cells of the spinal medulla, ganglions, cerebellum, retina and olfactory bulb. He was called upon by the Clark University (Worcester) in 1899 to

give an exposition of his investigations regarding the cerebral tegumen, and in 1900 the International Congress of Medicine, which met in Paris, gave him the Moscow International Award. He was awarded half the Nobel Prize for medicine in 1906. His work in three volumes, *Histologia del Sistema Nervioso de Hombre y de los Vertebrados,* appeared between the years 1897 and 1904. In May 1922 he was exempted, on account of long service, from his duties in connection with the chair which he held, and, on the initiative of the Government, he founded the Cajal Institute in Madrid.

RAMPION, the name given to herbs of the genus *Phyteuma,* belonging to the family Campanulaceae. There are 45 species, which inhabit Europe, Asia and the Mediterranean region; two are native to the British Isles. The flowers are small, usually blue, and are massed together in heads. The pollen is driven out of the narrow tube, formed by the corolla, by the elongation of the style, and is thereby exposed to visiting insects.

RAMPOLLA, COUNT MARIANO DEL TINDARO (1843–1913), Italian cardinal, was born on Aug. 17, 1843, at Polizzi, in the Sicilian diocese of Cefalù. Having completed his studies in the Capranica College at Rome, and having taken holy orders, he studied diplomacy at the College of Ecclesiastical Nobles, and in 1875 was appointed councillor to the papal nunciature at Madrid. Two years later he was recalled to Rome and received high office. After another brief stay in Madrid as nuncio he was created cardinal, and became papal secretary of State. New to the Sacred College and free from traditional preconceptions, he was admirably fitted to carry out the papal policy under Leo XIII. (*See* PAPACY.) Rightly or wrongly, he was held personally responsible for the *rapprochement* with France and Russia and the opposition to the Powers of the Triple Alliance; and this attitude had its effect on his career when Leo XIII. died. Rampolla was not selected as pope owing to the veto of Austria, and resigned his office as secretary of State. He died in Rome on Dec. 17, 1913.

RAMPUR, an Indian state, lying within the United Provinces, between the British districts of Moradabad and Pilibhit. Area, 894 sq.mi. The country is level and generally fertile; being watered in the north by the rivers Kosila and Nahul, and in the south by the Ramganga. The chief crops are wheat, barley, maize, rice and sugar cane. Pop. (1941) 477,042. The chief, whose title is nawab and who enjoys a salute of 15 guns, is a Rohilla Pathan, representing the family which established their power over this part of the country in the 18th century. When the Rohillas were subjugated by the nawab of Oudh, with the assistance of a force lent by Warren Hastings, one of their number, Faiz-ullah Khan, from whom the present nawab traces his descent, was permitted to retain possession of Rampur. During the Mutiny of 1857 the nawab of Rampur rendered important services to the British. The town of Rampur is on the left bank of the river Kosila. Pop. (1941) 89,322. There are manufactures of damask, pottery, sword-blades and sugar. It was once completely surrounded by a broad bamboo hedge, which formed a strong defence. In addition to a modern fort and several fine buildings, it contains an Arabic college, which attracts students from all parts of India.

RAMPUR BOALIA, a town of British India, the administrative headquarters of Rajshahi district in Bengal, on the left bank of the Ganges. Pop. (1931), 27,064. It is 28 m. by road from the Nator station of the Eastern Bengal State railway and has a steamer station on the Ganges. The town contains a Government college, and the museum of the Varendra Research Society.

RAMSAY, ALLAN (1686–1758), Scottish poet, was born at Leadhills, Lanarkshire, on Oct. 15, 1686. He was educated at the parish school of Crawford, and in 1701 was apprenticed to a wig-maker in Edinburgh. He married Christian Ross in 1712; a few years after he had established himself as a wig-maker (not as a barber, as has been often said) in the High Street, and soon found himself in comfortable circumstances. His first efforts in verse-making were inspired by the meetings of the Easy Club (founded in 1712), of which he was an original member; and in 1715 he became the Club Laureate. In the society of the members he assumed the name of "Isaac Bickerstaff," and later of "Gawin Douglas." By 1718 he had some reputation for occasional verse, which he published in broadsheets, and then (or a year earlier) he turned bookseller. A rough transcript (1716) of *Christ's Kirk on the Green* from the Bannatyne ms., with some additions of his own, was followed in 1718 by a new edition with supplementary verses. In the following year he printed a collection of *Scots Songs.* The success of these ventures prompted him to collect his poems in 1722. The volume was issued by subscription, and brought in the sum of 400 guineas. He then opened a circulating library (the first in Scotland) in new premises, and extended his business as a bookseller.

Meanwhile he had issued the first instalments of *The Tea-Table Miscellany* and *The Ever Green* (both 1724–27). *The Tea-Table Miscellany* is "A Collection of Choice Songs Scots and English," containing some of Ramsay's own, some by his friends, several well-known ballads and songs, and some Caroline verse. In *The Ever Green, being a Collection of Scots Poems wrote by the Ingenious before 1600,* Ramsay sought to reawaken an interest in the older national literature. He produced, in 1725, his dramatic pastoral *The Gentle Shepherd,* which passed through several editions, and was performed at the theatre in Edinburgh; its title is still known in every corner of Scotland, even if it be no longer read. Ramsay wrote little afterwards, though he published a few shorter poems, and new editions of his earlier work. A complete edition of his *Poems* appeared in London in 1731 and in Dublin in 1733. In 1736 he set about the erection of a new theatre, "at vast expense," in Carrubber's Close, Edinburgh, but the opposition was too strong, and the new house was closed in 1737. In 1755 he retired from his shop to the house on the Castle Rock, still known as Ramsay lodge where he died on Jan. 7, 1758.

The Tea-Table Miscellany was reprinted in 1871; *The Ever Green* in 1875; *The Poems of Allan Ramsay* in 1877. A selection of the *Poems* appeared in 1887. There are many popular reprints of *The Gentle Shepherd.*

RAMSAY, ALLAN (1713–1784), Scotch portrait-painter, the eldest son of the author of *The Gentle Shepherd,* was born in Edinburgh in 1713. He studied in London under the Swedish painter Hans Huyssing, and at the St. Martin's Lane Academy; and in 1736 he left for Rome, where he worked for three years under Solimena and Imperiali (Fernandi). In 1767 he succeeded Shakelton as principal painter to the king; and he painted the royal portraits which the king presented to ambassadors and colonial governors, employing a number of assistants—of whom David Martin and Philip Reinagle are the best known. But this prosperous career came to an end through an accidental dislocation of his right arm. He died at Dover on Aug. 10, 1784.

His bust-portraits of Scottish gentlemen and their ladies, which he executed before settling in London, are full of grace and individuality; the features show excellent draughtsmanship, and the flesh-painting is firm and sound in method, though frequently tending a little to hardness and opacity. His work is seen at its best in the portrait of his wife, in the Scottish National Gallery.

RAMSAY, SIR ANDREW CROMBIE, knighted 1881 (1814–1891), British geologist, was born at Glasgow on Jan. 31, 1814, the son of William Ramsay, manufacturing chemist. He served for forty years (1841–81) on the geological survey. To the first volume of the *Memoirs of the Geological Survey* (1846) he contributed a now classic essay, "On the Denudation of South Wales and the Adjacent Counties of England," in which he advocated the power of the sea to form great plains of denudation. In 1866 he published *The Geology of North Wales.* He became professor of geology at University College, London, in 1848, and lecturer in the same subject at the School of Mines in 1851. In 1872 he succeeded Murchison as director-general of the geological survey.

His best known work was his *Physical Geology and Geography of Great Britain* (5th ed., 1878). He became F.R.S. in 1862. He died at Beaumaris on Dec. 9, 1891.

His publications include: *The Old Glaciers of Switzerland and North Wales* (1860); *The Red Rocks of England* (1871); *The River Courses of England and Wales* (1872).

See *Memoir* by Sir. A. Geikie (1895).

RAMSAY, ANDREW MICHAEL (1686–1743), French

writer, of Scottish birth, commonly called the "Chevalier Ramsay," was born at Ayr on Jan. 9, 1686. Ramsay served with the English auxiliaries in the Netherlands, and in 1710 visited Fénelon, who converted him to Roman Catholicism. He remained in France until 1724, when he was sent to Rome as tutor to the Stuart princes Charles Edward and Henry, the future cardinal of York. He was driven by intrigue from this post, and returned to Paris. He died at St. Germain-en-Laye (Seine-et-Oise) on May 6, 1743. The best known of Ramsay's many works is *Les voyages de Cyrus* (London, 1728; Paris, 1727), written in imitation of *Télémaque*.

RAMSAY, SIR WILLIAM (1852–1916), British chemist, was born in Glasgow on Oct. 2, 1852. From 1866 to 1870 he studied in his native city, and in 1871 went to work under R. Fittig at Tübingen. In 1872 he became assistant in the Young laboratory of technical chemistry at Anderson's college, Glasgow, and from 1874 was tutorial assistant in the university. In 1880 he was appointed to the chair of chemistry at University college, Bristol, and made principal in the following year. In 1887 he succeeded A. W. Williamson as professor at University college, London, a position which he resigned in 1913. He was awarded the Davy medal of the Royal society in 1895 and the Nobel prize for chemistry in 1904. He was made a K.C.B. in 1902 and died at High Wycombe, Bucks., on July 23, 1916.

Ramsay's earliest investigations covered a wide field—from a new bismuth mineral to the physiological action of certain alkaloids—in the course of which he showed that the alkaloids are related to pyridine; later he specialized definitely on inorganic and physical chemistry. With S. Young and others, he investigated the critical state, the relationship between vapour pressure and temperature and other properties of liquids. With J. Shields he verified the Eötvös law of the constancy of the rate of change of molecular surface energy with temperature, and obtained evidence concerning the molecular complexity of certain liquids. In 1892 Lord Rayleigh had asked for suggestions from chemists to account for the difference between the densities of chemical and atmospheric nitrogen, and Ramsay became interested in the problem. He devised methods for removing oxygen and nitrogen completely from air, and found that there was present in addition a small quantity of a hitherto unknown gas; in Aug. 1894 Ramsay and Rayleigh announced the discovery of this new gas, afterward called argon, present to the extent of almost 1% in the atmosphere. The high density of this gas accounted for the atmospheric nitrogen's having a greater density than the chemical variety. In 1895, while searching for new sources of argon, Ramsay heated the mineral cleveite with acid and obtained a gas which gave a spectrum identical with that of helium, detected in the sun by Sir J. N. Lockyer and Sir E. Frankland in 1868; in this way helium was first obtained, but it was later found to be present in the air to the extent of about 1 part in 250,000.

Both helium and argon were found to be absolutely inactive chemically, and so were called the "inert gases." A study of their position in the periodic table led to the belief that at least three more such gases should exist, and Ramsay, with M. Travers, found them in 1898 in the liquid air residues from which oxygen and nitrogen had been removed; they were called neon, krypton and xenon, and were found to be present in the air only to an extremely minute extent (*e.g.*, xenon, 1 part in 170,000,000). Ramsay next turned to radioactivity since he noted the association of helium with radioactive minerals, and with F. Soddy (*q.v.*) he found in 1903 that helium was continuously produced as a disintegration product of radium emanation; this discovery led to the transmutation theory and its important consequences. In 1910 Ramsay obtained a small quantity of radium, and with D. Whytlaw Gray he was able, as a result of a wonderful piece of experimental work, to determine the density, and incidentally the atomic weight, of about one three-millionth part of a cubic inch of radium emanation. The atomic weight showed that this gas was the last of the inert gas series and it was called niton.

Ramsay's eminence, and his interest in educational matters, resulted in his being asked by the Indian government to advise on the best way to utilize the Tata bequest; as a consequence the Indian Institute of Science was founded at Bangalore. During World War I he was an active member of the Royal society committee for the pooling of scientific knowledge, to be placed at the command of the government. He made strong representations on the necessity of preventing cotton and fats from reaching central Europe. Ramsay was an inspiring teacher as well as a brilliant researcher; he had remarkable skill as a manipulator, and this, as well as his spirit of enthusiasm for research, contributed to his success as an investigator.

Ramsay's works include: *A System of Chemistry* (1891); *The Gases of the Atmosphere* (1896); *Modern Chemistry*, 2 vol. (1901); and *Essays Biographical and Chemical* (1908).

See Sir William Tilden, *Sir William Ramsay: Memorials of His Life and Work* (1918), and *Famous Chemists* (1921); obituary notice, *Proceedings Royal Soc.* (1916–17).

RAMSBOTTOM, urban district, Lancashire, Eng., 4 mi. N. of Bury on the London Midland Region railway. Pop. (1951) 14,587. Area 14.9 sq.mi. It has iron and brass foundries, machine factories and textile establishments. Municipal transport connects it with Bury and Rawtenstall.

RAMSDEN, JESSE (1735–1800), English astronomical instrument maker, was born at Salterhebble near Halifax, Yorkshire, on Oct. 6, 1735. After serving his apprenticeship with a clothworker in Halifax, he went in 1755 to London, where in 1758 he was apprenticed to a mathematical instrument maker. About four years afterward he started business on his own account and secured a great reputation with his products. He died at Brighton on Nov. 5, 1800. Ramsden's specialty was divided circles, which began to supersede the quadrants in observatories toward the end of the 18th century. His most celebrated work was a five-foot vertical circle, which was finished in 1789 and was used by G. Piazzi at Palermo in constructing his well-known catalogue of stars.

RAMSEY, a market town in Huntingdonshire, Eng., on the southwestern border of the Fen country, on branch lines of the Eastern Region railway, 13 mi. S.S.E. of Peterborough. Pop. of urban district (1951) 5,772. Area 24.9 sq.mi. According to a 12th-century chronicle of one of the monks, the name Ramsey is derived from "ram," referring to the tradition of a solitary ram's having taken up its abode there, and "ey" meaning an island. Ramsey, however, was not completely insulated. The abbey was founded by Ailwin, earl of the East Angles, in 969, and a charter of King Edgar granted lands and privileges for the purpose. Ramsey abbey was noted for the school established within its walls and for its library of Hebrew works. Its abbot was mitred. The lands were granted after the dissolution to Sir Richard Cromwell. The church of St. Thomas à Becket is transitional between Norman and Early English, and has a Norman east end. The tower was built in 1672 of stone from Ramsey abbey. An oak lectern, dating from the 15th century, carries a chained copy, in a Tudor binding of brass, of Dean Comber's (1655–99) book on the Common Prayer, and a black-letter copy of Erasmus' paraphrase of the Gospels. There are many interesting tombs in the churchyard, and the church register contains several entries relating to the Cromwell family, which moved to Ramsey from Huntingdon and owned the abbey estates till 1674. Of the ancient Benedictine abbey the only remains are a part of a gateway, a lodge and some buttresses, while some broken stone arches and walls remain of the conventual buildings. Ramsey has a market for agricultural produce, potatoes being the chief product of the district, and Ramsey mere, now entirely drained, forms excellent wheat land.

RAMSGATE, a municipal borough, watering place, seaport and member of the Cinque Port of Sandwich, in the Isle of Thanet parliamentary division of Kent, Eng., 79 mi. S.E. of London by the Southern Region railway. Pop. (1951) 35,748. Area, 5.7 sq.mi. Ramsgate (Ramesgate) was originally a small but prosperous place united until 1827 to the parish of St. Lawrence. The charter of Charles II mentions it as a member of Sandwich. In 1884 it was incorporated by royal charter, and a commission of the peace was granted in 1893. The jurisdiction of the Cinque Ports' justices thereupon ceased within its limits, which include the parishes of Ramsgate and St. Lawrence Intra. Under Elizabeth I, Ramsgate was still unimportant, though possessed of a fair before

the reign of Henry VIII. After 1668 the growth of trade increased its prosperity, and at the beginning of the reign of George I the pier was enlarged and pier-wardens appointed to collect the *droits*. In 1749, having been selected as a harbour of refuge for the Downs, it underwent great improvements, and henceforward paid £200 yearly to Sandwich out of the *droits* for clearing the Channel and repairing the banks of the river Stour within the Liberty; but by 1790 the harbour was of small account. During World War I, a large aerodrome was established at Manston, two miles from Ramsgate and considerable damage was done by bombs dropped on the town. In World War II 8,500 houses were damaged in the German raids of 1940–41. The conversion of $3\frac{3}{4}$ mi. of abandoned railway tunnels provided an air-raid shelter with accommodation for 60,000 persons. Ramsgate is practically contiguous with Broadstairs to the north. Before World War II the corporation, to improve the town as a seaside resort, undertook large works, including a new bathing pool (1935), tennis courts, bowling and putting greens, and ornamental gardens. The cliff promenades were extended by about a mile. The harbour, of 42 ac., was acquired by the town in 1934. During the season steamers connect it with London and the intermediate watering-places on the north coast, and with Calais and Boulogne. A fair coasting and fishing trade is carried on. Pegwell bay, famed for its shrimps, is supposed to have been the scene of the landing of Hengest and Horsa, and at Cliff's End (Ebbs Fleet) a monolithic cross marks the landing-place of St. Augustine in 596.

RAMUS, PETRUS or **PIERRE DE LA RAMÉE** (1515–1572), French humanist, was born at the village of Cuth in Picardy in 1515, a member of a noble but impoverished family; his father was a charcoal-burner. Having gained admission, in a menial capacity, to the college of Navarre, he worked with his hands by day and carried on his studies at night. The reaction against scholasticism was still in full tide, and Ramus outdid his predecessors in the impetuosity of his revolt. On the occasion of taking his degree (1536) he actually took as his thesis "Everything that Aristotle taught is false." This *tour de force* was followed up by the publication in 1543 of *Aristotelicae Animadversiones* and *Dialecticae Partitiones*, the former a criticism on the old logic and the latter a new textbook of the science. What are substantially fresh editions of the *Partitiones* appeared in 1547 as *Institutiones Dialecticae*, and in 1548 as *Scholae Dialecticae;* his *Dialectique* (1555), a French version of his system, is the earliest work on the subject in French. Meanwhile Ramus had opened courses of lectures, but was interdicted (1544) on the ground of undermining the foundations of philosophy and religion. The decree against him was presently cancelled, and in 1551 Henry II. made him professor of philosophy and rhetoric at the Collège de France. But in 1561 he embraced Protestantism, and was compelled to flee from Paris, and in 1568 from France. But he returned before the massacre of St. Bartholomew (1572), of which he was one of the victims.

The logic of Ramus enjoyed a great celebrity for a time, and there existed a school of Ramists boasting numerous adherents in France, Germany and Holland. There is even a little treatise from the hand of Milton, published two years before his death, called *Artis Logicae Plenior Institutio ad Petri Rami Methodum concinnata.*

See Waddington-Kastus, *De Petri Rami vita, scriptis, philosophia* (1848), and *Ramus, sa vie, ses écrits et ses opinions* (1855), in which a list of 50 writings by Ramus is given; C. Desmaze, *Petrus Ramus, professeur au Collège de France, sa vie, ses écrits, sa mort* (1864); P. Lobstein, *P. Ramus als Theolog* (Strasbourg, 1878); E. Saisset, *Les précurseurs de Descartes* (1862); J. Owen, *French Skeptics of the Renaissance* (1893); Voigt, *Über den Ramismus der Universität Leipzig* (Leipzig, 1888); F. P. Graves, *Peter Ramus and the Educational Reformation of the 16th Century* (1912).

RAMUSIO, GIAN BATTISTA (1485–1557), geographer, was born at Treviso in 1485 (June 20), the son of Paolo the Elder (*c.* 1443–1506). Gian Battista was educated at Venice and at Padua and entered the public service (1505), becoming in 1515 secretary of the senate and in 1533 secretary of the Council of Ten. He served the republic in various missions to foreign states, *e.g.*, Rome, Switzerland and France. He died on July 10, 1557.

Ramusio had witnessed from his boyhood the unrolling of that great series of discoveries by Portugal and Spain in East and West, and geography was his chief study and delight. It appears from a letter addressed to him by his friend Andrea Navagero, that as early as 1523 the preparation of material for his great work, *Navigationi e Viaggi*, had already begun. The task had been suggested by Girolamo Fracastoro, his lifelong friend. Among Ramusio's correspondents were Cardinal Pietro Bembo, Damiano de Goez and Sebastian Cabot; among lesser lights, Vettor Fausto, Daniel Barbaro, Paolo Manuzio, Andrea Navagero, the cardinals Gasparo Contarini and Gregorio Cortese, and the printer Tommaso Giunti, editor after Ramusio's death of the *Navigationi.*

Two volumes only of the *Navigationi e Viaggi* were published during his lifetime, vol. i. in 1550, vol. iii. in 1556; vol. ii. did not appear till 1559, two years after his death. Ramusio had intended to publish a fourth volume, containing, as he mentions himself, documents relating to the Andes, and, as appears from one of the prefaces of Giunti, others relating to explorations towards the Antarctic. Ramusio ransacked Italy and the Spanish peninsula for contributions, and translated them when needful into the racy Italian of his day. The invaluable travels of Barbosa and Pigafetta's account of Magellan's voyage were not publicly known in complete form till the present century. Of two important articles at least the originals have never been otherwise printed or discovered; one of these is the *Summary of all the Kingdoms, Cities, and Nations from the Red Sea to China*, a work translated from the Portuguese, and dating apparently from about 1535; the other, the remarkable Ramusian redaction of Marco Polo (*q.v.*). The *Prefatione, Espositione* and *Dichiarazione*, which precede this version of Marco Polo's book, are the best and amplest examples of Ramusio's own style.

There were several editions of the *Navigationi e Viaggi*, and its bibliography is extremely complicated and the contents of the editions vary. It must suffice here to say that a set of Ramusio, to be as complete as possible, should embrace—for vol. i., 1563 or any subsequent edition; for vol. ii., 1583 or 1606; for vol. iii., 1606.

Besides the circumstances to be gathered from the *Navigationi* regarding the Ramusio family, *see* the *Iscrizioni Venete* of Emanuele Cigogna. There is also in the British Museum *Monografia letta il 14 Marzo 1883* . . . by Guglielmo Carradori (Rimini, 1883); but little has been found in this.

RAMUZ, CHARLES FERDINAND (1878–1947), French-Swiss author, born at Cully, in the canton of Vaud. In the opening years of the 20th century he gained a well-merited reputation in a restricted circle; but nearly 25 years were to pass before proper appreciation was accorded by foreign critics to a writer of rare talent with a purely original style owing nothing to the "Latin" and "Classical" tradition. In his numerous works (including *Aline, Samuel Belet, Aimé Pache, Le Règne de l'esprit malin, La Guérison des maladies, Passage du poète, La Beauté sur la Terre* and *The End of All Men*, etc.), Ramuz gave, with broad and simple strokes, a picture of primitive human sentiments in language, the rhythm and phrasing of which intimately recall a definite district—namely, the Leman basin above Lausanne—a narrow strip of vineyard country backed by mountains and looking out over the Rhone and the luminous expanse of Lake Geneva. Though his outlook on the world and mankind was restricted to and conditioned by the influences of this district, Ramuz was the very opposite of a regionalist. In a country where so many others abused the facile picturesque and used "local colour" without distinction, his originality was the more striking. No one approached him in his humble self-subjection to the spirit of the country; he was completely under the spell of nature seen at close quarters. His own thoughts and aspirations were expressed in his characters; nevertheless his work is a most varied and representative picture gallery of a well-defined race, universal in its appeal though in appearance exclusively *Vaudois.* He died on May 23, 1947, in London. (C. Cl.)

RANADE, MAHADEO GOVIND (1842–1901), Indian lawyer, reformer and author, was born on Jan. 18, 1842, at Niphad, in Nasik district, of a Chitpavan Brahman family. When his father was minister at Kolhapur he attended the Anglo-

vernacular school in that town. He joined the Elphinstone institute in Bombay at the age of 14 and was one of the first graduates of the Bombay university, taking the B.A. in 1862 and the LL.B. in 1866. Having entered government service he became presidency magistrate and then fourth judge of the small cause court at Bombay in 1871, first-class subjudge at Poona in 1873 and judge of the Poona small cause court in 1884, after which, as special judge under the Deccan Agriculturists' Relief act from 1887, he came into close contact with the difficulties of the agrarian classes.

In 1886 he was a member of the finance committee appointed to report on the expenditure, both imperial and provincial, with a view to retrenchment. This service won him the decoration of C.I.E. He became a member of the legislative council of Bombay in 1885 and occupied that position until raised to the high court in 1893. Being an energetic social reformer, he directed his efforts against infant marriages, the shaving of widows, the heavy cost of marriages and other social functions and the caste restrictions on travelling abroad.

He strenuously advocated widow remarriage and female education. He was the founder of the social conference movement, which he supported till his death. In the political sphere he founded the Poona Sarvajanik Sabha. He was also one of the originators of the Indian National Congress.

In Bombay university, where he held the offices of syndic and dean in arts, he displayed much organizing power and great intimacy with the needs of the student class. Himself a thorough Marathi scholar, he encouraged the translation of standard English works and tried, with some success, to introduce vernacular languages into the university curriculum. He joined with his friends Atmaram Pandurang, Bal Mangesh Wagle and Vaman Abaji Modak in founding a new sect in Bombay known as the Parthana Samaj. This community resembles, in all essential points, the Brahma Samaj of Bengal. He died on Jan. 17, 1901.

See G. A. Mankar, *Justice M. G. Ranade* (Bombay, 1902).

RANAVALO (RANAVALONA) **III** (1864–1917), the last queen of Madagascar. She succeeded to the throne of Madagascar after the death of Queen Ranavalo II, on July 14, 1883. Although nominally queen, she took no share in the government, which her prime minister, Rainilaiarivony, had controlled since 1864. After placing her on the throne, he married her before the close of the year. For the events which resulted in the establishment of a strict French protectorate *see* MADAGASCAR: *History*. Gen. Joseph Gallieni abolished the sovereignty by proclamation in Feb. 1897 and exiled Ranavalo to Réunion. In March 1899 she was moved to Algiers. She died May 23, 1917.

RANC, ARTHUR (1831–1908), French politician and writer, was born at Poitiers on Dec. 20, 1831, and studied law. His anti-imperialist activities led to his deportation to Algeria in 1855, but he returned to Paris at the amnesty of 1859. He sat in the commune, and in 1873 was returned to the national assembly, where he sat on the extreme left. A threatened prosecution for his share in the commune obliged him to escape to Belgium, where he remained until the amnesty of 1879, continuing his collaboration on *La République française*. He succeeded Georges Clémenceau as editor of the *Aurore*. In 1903 he became senator for Corsica, and died on Aug. 10, 1908.

In addition to his political writings, Arthur Ranc published political novels of the second empire, *Sous l'empire* (1872) and *Le roman d'une conspiration* (1868).

RANCÉ, ARMAND JEAN LE BOUTHILLIER DE (1626–1700), founder of the Trappist Cistercians. He was ordained in 1651 and embarked on the ambitious and worldly career of a court *abbé* in the days of Louis XIV. But after a few years he underwent a complete change, and in 1662 he retired to his abbey of La Trappe, of which he became regular abbot in 1664 and introduced an austere reform. (*See* TRAPPISTS.) The best-known episode of his subsequent life was the "contestation" with Mabillon on the lawfulness of monks' devoting themselves to study, which De Rancé denied. He resigned his abbacy in 1695, because of declining health, and died in 1700.

The best of the early lives is that of P. le Nain, his subprior (1715); *see* also Serrant, *L'Abbé de Rancé et Bossuet* (1903).

RANCHI, a town and district of India, in the Chota Nagpur division of Bihar. The town, which is situated about 2,100 ft. above sea level, is the headquarters not only of the division and the district but also of the provincial government during the hot weather months. Pop. (1941) 54,178. The town contains a cantonment, a radium institute and two mental hospitals, one for European patients from the whole of northern India, the other, which can accommodate 1,378 patients, for Indians of Bengal as well as Bihar and Orissa.

THE DISTRICT OF RANCHI, formerly called Lohardaga, after the town which was its headquarters, has an area of 7,159 sq.mi. and a population (1941) of 1,675,413. It consists of two tablelands, of which the higher rises to about 2,000 ft. The whole area is broken by hills and undulations, which are terraced for rice. The steep slopes are covered with forest, where wild animals still abound. The principal rivers are the Subarnarekha and the North and South Koel.

Rice is the staple crop. Tea cultivation was also introduced. The only industry on a large scale is the manufacture of shellac. Myrobalans are also exported. Deposits of bauxite have been found and await exploitation.

Ranchi is connected with Purubia and the main system of the Bengal-Nagpur railway by a narrow-gauge railway, which was extended through the district to Lohardaga. The most numerous and characteristic races are the aboriginal Mundas and Oraono. Nearly 200,000 persons returned themselves as Christians at the census of 1921.

RAND, a Dutch word, in use in South Africa, meaning rim, edge, ridge of hills; specifically, it is an abbreviated form of Witwatersrand, an elevated ridge in south Transvaal, forming the water parting between the Vaal river and the Olifants river. The Rand is famous for its auriferous reefs (*see* GOLD), and the word is often used as a synonym for the extensive gold mining industry of this area, or for Johannesburg (*q.v.*), the city which the industry created.

RANDALL, JAMES RYDER (1839–1908), U.S. journalist and poet, born at Baltimore, Md., Jan. 1, 1839. His academic education was received at Georgetown college, after which he travelled in South America and then became professor of English literature at Poydras college at Pointe-Coupée, La., where he was when the Civil War broke out. The attack made by citizens of Baltimore upon Massachusetts and Pennsylvania troops as they passed through the city was the occasion of his writing "Maryland! My Maryland!" first published in the *New Orleans Delta*. The poem was widely copied and a few days later came to the attention of Baltimore people. There it was first sung by Hetty Cary to the classic melody of "Lauriger Horatius." Words and music were happily united and from that time forth the song was heard in all the homes and camps of the south and in time became a national favourite. After the war Randall became the associate editor of the *Augusta Constitutionalist* (Ga.). He was later Washington correspondent for a number of southern papers. He died at Augusta, Jan. 14, 1908.

See *The Poems of James Ryder Randall* (1910), with introduction.

RANDALL, SAMUEL JACKSON (1828–1890), American politician, was born in Philadelphia, Pa., on Oct. 10, 1828. He was educated in the public schools and in the University academy, Philadelphia. In 1858–59 he was a Democratic member of the State senate. During the Civil War he served in the Union army, rising to the rank of captain and playing an important part in the Gettysburg campaign. From 1863 until his death he was a Democratic representative in Congress. During the session of 1874–75 he first gained a national reputation by the masterful manner in which he prevented the Republican majority from passing the Force Bill or Federal Election Law. Under his leadership discipline and party harmony were established among the Democrats for the first time after the Civil War. He was speaker of the House from Dec. 1876 to March 1881, during a period marked by rancorous debates concerning the disputed Hayes-Tilden presidential election. He was noted for his work as chairman of the committee on appropriations and as a member

of the committee on banking currency and retrenchment. He was a leader of the Protectionist wing of the party. He died in Washington, D.C., on April 13, 1890.

RANDAZZO, a town of Sicily, in the province of Catania, at the north foot of Mt. Etna, 43 mi. N.W. of Catania by rail and 26 mi. direct. Pop. (1951) 13,396 (commune). Remains of architecture of the 13th and 14th centuries include three Norman churches and some interesting palaces. The former contain some fine sculptures and goldsmith's work, while the Museo Vagliasindi has interesting objects from a Greek necropolis in the neighbourhood.

Randazzo is the nearest town to the summit of Etna (9 mi.).

RANDEGGER, ALBERTO (1832–1911), Italian musical composer and conductor, was born in Trieste April 13, 1832. He settled in London in 1854. He became professor of singing at the Royal Academy of Music in 1868 and at the Royal College of Music in 1896. He was conductor of the Carl Rosa company from 1879 to 1885 and conducted the Norwich festivals 1881–1905. Randegger, who died in London on Dec. 18, 1911, assisted the popular revival of opera in England. His works include *Bianca Capello* (1854) and other operas, and also *Primer on Singing*.

RANDERS, a town of Denmark, capital of the *amt* (county) of its name in Jutland, on the Gudenaa at the point where it begins to widen into Randers fiord, an inlet of the Kattegat. Pop. (1950) 40,098. Randers is best known in history as the scene of the assassination of Count Gerhard by Niels Ebbesin in 1340. Though a place of considerable antiquity—being mentioned in 1086 as the meeting place of insurgents against Canute IV—Randers has few remains of old buildings and bears the stamp of a compact, modern manufacturing town that owes its importance to its distilleries, manufactories of gloves, railway carriages, etc. St. Marten's church dates from the 14th century. The high school is housed in a mediaeval monastery. The town is 15 mi. from the open Kattegat and the harbour is 15 ft. deep.

RANDOLPH, EDMUND (JENNINGS) (1753–1813), U.S. statesman, was born on Aug. 10, 1753, at Tazewell hall, Williamsburg, Va., the family seat of his grandfather, Sir John Randolph (1693–1737), and his father, John Randolph (1727–84), who (like his uncle Peyton Randolph) were king's attorneys for Virginia. Edmund graduated from the College of William and Mary and studied law with his father, who felt bound by his oath to the king and went to England in 1775. In Aug.–Oct. 1775 Edmund was aide-de-camp to Washington. In 1776 he was a member of the Virginia convention and was on its committee to draft a constitution. In the same year he became the first attorney general of the state (serving until 1786). He served in the Continental Congress in 1779 and again in 1780–82. He had a large private practice, including much legal business for Washington. In 1786 he was a delegate to the Annapolis convention and in 1787–88 was governor of Virginia. He was a delegate to the constitutional convention of 1787, and on May 29 presented the "Virginia plan" (sometimes called the "Randolph plan"). In the convention Randolph advocated a strongly centralized government, the prohibition of the importation of slaves, and a plural executive, suggesting that there should be three executives from different parts of the country, and refused to sign the constitution because too much power over commerce was granted to a mere majority in congress and because no provision was made for a second convention to act after the present instrument had been referred to the states. In Oct. 1787 he published an attack on the constitution; but in the Virginia convention he urged its ratification, arguing that it was too late to attempt to amend it without endangering the union, and thinking that Virginia's assent would be that of the necessary ninth state. In 1788 he refused re-election as governor and entered the house of delegates to work on the revision and codification of the state laws (published in 1794).

Service in Cabinet.—In Sept. 1789 he was appointed by President Washington first attorney general of the United States. He worked for a revision of Ellsworth's judiciary act of 1789, and especially to relieve justices of the supreme court of the duties of circuit judges, and advocated a federal code; in 1791 he considered Hamilton's scheme for a national bank unconstitutional; and in 1792–93, in the case *Chisolm* v. *Georgia* before the supreme court, argued that a state might be sued by a citizen of another state.

On Jan. 2, 1794, he succeeded Thomas Jefferson as secretary of state. In 1795 he wrote 13 letters (signed "Germanicus") defending the president in his attack on the American Jacobin or democratic societies. He was the only cabinet member who opposed the ratification of the Jay treaty. Before it was ratified the delicate task of keeping up friendly diplomatic relations with France fell to him. Home dispatches of the French minister, Joseph Fauchet, intercepted by a British man-of-war and sent to the British minister to the United States, accused Randolph of asking for money from France to influence the administration against Great Britain. Although this charge was demonstrably false, Randolph when confronted with it immediately resigned, and subsequently secured a retraction from Fauchet; he published *A Vindication of Mr. Randolph's Resignation* (1795) and *Political Truth, or Animadversions on the Past and Present State of Public Affairs* (1796). He died at Carter hall, Millwood, Clarke county, Va., on Sept. 12, 1813.

See M. D. Conway, in his *Omitted Chapters of History Disclosed in the Life and Papers of Edmund Randolph* (1888; 2nd ed., 1889).

RANDOLPH, JOHN, of Roanoke (1773–1833), U.S. statesman and orator, was born at Cawsons, Va., on June 2, 1773. Through his father, John Randolph, and his mother, Frances Bland, he was related to the Randolphs of Turkey Island and the Blands of Westover, two of the most conspicuous families of colonial Virginia; and, through an ancestress, Jane Bolling, he was a descendant of the Indian princess Pocahontas. He received his collegiate education at Princeton, Columbia and William and Mary colleges. In 1799 he was elected to the house of representatives, after a historic debate with Patrick Henry. In the house, his rise was so rapid that, after the election of Jefferson to the presidency in 1801, he was made chairman of the house committee on ways and means and became the leader of the house Republicans. Soon, however, he drifted away from Jefferson and lost both chairmanship and leadership. Afterward he was, for many years, a mere free-lance, but in 1820 his resolute resistance to the Missouri Compromise made him again a truly powerful figure in the house. After his first election in 1799 he was re-elected to the house every two years until 1829, except in 1813, when his opposition to the War of 1812 resulted in his defeat by John W. Eppes, and in 1817, when he declined to be a candidate. After re-election to the house in 1825, he was elected to the U.S. senate, but he was defeated for re-election by John Tyler. In 1807 he was the foreman of the grand jury which indicted Aaron Burr for treason, and he was a prominent member of the famous Virginia constitutional convention of 1829–30. In 1830 he was sent by Andrew Jackson on a special mission to Russia. In the succeeding year he returned and later denounced, in a series of speeches, the nullification proclamation of Andrew Jackson. He died at Philadelphia on May 24, 1833. Randolph was a passionate partisan of state sovereignty and, therefore, opposed to a national bank, protection and federal internal improvements and interference with slavery; but he disliked slavery and freed his slaves by his will. He filled with admirable efficiency the chairmanship of the house committee on ways and means. Jefferson said that his "popular eloquence gave him such advantages as to place him unrivalled as the leader of the House."

At the time of the Missouri Compromise, his influence was so great that Henry Clay afterward declared in a speech: "His acts came near shaking this Union to the centre, and desolating this fair land." After his return to the house in 1827, it was again so great that the failure of John Quincy Adams to be re-elected to the presidency was largely due to it. "Wit and genius *all* allowed him," Thomas H. Benton tells us. "He has probably," declared Horace Binney, "spoken to more listeners than any other man of his day; having been unrivalled in the power of riveting the attention by the force and pungency of his language, the facility

and beauty of his enunciation, and the point and emphasis of his most striking manner." Some of Randolph's speeches in congress are found in most anthologies of American eloquence. One of the most brilliant and disinterested, though by no means one of the most useful, of American public men, he was a captivating talker, a delightful letter writer, a ripe scholar and a devotee of the horse, the dog and the gun. Randolph was the scion of old and distinguished family stocks, the lonely occupant, when at Roanoke, of two rude dwellings in the heart of a primaeval forest, and yet the possessor of a vast landed estate, a numerous retinue of slaves, a splendid stud of thoroughbreds and a choice library. Since he was, moreover, marked by startling peculiarities of voice, face and form which, once heard or seen, were never forgotten, always eccentric and sick and sometimes actually demented, a party to two duels and many quarrels, dauntlessly intrepid, intensely malignant at times and yet susceptible also to impulses of love and pity, it is not surprising that John Randolph of Roanoke should occupy, in U.S. history, a place that is likely forever to remain unique.

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RANDOLPH, PEYTON (1721–1775), U.S. politician, was born at Tazewell hall, Williamsburg, Va., in 1721, a son of Sir John Randolph (1693–1737), the king's attorney for Virginia. He graduated at the College of William and Mary, studied law at the Inner Temple, London, and in 1748 was appointed the king's attorney for Virginia. Randolph wrote the address of remonstrance to the king on behalf of the burgesses against the suggested stamp duties in 1764. His policy was conservative and moderate, and in May 1765 he opposed Patrick Henry's radical "Stamp Act resolutions." In 1766 he resigned as king's attorney and was succeeded by his brother John (1727–84). In 1769 he acted as moderator of the privately convened assembly which entered into the nonimportation agreement, and in May 1773 he became chairman of the first Virginia intercolonial committee of correspondence. He presided over the provincial convention of Aug. 1774, was a member of the first Continental Congress, of which he was president from Sept. 5 to Oct. 22, 1774, and was re-elected to congress in March 1775. Randolph died of apoplexy in Philadelphia on Oct. 22, 1775. He was provincial grand master of the Masons of Virginia and was an intimate friend of George Washington.

RANDOLPH, THOMAS (1523–1590), English diplomatist, son of Avery Randolph, a Kentish gentleman, was educated at Christ Church, Oxford, and in 1549 became principal of Pembroke college, Oxford, then known as Broadgates hall. During the reign of Mary, Randolph, who was a zealous Protestant, sought refuge in Paris, where he cultivated the society of scholars. Returning to England after the accession of Elizabeth I, he was employed as a confidential diplomatic agent of the English queen in Scotland. Randolph's dispatches from Scotland between 1560 and 1585 supply important material for the history of the political intrigues of that period. In 1568 he undertook a mission to Russia which resulted in the concession by Ivan the Terrible of certain privileges to English merchants; in 1570 he returned to Scotland. After carrying through certain diplomatic business in France in 1573 and 1576, Randolph returned in Jan. 1581 to Scotland, where the earl of Morton, the regent, had been arrested a few days previously. Randolph, acting on Elizabeth's instructions, intrigued with Angus and the Douglases in favour of a plot to seize the person of the young King James and to save Morton by laying violent hands on the earl of Lennox. Douglas of Whittingham made revelations which imperilled Randolph, who withdrew to Berwick before the execution of Morton in June 1581. In 1585, when he next visited Scotland, he helped to arrange a treaty between England and Scotland. For the next four years he was chancellor of the exchequer in England, and he died in London in June 1590.

See M. J. Thorpe (ed.), *Calendar of State Papers relating to Scotland (1509–1603)*, 2 vol.

RANDOLPH, THOMAS (1605–1635), English poet and dramatist, was born near Daventry in Northamptonshire, and was baptized on June 15, 1605. Ben Jonson adopted him as one of his "sons." He addressed three poems to Jonson, one on the occasion of his formal "adoption," another on the failure of *The New Inn* and the third, an eclogue, describing his own studies at Cambridge. He was buried in Blatherwick church on March 17, 1635.

Randolph's earliest printed work is *Aristippus, Or, The Joviall Philosopher. Presented in a private shew, To which is added, The Conceited Pedlar* (1630). It is a gay interlude burlesquing a lecture in philosophy, the whole piece being an argument to support the claims of sack against small beer. His other authenticated works are *The Jealous Lovers* (1632); *The Muse's Looking-Glass; Amyntas, or The Impossible Dowry*, a pastoral printed in 1638; and some Latin and English poems. *Hey for Honesty, down with Knavery*, a comedy, is doubtfully assigned to him. His works were edited by W. C. Hazlitt in 1875.

RANDOM, an adjective originally meaning impetuous, hasty, hence done without purpose or aim, haphazard. The term "random work" is used in architecture, by the ragstone masons, for stones fitted together at random without any attempt at laying them in courses. (*See* MASONRY.)

RANDS, WILLIAM BRIGHTY (1823–1882), English essayist and writer for children, was born in Chelsea on Christmas eve, 1823. After miscellaneous employments he became a reporter in the committee rooms of the house of commons (1857–75). He occupied his spare time in writing for a large number of magazines and periodicals as well as for his own publications. The latter comprised: under his own name, an edition of *The Poetical Works of Robert Bloomfield* (1855) and *Chain of Lilies and Other Poems* (1857); anonymous, *The Frost upon the Pane; a Christmas Story* (1854) and his best-known works, the books of poems for children, *Lilliput Levee* (1864), *Lilliput Lectures* (1871), *Lilliput Revels* (1871) and *Lilliput Legends* (1872); and pseudonymous, *Tangled Talk* (1864) by "Thomas Talker," *Henry Holbeach, Student in Life and Philosophy* (1865) and *Shoemakers' Village* (1871; previously in the *Argosy*, 1867) by "Henry Holbeach," and *Verses and Opinions* (1866) and the more valuable *Chaucer's England*, 2 vol. (1869), by "Matthew Browne." He died on April 23, 1882, at East Dulwich, Surrey. *Lazy Lessons and Essays in Conduct* was posthumously edited by R. B. Johnson.

See A. H. Miles (ed.), *Poets and Poetry of the Century*, vol. 5 (1893).

RANELAGH, formerly a resort by the Thames river in Chelsea, London, Eng. About 1690 land lying east of Chelsea hospital and bordering the river was acquired by Richard, Viscount Ranelagh, later earl of Ranelagh. He built a mansion and laid out gardens, which in 1742 were thrown open as a proprietary place of entertainment. A building called the Rotunda was erected for concerts, and the gardens became a resort of fashionable society. By the close of the 18th century Ranelagh was ceasing to attract, and in 1803 the Rotunda was closed. The buildings were removed, and the grounds passed to Chelsea hospital.

RANGABÉ, ALEXANDROS-RIZOS (1810–1892), Greek poet, archaeologist and statesman, born at Constantinople in 1810, was the son of Jean-Rizos Rangabé, a celebrated poet and scholar. In 1829 Alexandros entered the ranks of the Bavarian army, but after the establishment of the Greek republic he returned to his native country where he became successively minister of education (1833) and director of the royal printing press (1841). In 1844 he became professor of archaeology at the University of Athens, and for the next 12 years, in company with C. Bursian, he investigated the ruins of the temple of Juno, near Argos, bringing to light many statues and bas-reliefs and discovering the entire formation of the building. He died at Athens on Jan. 28, 1892.

Rangabé advocated a revival of the ancient Greek language and wrote poetry and dramas in Greek, including *Phrosyne*, *The Vigil* and *The Thirty Tyrants*. He also wrote various archaeological works in French, notably *Antiquités helléniques* (1842–55) and *Antiquités troyennes* (1874).

RANGE: *see* HOUSEHOLD APPLIANCES; GAS STOVES.

RANGE FINDERS. Range finders are used to establish surveys and maps, to enable the accurate direction of gun, rocket and missile fire, to test and study air vehicle characteristics and to determine the lens focus setting for cameras. Triangulation methods have long been used for the determination of ranges, and precise optical methods have been devised for this purpose.

With the development of pulse-time techniques for use with radio equipment, a new series of instruments evolved for the determination of range. (*See* RADAR.) The development of radio ranging at the beginning of World War II became an important factor in naval gunnery and anti-aircraft fire; large optical range finders formerly indispensable in the direction of such fire assumed a secondary or stand-by role. Optical range finders have the advantages of high resolution, compact size, relatively simple maintenance and accuracy at short ranges, but they are unreliable during bad visibility conditions and at long ranges, require a relatively long time to make the range determination and, for most purposes, are useless at night. Radio range finders consist of a highly complex electrical network which requires large electrical power supplies and constant attendance by highly trained technicians.

Basically, an optical range finder is a triangulation device with which two angles and the included base are measured to determine the range to the target situated at the apex of the triangle so formed. The most accurate ranging is accomplished by: (1) a two-station system of triangulation in which the base line is long and the optical stations are separated by distances of several hundred yards or many miles; (2) the short base monostatic range finder, a one-station system of triangulation which is a self-contained optical system; its accuracy depends on the precise mounting of its optics on an optical bar. The two-station system suffers from the difficulty of establishing time coincidence when measuring ranges to moving or intermittent targets, the complex communication network required to co-ordinate the ranging, and the difficulty of insuring that the two stations are set on a common target and the lengthy process of calculating the range. The one-station system, at the expense of accuracy, avoids these difficulties.

Two-Station System.—The two-station system of triangulation has undergone a high degree of development throughout recorded history beginning, perhaps, with the attempts of the Egyptians who were required to re-establish property lines after the annual inundation of the Nile. In modern times, the development of the optical theodolite resulted in highly precise measurements. The theodolite is used to measure angles—measurements which, in order to minimize operators' errors, are averaged from a number of readings in order to determine the true angle. By United States coast and geodetic procedure an angle is turned 16 times in a first order survey, 4 times in a second order survey, and twice in a third order survey. The accuracy of the distances so measured must not have an error exceeding 1 in 25,000 in a first order survey, 1 in 10,000 in a second order survey, and 1 in 5,000 in a third order survey. This precision is possible only because the targets are fixed and easily identifiable from each other.

In many situations, especially in military usage, the targets are either moving or intermittent, as in the determination of the ranges to vehicles or gun flashes. In such cases, a reading can be taken only once and the two base angle readings must be taken simultaneously. An elaborate communication network between the stations must be set up and timing coincidence must be established. One military system consists of a shutter assembly which is attached to the objective of a sighting telescope. A network of these instruments is established by survey with the shutters connected over communication wires so that the shutters can be simultaneously opened or closed electrically from a central control station. This system is particularly useful in spotting muzzle flashes from artillery fire. When an observer notes a muzzle flash through his telescope he closes the shutters, thus establishing time coincidence. The operators then take a reading of the bearing of their sighting telescope and relay the bearing position to the central control station where a range plot is made.

For proof-testing and in checking the accuracy of anti-aircraft fire, a more elaborate network is established by using phototheodolites. A phototheodolite, as shown in fig. 1, consists of a camera with a long focal length lens mounted on a theodolite base. The theodolite is turned by a hand wheel or synchronous motor directed by an operator, who sights through a telescope which is fixed to the theodolite base. Time coincidence among the phototheodolite stations is established by a signal which is transmitted over a communication system. Time markers are actuated to give an indication printed on the film; the signal may also operate the shutter. It is possible to operate the phototheodolites over base lines as long as 15 mi. The camera, usually a 35-mm. movie type, takes a picture of the target being tracked by the operator, fiducial marks which establish the zero position on the film as well as pictures indicating the position of the theodolite base in both azimuth and elevation. The angular errors in tracking are reduced by developing the film and making corrections to the indicated azimuth and elevation readings by applying tracking corrections determined from the measured position of the target

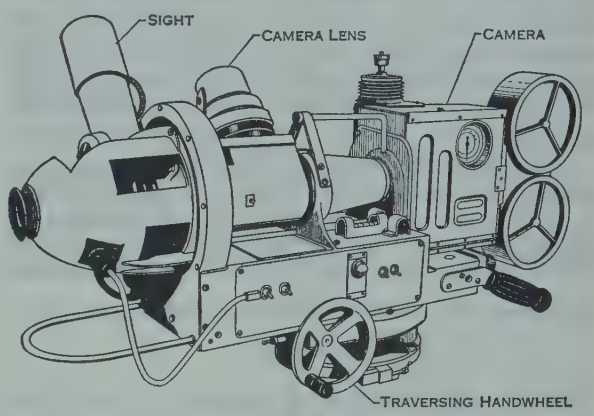

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FIG. 1—PHOTOTHEODOLITE

with respect to the fiducial marks. By averaging measurements made by a system of four or five phototheodolites, it is possible to obtain range accuracies of 1 in 10,000 at ranges less than 10,000 yd.

Short Base Range Finders.—Attempts were made as early as 1770 to couple two theodolites closely on a short base line to circumvent communication difficulties in military range finding. Georg Friedrich Brander in 1781 built a range finder for one operator and Alexander James Adie (1860) constructed a split coincidence range finder. Guy Barr and William Stroud in England culminated a rapid development of range finders in 1888 when they brought out their coincidence range finder, prototypes of modern instruments. Later in 1893 Carl Zeiss in Germany built a stereoscopic range finder. The Germans continued to favour the stereoscopic type made both by Zeiss and Carl Goerz; the British favoured coincidence types. U.S. manufacturers, Bausch and Lomb, Eastman Kodak and Kueffel and Esser, continued to make both types. Military range finder developments were largely concerned with refinements of these two designs. Efforts were made to study methods of training operators, improving the presentation of the image, testing the psychological and physiological ability of the operator, and finally bringing the precision of the instrument to a refinement commensurate with latest optical and mechanical skill.

Coincidence and Stereoscopic Range Finders.—In the development of the modern range finder there was considerable controversy concerning the comparative effectiveness of the coincidence and stereoscopic range finders. The general advantage of one over the other had not been proved by mid-20th century. The two appear similar except that usually the coincidence type has a single eyepiece as compared with two in the stereoscopic type. Fig. 2 and 3 illustrate the schematic arrangement of the commonly used coincidence and stereoscopic range finders.

Monostatic range finders are built, self-contained, with two optical extended "arms" which define the base length. The outer case usually contains windows, the optical square and the eyepieces. An inner "optical bar," insulated from temperature differentials and vibrations, contains the objectives, deviation prism

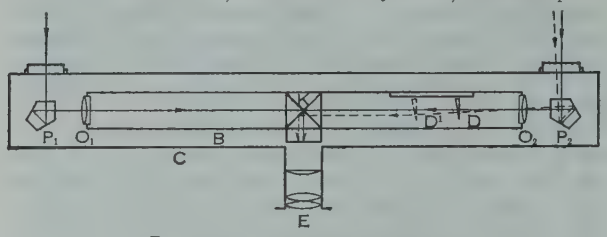

FIG. 2—COINCIDENCE RANGE FINDER

and the reticles. As the field of view is small, the range finder is mounted on bearings and must be rotated to follow the target. The range operator who observes the images formed by the two objectives adjusts the range drum to establish coincidence or stereoscopic contact; the range can then be read from the drum. Monostatic range finders having a base length of one-half yard to a yard are portable and used by armies in the field; they are accurate to several thousand yards. Larger range finders having base lengths of $4\frac{1}{2}$ ft. to 40 ft. are used to measure ranges up to 20 mi. to adjust naval and anti-aircraft fire.

Accuracy of Monostatic Range Finders.—The fundamental equation for the range finder can be stated simply from fig. 6. At O_1 is a right angle and at O_2 is an angle θ which gives the bearing to the target. As this angle is always very small, the range is given as $R = \frac{B}{\theta}$ (approximately) where B is the base separation. The statement for the range error then becomes:

$$dR = \left|\frac{d\theta}{B} R^2\right|. \qquad (1)$$

The most useful function of this formula is to show that the range error varies as the square of the distance. This error may be compared with radio range finders for the radio range determination depends on measuring the time during which a radio wave travels from the target to the observer. As the velocity of a radio wave is substantially invariant, the range error is largely independent of the range. With an optical range finder, the accuracy with which $d\theta$ and B can be measured under field conditions is a complex function of the construction of the instrument; *i.e.* magnification, temperature stability, mechanical rigidity, backlash and the presentation of the image; a function of the target shape and size; a function of atmospheric visibility; and a function of the training and physiological condition of the operator. In measuring the accuracy of range finders the term "unit of error" (*UOE*) is frequently used. It may be defined as the greatest angle of deviation from the true coincidence setting or stereoscopic contact which may be detected by the operator.

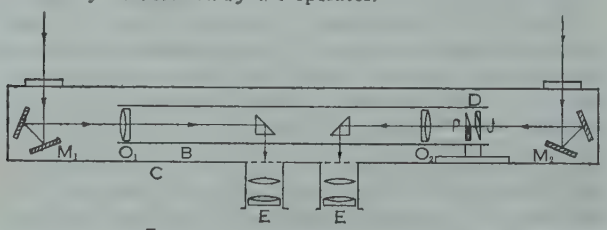

FIG. 3—STEREOSCOPIC RANGE FINDER

The measurement of the angle $d\theta$ when considering only the visual acuity of the observer and the geometric magnification M of the telescope becomes $d\theta = UOE/M$. The error in optical range finding is then given by the formula

$$dR = \frac{(UOE)}{BM} R^2. \qquad (2)$$

This is a very idealized formula and its application can only be considered as a goal to be achieved by eliminating all instrumental and operator errors. In the English speaking countries a *UOE* of 12 sec. of arc is commonly accepted. If the range is given in thousands of yards R_M, the base length in yards b, then the range error in yards is

$$dR = \frac{60}{bM} R_M^2. \qquad (3)$$

An instrument having a 1-yd. base and a magnification of $15X$ has then an ideal range error of $dR = 4R_M^2$. In actual field use, an instrument with a like base and magnification having an error factor of $dR = 10R_M^2$ would be an excellent instrument. By increasing the base distance and the magnification, the range error is decreased, although not as much as indicated by formula (3).

Construction.—The two ends of the base line are defined by the optical square which changes the incoming light path at the two arms of the range finder by 90°. A penta prism P, as shown in fig. 2, is ideally suited for the purpose since it has the characteristic of changing the light path through a constant fixed angle independently of the incident angle. The prism has its two reflecting surfaces 45° to each other. In larger range finders it is necessary to use mirror surfaces M as reflecting surfaces, as shown in fig. 3, for it is impossible to obtain satisfactory prisms in the larger sizes. The choice of penta prisms or mirrors depends on the size of range finders and not on the type.

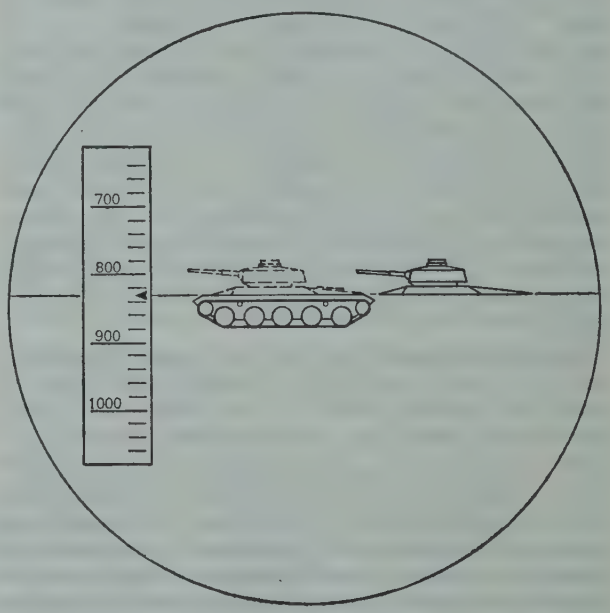

FIG. 4—FIELD OF COINCIDENCE RANGE FINDER

In order to effect coincidence or establish stereoscopic contact it is necessary to displace the image which is formed through one arm of the range finder. This can be accomplished by movement of one of several optical components. To accomplish the displacement in military instruments it proved most suitable to use a deviation prism or prisms; of a large number of systems devised two were found most useful. One type of deviation device is a low power prism placed in the converging beam of one arm of the range finder (fig. 2) which if displaced to the position indicated by the dotted line results in a corresponding displacement of the image formed from that arm. The prism must be placed in the converging beam. A calibrated scale and indicator coupled to the prism indicates the range. The second type is known as a diasporameter and is indicated in D, fig. 3. It consists of two low power prisms placed in opposition which may be placed in the parallel beam ahead of the objective lenses. In the opposition position the deviation caused by one prism is cancelled by the deviation from the other. Now if the prisms are rotated in opposite directions about the optic axis, as indicated in fig. 3, the vertical displacement caused by the two prisms will cancel and only a

horizontal displacement will result. The two prisms, which are mounted in an edge driven mount, need not be located together as is shown in figure 3 but may be separated with one placed in each arm of the range finder.

The range finder includes a telescope not only for the purpose of forming an image from the radiation arriving at the penta prisms but also to aid the operator in seeing objects at a distance. The difference in the two types of ranges is apparent in the telescopic system. The two objectives of the coincidence range finder form an image in a common focal plane which may be viewed either by a single or a binocular eyepiece. In a stereoscopic range finder two complete telescopes are used with their own objectives and eyepieces. Stereoscopic contact is established physiologically by the operator.

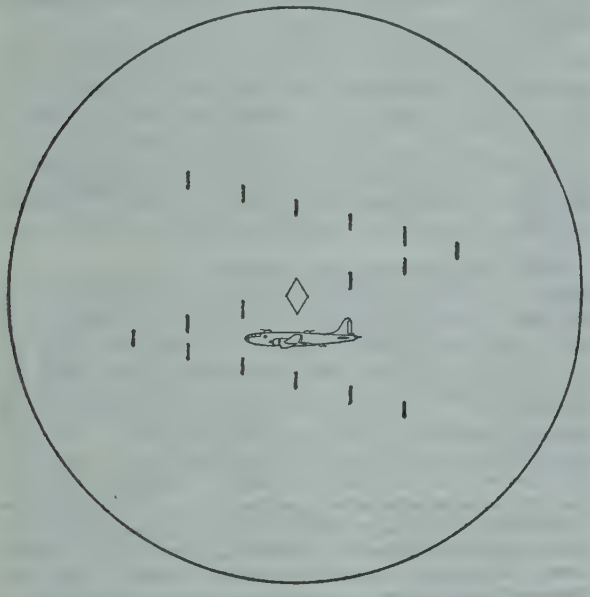

FIG. 5—FIELD OF STEREOSCOPIC RANGE FINDER

The coincidence in a range finder is achieved by melding the images from the two arms by a combination of prisms. In simpler types of range finders half-silvered mirrors may be used; in more precise instruments the prism combination becomes complex to achieve the proper presentation. In fig. 2 the prism is only indicated; actually it is made up of a combination of roof prisms. The prism combination may be so constructed that not only the fields from the two arms are shown but also as indicated in fig. 4 a scale indication of the range is made. As shown in fig. 4, the target may be presented as a split image with the field divided in the centre. Adjustment of the range drum shifts one field until coincidence is established as shown by the dotted line in the figure. Other presentations might be used; as a superimposed image as shown in fig. 7, as a double image one above the other, or as a double image with one inverted. The split image adjustment is particularly effective when definite vertical lines are visible on the target; the invert double image is effective with targets where the sense of symmetry aids in the adjustment. In using the split image the fineness of the dividing line is important; for precise instruments, a satisfactory line can only be produced by coincidence prisms. In order to insure the optimum performance an adjustment to correct the relative location of the two target images must be provided so that upon adjustment the images match in the field. This is done with a "halving adjustment." The adjustment may be effected by rotating a parallel plate in the converging beam of one of the arms.

The two telescopes of a stereoscopic range finder have reticles marked with a single mark or a "picket" of spaced marks. The marks are so placed that, when they are viewed by the two eyes of the observer, the marks are fused and appear to float in space because of the stereoscopic perception of the observer. If the image of the target is positioned on the reticle with the proper spacing, the target will be seen stereoscopically in three dimensions. The effect may be altered by displacing the image on the reticle and objects will appear to approach or recede. By means of the deviation prisms the target may be displaced and stereoscopic contact is established when the target appears to be at the position in depth of the reticle spot. The reticle spot, known as the wandermark, may have various shapes such as a circle, a line or a diamond. Under adverse lighting conditions it appears advantageous to illuminate the wandermark so that a spot of light appears in the field. If the picket of wandermarks as shown in fig. 5 is used, the spacing between the two reticles is such as to form a series of lines which in the field of view apparently recede into space. It may be that such an arrangement is helpful in correcting the range drum reading on targets when there is not time to establish stereoscopic contact with the central wandermark.

A large variety of novel presentation arrangements have been made by U.S. range finder makers in order to improve the stereoscopic range finder. One arrangement worthy of note, the psuedo stereoscopic range finder, has in addition to the normal field a second crossed field produced from opposite objectives so that a double image of the target is produced. As the adjustment for stereoscopic contact is made the two images appear to move, one moving forward toward the wandermark and the other moving away from the observer toward the wandermark.

As the range finder is a precise optical instrument, it is subject not only to the shifting of its parts because of temperature changes, vibration and shock, but is also subject to the idiosyncrasies of the operator. For these reasons it must be calibrated often in use and when operators are changed. The most effective adjustment is to range on an object at infinity such as the moon or stars. Lacking these a "lath" is used for small range finders which consists of a board having two marks spaced in accordance with the dimensions of the optical separation of the instrument. This board when viewed through the range finder has the appearance of being at infinity. Larger range finders have a built-in optical system which forms an artificial target at infinity for use in adjustment.

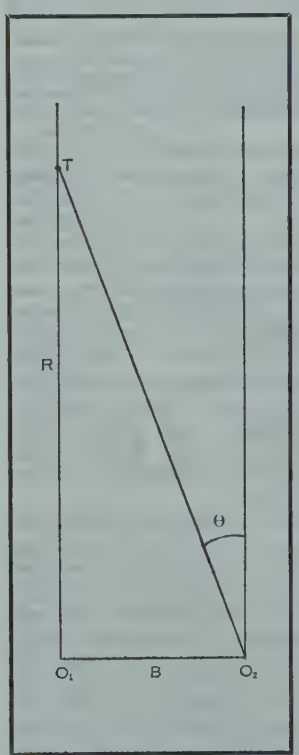

FIG. 6.

Height Finders.—When ranging on air targets, the range finder determines the slant range. Often the altitude or vertical component to the target is required. This, a function of the elevation angle and the slant range, may be computed mechanically by a system of cams.

Photographic Range Finder.—With the development of press photography and the interest in the candid camera, rapid adjustment of the camera focus became important. A range finder made by the Kalart company, permitting the rapid and accurate focusing of the lens, is shown in figure 7. Photographic range finders are invariably of the coincidence type and may be of either the split image or superposition of image type. They may be coupled directly to the camera through a mechanical linkage or they may be separate and give a range scale reading. An attachment is also available which projects a spot of light which under unfavourable lighting conditions forms a target reflected from the subject which can easily be brought into coincidence in the range finder. A number of range finders made by various camera manufacturers appeared on the market. These, although simple in construction, may have various complexities as described in *Coincidence and Stereoscopic Range Finders*, above.

Eastman Kodak company marketed split image coincidence finders, one type with a split image coincidence prism and adjusted by moving one objective. Zeiss made a range finder having an adjustment by a diasporameter. The Leica range finder is similar to that shown in fig. 7.

Camera range finders have base lines which may be an inch and a

half long to about four inches. That the instrument must be carefully made can be understood, as a movement of 3° in the mirror corresponds to a change in the setting of the range finder from three and one-half feet to infinity.

Stadiometric Ranging.—The determination of distances by stadia rods has long been used in survey work. The method depends upon

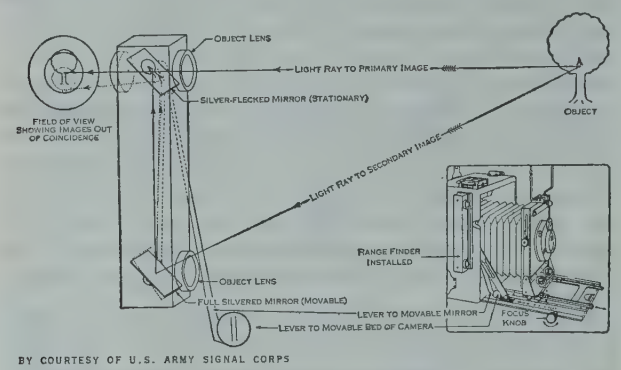

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FIG. 7—PHOTOGRAPHIC RANGE FINDER COUPLED TO CAMERA

solving the triangle established by the angle subtended at the observer's position by an object of known size to determine the range to the object. In surveying procedure a stadia rod having markings with known spacings is observed through a theodolite and standard tables give the range to the rod. A range finder using similar principles is used for military purposes. It consists of a telescope or binoculars having either a lattice of horizontal markings, or a single mark or pattern of adjustable size. By observing the image of a man, or a vehicle of known size, superimposed on the reticle the angle subtended by the object is determined. Inasmuch as aircraft have well-known dimensions, the stadiometric device is used for a simple ranging device to determine ranges to aircraft.

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RANGER, a city of Eastland county, Texas, U.S., 86 mi. W. by S. of Fort Worth, at an altitude of 1,458 ft.; on federal highway 80, and served by the Texas and Pacific and the Wichita Falls and Southern railways. Pop. (1950) 3,951. Oil was discovered on Oct. 21, 1917, and within a few weeks the town of 500 inhabitants was transformed into a camp of 30,000 living in tents and shacks, half of this number becoming permanent residents when the first boom was over. Ranger is field headquarters for several refining and pipe-line companies, shipping about 5,000,000 gal. of casing-head gasoline per month and thousands of gallons of butane, propane and butadienne from its large fractionating plant. The city is surrounded by rich farming and stock-raising country; peanuts are the main crop of the county. Large deposits of clay and limestone are found adjacent to the city. Ranger derived its name from a group of Texas rangers stationed in a fort near town. The city was chartered in 1919.

RANGOON, the capital of Burma, situated on the left bank of the Hlaing or Rangoon river, 21 mi. from the sea, in 16° 47′ N. lat. and 96° 13′ E. long. In 1880 the city was detached from the main district, called Hanthawaddy, and formed into a separate district, with an area of 19 sq.mi. This was continually increased; the census area of Rangoon town district in 1931 was 77 sq.mi. The population was 400,000 in 1931 and 501,219 in 1941. On Aug. 1, 1926, the district became part of the Pegu division. From a comparatively insignificant place, Rangoon rose in less than half a century to be the third seaport in India, being surpassed only by Calcutta and Bombay in the volume of its trade. During the busy season of rice-export, which lasts from the end of December to the middle of May, the pool forming the port of Rangoon presents almost as crowded a scene as the Hugli at Calcutta. Rangoon has the double advantage of standing near the sea and being in easy communication with a great river navigable for 900 mi. behind it. It is, in addition, the centre of the Burmese railway system. In the broad and deep river is concentrated the whole of the rich trade of the delta of the Irrawaddy. A great part of the river frontage is occupied with rice-mills, teak wharves and similar buildings. Because of the need for wharfage accommodation, the majority of the mills were removed to the opposite or Dalla shore of the Rangoon river, or along the banks of the Pegu river east of Rangoon. The rice exported from Rangoon in the years from 1930–31 to 1939–40 averaged about 2,250,000 tons.

Architecture and History.—The city is dominated by the great golden pile of the Shwe Dagon pagoda, the centre of Burmese religious life. Rising to a height of 368 ft., this magnificent building stands on an eminence itself 168 ft. above the level of the city. It is covered with pure gold from base to summit, and once in every generation this gold is renewed by public subscription. The pagoda is a solid stupa of brick, in the form of a cone, raised over a relic chamber; and the place of worship is the surrounding platform with a perimeter of nearly 1,400 ft.

Though traditionally a site of great sanctity, Rangoon owes its first importance to its rebuilding in 1753 by Alompra, the founder of the Burmese monarchy, who gave it the name of Yan Kon, "the end of strife." The modern Burmese designation of the town is Yangon. The city was taken by the British on the outbreak of the first Burmese War in 1824, but was subsequently restored. It was captured a second time in 1852 and passed with the province of Pegu into the hands of the British. It was destroyed by fire in 1850, and serious conflagrations occurred again in 1853 and 1855.

Administration and Improvements.—Until 1874, when the modern municipality was constituted, the administration was in the hands of the local government, which devoted itself to raising the centre of the town above the river level, providing land fit for building purposes from the original swamp, which was flooded at spring-tides, and making roads, bridges, culverts and surface drains. In 1892 the sewage system was introduced, and Rangoon developed an excellent drainage system. The water supply, drawn at first from the Victoria lake, 5 mi. distant, was later drawn from a large reservoir lake 17 mi. distant, and from the Pegu Yoma water scheme completed in 1941. The city proper of Rangoon with the Kemmendine suburb is laid out on the block system, each block being 800 by 860 ft., intersected with regular streets. The city has an extensive electric tramway system, supplemented by motor bus services. Rangoon has many fine public buildings including the secretariat, the law courts, post office, customs house and general hospital.

There are two large maidans, or commons, which are used as military parade grounds and for sport, the larger being used as golf links. There are also spacious and well-kept zoological gardens, botanical gardens and a well-kept garden in the cantonments under the pagoda. Beyond these lie the Royal Lake and Dalhousie park, with 160 ac. of water and well-laid out and well-timbered park land. There are two cathedrals, Church of England and Roman Catholic, a Presbyterian church and churches of most denominations with services in English, Burmese and the principal Indian languages. Buddhists, Hindus, Mussulmans, Parsees, Armenians and Jews all own lands and pagodas, temples, mosques, churches and synagogues.

The chief educational institution is the University of Rangoon, constituted in 1920. It formerly included the university college, Judson (American Baptist mission) college, the medical college and the teachers' training college in Rangoon, together with the agricultural college and an intermediate college at Mandalay, but it abandoned the collegiate system in favour of the unitary principle. The greater part of the university occupies magnificent buildings, erected between 1927 and 1930 on a site overlooking Victoria lake; but some of its buildings suffered severe damage by air bombardment in 1945. In 1939–40 there were 1,590 students in the university college and 415 in Judson college; by 1950 the total number of students was about 4,000. Rangoon also has numerous secondary and high schools.

Rangoon has several hotels, a number of cinemas, the largest of which are used for stage plays by travelling companies, fine shops and a number of clubs, notably the Pegu, Orient, Golf and Boat clubs. The European residences are mainly on the outskirts

of the city to the northwest in what is called the cantonments. At Mingaladon is one of the finest 18-hole golf courses in the east. The development of Rangoon was placed in the hands of the Rangoon Development trust, which administered the Rangoon Government estate on behalf of the government. The trust developed the land, then handing over the completed roads, etc., for maintenance by the Rangoon corporation. A race course at Kyaikkasan was completed in 1926.

The affairs of the port were placed under the administration of the Rangoon port commissioners. Rangoon handles about 85% of the total trade of the province. Rangoon town is the business centre of Burma, but the rice-milling (at Dalla), oil-refining (at Syriam) and teak-working, which form the staple industries, are carried on outside the town proper. The chief exports of Rangoon (with the quantities handled in 1936–37) are: rice (more than 2,000,000 tons), bran and pollard (220,000 tons), mineral oils (880,000 tons), timber (232,000 cubic), oil cake (65,135 tons), pulse (119,000 tons), lead (75,774 tons), zinc ore (84,645 tons), wax candles, cotton, oilseed and tobacco. The port is visited in normal years by about 1,600 vessels (steamers 7,000,000 tons gross, sailing vessels 15,000).

Until 1942 most of the labour in the port and the town was immigrant Indian labour; much of the skilled labour, especially in building trades, has been supplied by Chinese. The trading and clerical communities were also mainly Indian. Rangoon was thus by no means a typical Burmese city; in 1931 out of a population of 400,415 there were only 121,998 Burmese, compared with 140,458 Hindus, 57,535 Moslems, 30,000 Christians (mainly Europeans, Anglo-Indians and Indians) and 30,626 Chinese. As a result of the Japanese invasion of Burma in 1941–42, the Indian and European populations were much reduced, and the attainment of independence by Burma in 1948 caused a second exodus by many who had returned after the war. Rangoon became very much a Burmese city. Since World War II also caused much destruction of buildings, many squatters erected unsightly and unhealthful huts along the roadsides.

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RANGPUR, a town and district in the East Bengal province of Pakistan. The town is situated on the little river Ghaghat. Pop. (1941) 34,039. It is a long straggling town, with a railway station at one end and the public offices 3 mi. away at the other.

The DISTRICT OF RANGPUR, with an area of 3,606 sq.mi. and a population (1941) of 2,877,847, is one vast plain. The greater part of it, particularly toward the east, is inundated during the rains, and the remainder is traversed by a network of streams. The river system is constituted by the Brahmaputra and its tributaries, chief of which are the Tista, Dharla, Sankosh and Dudhkumar. About three-fourths of the district is under continuous cultivation. The staple crops are rice, oilseeds, jute and tobacco. The east district is well served by railways. Saidpur (pop. [1941] 19,516), with the workshops of the metre-gauge system of the E. Bengal state railway, is an important railway town.

RANJIT SINGH, MAHARAJA (1780–1839), Indian ruler, was born on Nov. 2, 1780, the son of Sirdar Mahan Singh, whom he succeeded in 1792 as head of the Sukarchakia branch of the Sikh confederacy. He was by birth only one of many Sikh barons and owed his rapid rise entirely to force of character and will. At the age of 20 he obtained from Zaman Shah, the king of Afghanistan, a grant of Lahore, which he seized by force of arms in 1799. Subsequently he attacked and annexed Amritsar in 1802, thus becoming master of the two Sikh capitals. When Jaswant Rao Holkar took refuge in the Punjab in 1805, Ranjit Singh made a treaty with the British, excluding Holkar from his territory. Shortly afterward acute difficulties arose between him and the British as to the Cis-Sutlej portion of the Punjab. It was Ranjit Singh's ambition to weld the whole of the Punjab into a single Sikh empire, while the British claimed the territory south of the Sutlej by right of conquest from the Marathas. The difference proceeded almost to the point of war, but at the last moment Ranjit Singh yielded. In 1808 Charles Metcalfe was sent to settle this question with Ranjit Singh, and a treaty was concluded at Amritsar on April 15, 1809.

The maharaja organized a powerful force, which was trained by French and Italian officers such as Generals Ventura, Jean François Allard and Paolo di Bartolomeo Avitabile, and thus forged the formidable fighting instrument of the Khalsa army, which afterward gave the British their hardest battles in India in the two Sikh wars. In 1810 he captured Multan after many assaults and a long siege; by 1820 he had consolidated the whole of the Punjab between the Sutlej and the Indus under his dominion. It was not until 1834, five years before his death, that Peshawar passed into Sikh hands. Though he disapproved of Lord Auckland's policy of substituting Shah Shuja for Dost Mohammed, he loyally supported the British in their advance on Afghanistan. He was known as the "Lion of the Punjab." Ranjit Singh died of paralysis on June 27, 1839. (*See* also PUNJAB: *History*).

See Sir Lepel Griffin, *Ranjit Singh* (Oxford, 1892); Gen. Sir John Gordon, *The Sikhs* (Edinburgh and London, 1904); S. S. Thorburn, *The Punjab in Peace and War* (London, 1904) and G. L. Chopra, *The Punjab as a Sovereign State* (Lahore, 1928).

RANJITSINHJI, KUMAR SHRI (1872–1933), maharajah of Nawanagar, was born at Sarodar in Kathiawar, India, on Sept. 10, 1872. By race a Rajput, he was educated first at Rajkumar college, Rajkot, and afterward at Trinity college, Cambridge.

He did not get his "blue" until his last year, 1893, but thereafter leaped at once into the highest place in English cricket. From 1895 to 1904 he played for Sussex and was captain from 1899 to 1903; his last appearance was in 1920. He went to Australia with A. E. Stoddart's team in 1897–98 and took a team to America in 1899. He made in all 14 scores of more than 200 and in 1900 made more than 3,000 runs for an average of 87 and more than 200 five times. His greatest feat was at Hove against Middlesex. On the last day of the match, on a bad wicket, he made 202, when Vine (17) was the only other man on the side to get into double figures.

In 1907 he succeeded his cousin as chief of the state of Nawanagar and proved an enlightened ruler. He provided troops for the Allies in World War I and himself served at the front. He died on April 2, 1933.

BIBLIOGRAPHY.—Ranjitsinhji's works comprise *The Jubilee Book of Cricket* (London, 1897); *With Stoddart's Team in Australia* (London, 1898); *How to Play Cricket* (London, 1906). *See* also P. C. Standing, *Ranjitsinhji, Prince of Cricket* (London, 1903); G. W. Beldam and C. B. Fry, *Great Batsmen* (London, 1905); Roland Wild, *The Biography of Colonel His Highness Shri Sir Ranjitsinhji* (London, 1934).

RANKE, LEOPOLD VON (1795–1886), German historian, was born on Dec. 20 or 21, 1795, at Wiehe, in Thuringia. He studied classics and theology at Halle and Berlin. In 1818 he began to teach history in a school at Frankfort-on-the-Oder, thereby entering the service of the Prussian government.

With the scholar's dislike of textbooks, he rapidly acquired a thorough knowledge of the ancient historians, quickly passed on to mediaeval times, and determined to make a study of universal history. At Frankfort he wrote his first work, *Geschichte der romanischen und germanischen Völker 1494–1514* (1824), which included a critical dissertation on the historians of this period (*Zur Kritik neuerer Geschichtschreiber*), exposing the untrustworthiness of much traditional history. This dissertation was as important for modern history as the critical work of B. G. Niebuhr had been in ancient history. A copy of the book was sent to the Prussian minister of education K. A. Kamptz, and Ranke was appointed supernumerary professor in the University of Berlin, and began his 50-year connection with the university. His *Fürsten und Völker von Südeuropa im 16 und 17 Jahrhundert* (1827) was based on the study of ms. records in the Berlin library. In later editions the book was called *Die Osmanen und die spanische Monarchie.* The Prussian government now provided him with means to prosecute his researches abroad. He visited Vienna, where the friendship of Friedrich von Gentz and the protection of Metternich opened to him the Venetian archives, of which many

were preserved in that city—then a virgin field. He wrote a short book on *Die serbische Revolution* (1829), afterward expanded into *Serbien und die Türkei im 19 Jahrhundert* (1879), from material supplied to him by Wuk Stephanovich, a Serbian who had himself been witness of the scenes he related. He spent three years (1828–31) in Italy. The recommendations of Metternich opened to him almost every library except the Vatican.

For a time Ranke was editor of a periodical in which Friedrich Perthes sought to defend the Prussian government against the democratic press. He failed; men desired not the scientific treatment of politics, but satire and invective. He earned the hatred and suspicion of the liberals and did not satisfy the Prussian conservatives, and after four years the *Historisch-Politische Zeitschrift* came to an end. Two-thirds of the matter had been contributed by the editor, and the two stout volumes in which the numbers were collected contained the best political thought which had for long appeared in Germany. For Ranke the failure was not to be regretted; the rest of his life was to be wholly devoted to history proper. *Die römischen Päpste, ihre Kirche und ihr Staat im 16 und 17 Jahrhundert* (3 vol., 1834–36, and many other editions), in form, as in matter, the greatest of his works, contains the results of his studies in Italy. The English translation by Mrs. Austin was the occasion of one of Macaulay's most brilliant essays. Before it was completed Ranke had already begun the researches for the second of his masterpieces, his *Deutsche Geschichte im Zeitalter der Reformation* (1839–47), a necessary pendant to his book on the popes. In 1837 he became full professor at Berlin; in 1841 Frederick William IV appointed him Prussian historiographer. In this capacity he wrote the *Neun Bücher preussischer Geschichte* (1847–48), a work which makes severe demands on the attention of the reader—he is the "Dryasdust" of Carlyle's Frederick; but in it he laid the foundation for the modern appreciation of the founders of the Prussian state. The 9 books were subsequently expanded to 12 (Leipzig, 1874). His *Französische Geschichte, vornehmlich im 16 und 17 Jahrhundert* (Stuttgart, 1852–61) was followed by his *Englische Geschichte, vornehmlich im 16 und 17 Jahrhundert* (1859–68). This, the longest of his works, lacked something of the freshness of his earlier books; he was over 70 when it was completed, and he was never quite at home in dealing with the foundations of English public life. In his 81st year he began to write the *Weltgeschichte* (9 vol., Leipzig, 1883–88). Drawing on the knowledge accumulated during 60 years, he had brought it down to the end of the 15th century before his death in Berlin on May 23, 1886.

Ranke's other writings include *Zur deutschen Geschichte vom Religionsfrieden bis zum 30-jährigen Kriege* (Leipzig, 1868); *Geschichte Wallensteins* (Leipzig, 1869; 5th ed., 1896); *Abhandlungen und Versuche* (Leipzig, 1877; a new collection of these writings was edited by A. Dove and T. Wiedemann, 1888); *Aus dem Briefwechsel Friedrich Wilhelms IV mit Bunsen* (Leipzig, 1873); *Die deutschen Mächte und der Fürstenbund. Deutsche Geschichte 1780–90* (1871–72); *Historisch-biographische Studien* (Leipzig, 1878); *Ursprung und Beginn der Revolutionskriege 1791–92* (Leipzig, 1875); and *Zur Geschichte von Oesterreich und Preussen zwischen den Friedensschlüssen zu Aachen und Hubertusberg* (Leipzig, 1875). He also wrote biographies of Frederick the Great and Frederick William IV for the *Allgemeine Deutsche Biographie*. Ranke married, at Windermere, in 1843, Clara Graves, daughter of an Irish barrister. She died in 1870, leaving two sons and one daughter.

At the time of his death Ranke was generally regarded as the first of modern historians. His reputation was due, in part, to his success as a teacher. In his more private classes, where he dealt with the technical work of a historian, he trained generations of scholars. No one since C. G. Heyne has had so great an influence on German academical life, and for a whole generation the Berlin school had no rival. Ranke's example and training has made it impossible for any one to attempt to write modern history except on the "narratives of eye-witnesses and the most genuine immediate documents" preserved in the archives. He was determined never to allow himself to be misled, in his search for truth, by those theories and prejudices by which nearly every other historian was influenced—Hegelianism, Liberalism, Romanticism, religious and patriotic prejudice.

Many of Ranke's works have been translated into English. Among these are *Civil Wars and Monarchy in France*, by M. A. Garvey (1852); *History of England, principally in the 17th Century* (1875); *History of the Latin and Teutonic Nations, 1494–1514*, by P. A. Ashworth (1887) and again by S. R. Dennis (1909); *History of the Reformation in Germany*, by S. Austin (1845–47); *History of Servia and the Servian Revolution*, by Mrs. A. Kerr (1847); *Ferdinand I and Maximilian II of Austria; State of Germany after the Reformation*, by Lady Duff Gordon (1853); *Memoirs of the House of Brandenburg and History of Prussia during the 17th and 18th Centuries*, by Sir Alexander and Lady Duff Gordon (1849); and *History of the Popes during the 16th and 17th Centuries*, by S. Austin (1840; new ed., 1841 and 1847), W. K. Kelly (1843), and E. Foster (1847–53). A collected edition of Ranke's works in 54 volumes was issued at Leipzig (1868–90), but this does not contain the *Weltgeschichte*.

For details of Ranke's life and work *see* his own *Zur eigenen Lebensgeschichte*, edited by A. Dove (Leipzig, 1890); and the article by Dove in the *Allgemeine deutsche Biographie*. *See* also Guglia, *Leopold von Rankes Leben und Werke* (Leipzig, 1893); M. Ritter, *Leopold von Ranke* (Stuttgart, 1895); H. F. Helmolt, *L. Rankes Leben und Wirken* (Leipzig, 1921) and H. Oncken, *Aus Rankes Frühzeit* (Gotha, 1922).

RANKIN, a borough of Allegheny county, Pennsylvania, U.S., on the Monongahela river, 9 mi. S.E. of the centre of Pittsburgh, adjoining Braddock and North Braddock (*qq.v.*). It is served by the Baltimore and Ohio, the Pittsburgh and Lake Erie, the Pennsylvania and the Union railways. The population of Rankin in 1950 was 6,941; in 1940 it was 7,470; in 1920, 7,301. Rankin, Braddock and North Braddock form one community.

RANKINE, WILLIAM JOHN MACQUORN (1820–1872), Scottish engineer and physicist, was born at Edinburgh on July 5, 1820, and completed his education in its university. He was trained as an engineer under Sir J. B. Macneill, working chiefly on surveys, harbours and railroads, and was appointed in 1855 to the chair of civil engineering in Glasgow. Rankine was the earliest of the three founders of the modern science of thermodynamics (*q.v.*) on the bases laid by Sadi Carnot and J. P. Joule respectively, and the author of the first formal treatise on the subject; 150 scientific papers are credited to him in the Royal society's *Catalogue*. The more important of these were collected and reprinted in *Rankine's Scientific Papers* (1881), which contains a memoir of the author by P. G. Tait. Rankine died at Glasgow on Dec. 24, 1872.

See also his *Civil Engineering; The Steam-Engine and other Prime Movers; Machinery and Millwork;* and *Applied Mechanics*.

RANNOCH, district of northwest Perthshire, Scotland, partly extending into Argyllshire. It measures 32 mi. east and west and from 10 to 12 mi. north and south and is surrounded by the districts of Badenoch, Atholl, Breadalbane, Lorne and Lochaber. Dugald Buchanan (1716–68), the Gaelic poet, was schoolmaster of Rannoch village, and a granite obelisk has been erected to his memory.

RANSOM, the price for which a captive in war redeemed his life or his freedom, a town secured immunity from sack and a ship was repurchased from its captors. The customs of feudal warfare recognized that captives of knightly rank had the right of buying their liberty from their captors. It was the duty of a feudal tenant to contribute toward his lord's ransom, and a king would often show his appreciation of a knight's services by redeeming him from captivity. The practice introduced a commercial element into mediaeval warfare, which became very prominent in the Hundred Years War between England and France and in the internal wars of Italy in the 15th century. In the former war, the ransom paid by John, king of France, and David II, king of Scotland, sensibly relieved the finances of Edward III's administration and at an earlier date the ransom paid by Richard I to the emperor led to the introduction of new financial devices which are important in the history of English taxation.

RANTERS, an antinomian and spiritualistic English sect in the time of the Commonwealth, who may be described as the dregs of the Seeker movement. Their central idea was pantheistic.

See Rufus M. Jones, *Studies in Mystical Religion*, 1909, ch. xix.

RANUNCULACEAE, a family of Dicotyledons belonging to the series Ranales, and containing 40 genera with about 700

species, which are distributed through temperate and cold regions but occur more especially in the northern hemisphere.

It is generally regarded as a genetic family which gave rise to the higher Dicotyledons, as well as the Monocotyledons. It contains many well-known forms, such as buttercup, larkspur, anemone, columbine, clematis, marsh marigold, peony, etc. It is well represented in Britain, where 12 genera are native. In North America there are about 25 genera. The plants are mostly herbs, rarely shrubby, as in *Clematis,* which climbs by means of the leaf-stalks, with alternate leaves, opposite in *Clematis,* generally without stipules. The flowers, which show considerable variation in the number and development of parts, are characterized by free hypogynous sepals and petals, numerous free stamens, usually many free one-celled carpels and small seeds containing a minute straight embryo embedded in a copious endosperm. The parts of the flower are generally arranged spirally on a convex receptacle. The fruit is one-seeded, an achene or a many-seeded follicle, rarely, as in *Actaea,* a berry.

The family falls into several well-defined tribes which are distinguished by characters of the flower and fruit.

Tribe I. Paeonieae, peony group, are mostly herbs with deeply cut leaves and large solitary showy flowers in which the parts are spirally arranged, the sepals, generally five in number, passing gradually into the large coloured petals. There are two to five free carpels which bear a double row of ovules along the ventral suture. There are no honey-leaves (nectaries) but honey is secreted by a ringlike swelling round the base of the carpels, which become fleshy in the fruit and dehisce along the ventral suture. There are only three genera, the largest of which, *Paeonia,* occurs in Europe, temperate Asia and western North America. *P. officinalis* is the common peony. *P. suffruticosa* is the so-called tree peony, native of China.

Tribe II. Helleboreae are almost exclusively north temperate or subarctic. The plants are herbs, either annual, *e.g., Nigella* (love-in-a-mist), or perennial by means of a rhizome, as in *Aconitum* or *Eranthis* (winter aconite). The leaves are simple, as in *Caltha,* but more often palmately divided as in hellebore, aconite and larkspur. The flowers are solitary (*Eranthis*) or in cymes or racemes, and are generally regular as in *Caltha* (king-cup, marsh marigold), *Trollius* (globeflower), *Helleborus* (hellebore), *Aquilegia* (columbine); sometimes markedly irregular as in *Aconitum* (aconite) and *Delphinium* (larkspur). The carpels, generally three to five in number, form in the fruit a many-seeded follicle, except in *Actaea* (baneberry), where the single carpel develops to form a many-seeded berry, and in *Nigella,* where the five carpels unite to form a five-chambered ovary. There is considerable variety in the form of the floral envelopes and the arrangement of the parts. The outer series, or sepals, generally five in number, is generally white or bright-coloured. Thus in *Caltha* and *Trollius* the sepals form a brilliant golden-yellow cup or globe, and in *Eranthis* a pale yellow star which contrasts with the green involucre of bracts immediately below it; in *Nigella* they are blue or yellow, and also coloured in *Aquilegia.* In *Helleborus* the greenish sepals persist till the fruit is ripe. *Aconitum* and *Delphinium* differ in the irregular development of the sepals, the posterior sepal being distinguished from the remaining four by its helmet shape (*Aconitum*) or spur shape (*Delphinium*). In *Caltha* there are no petals, but in the other genera there are honey-secreting and storing structures varying in number and in form in the different genera. In *Trollius* they are long and narrow with a honey-secreting pit at the base, in *Nigella* and *Helleborus* they form short-stalked pitchers, in *Aquilegia* they are large and coloured with a showy petal-like upper portion and a long basal spur in the tip of which is the nectary. In *Delphinium* they are also spurred, and in *Aconitum* form a spurlike sac on a long stalk. The parts of the flower are generally arranged in a spiral (acyclic), but are sometimes hemicyclic, the perianth forming a whorl as in winter aconite; rarely is the flower cyclic, as in *Aquilegia,* in which case the parts throughout are arranged in alternating whorls. In *Caltha,* where there are no petals, honey is secreted by two shallow depressions situated on the side of each carpel.

FROM J. ROQUE, "PHOTOGRAPHIC MEDICALE" (E. GORMAN & CO.)

GLOBEFLOWER (TROLLIUS EUROPAEUS)

Tribe III. Anemoneae, are chiefly north temperate, arctic and alpine plants, but also pass beyond the tropics to the southern hemisphere. They differ from the two preceding tribes in the numerous carpels, each with only one ovule, forming a fruit of numerous achenes. They are annual or perennial herbs, erect as in *Anemone, Thalictrum* (meadow rue) and many buttercups, or creeping as in *Ranunculus repens;* the section *Batrachium* of the genus *Ranunculus* (*q.v.*) contains aquatic plants with submerged or floating stems and leaves. The flowers are solitary, as in *Anemone pulsatilla* (pasqueflower), or cymose as in species of *Ranunculus,* or in racemes or panicles as in *Thalictrum.* The parts are spirally arranged throughout as in *Myosurus* (mousetail), where the very numerous carpels are borne on a much elongated receptacle, *Adonis* (pheasant's eye), or the perianth is whorled as in *Anemone* and *Ranunculus.* In *Anemone* and *Thalictrum* there is only one series of perianth leaves, which are petaloid and attractive in *Anemone* where honey is secreted by modified stamens, as in *A. pulsatilla,* or, as in *A. nemorosa* (wood anemone), there is no honey and the flower is visited by insects for the sake of the pollen; in *Thalictrum* the perianth is greenish or slightly coloured, and the flower is wind-pollinated (*T. minus*) or visited for its pollen. In *Ranunculus* and *Adonis* a calyx of green protective sepals is succeeded by a corolla of showy petals; in *Ranunculus* there is a basal honey-secreting gland which is absent in *Adonis.* In *Anemone* the achenes bear the persistent naked or bearded style which aides in dissemination; the same purpose is served by the prickles on the achenes of *Ranunculus arvensis. Clematis* (*q.v.*) is characterized by its shrubby, often climbing habit, opposite leaves and the valvate, not imbricate as in the other tribes, aestivation of the sepals. The usually four sepals are whorled and petaloid, the numerous stamens and carpels are spirally arranged; the flowers are visited by insects for the sake of the abundant pollen. The fruit consists of numerous achenes which are generally prolonged into the long feathery style, whence the popular name of the British species, old man's beard (*Clematis vitalba*).

There are special articles on the more important genera of Ranunculaceae, *e.g.,* ACONITE, ADONIS, ANEMONE, BANEBERRY, CLEMATIS, COLUMBINE, HELLEBORE, RANUNCULUS.

For further details *see* Engler and K. Prantl, *Die natürlichen Pflanzenfamilien* (Leipzig, 1887–1908); A. B. Rendle, *Classification of Flowering Plants* (Cambridge, 1925).

RANUNCULUS, familiarly known as buttercup, or crowfoot, a characteristic genus of the botanical family Ranunculaceae. The Latin name, which means a little frog or tadpole (dim. of *rana,* frog), was also given to a medicinal plant, which has been identified by some with the crowfoot. The members of the genus *Ranunculus* are more or less acrid herbs, sometimes with fleshy root-fibres, or with the base of the stem dilated into a kind of tuber (*R. bulbosus*). They have tufted or alternate leaves, dilated into a sheath at the base, and very generally, but not universally, deeply divided above. The flowers are solitary, or in loose cymes, and are remarkable for the number and separation (freedom from union) of their parts. Thus there are five sepals, as many petals, and numerous spirally arranged stamens and carpels. The petals have a little pit or honey-gland at the base, which is interesting as foreshadowing the more fully developed tubular corollas of the nearly allied genera *Aconitum* and *Helleborus.* The fruit is a head of "achenes"—dry, one-seeded fruits.

The genus contains a large number of species (about 300) and occurs in most temperate countries in the northern and southern hemispheres, extending into arctic and antarctic regions, and appearing on the higher mountains in the tropics. About 15 species are found in Great Britain. *R. acris, R. repens, R. bulbosus,* are

the common buttercups. *R. arvensis,* which is found in cornfields, has smaller pale yellow flowers and the achenes covered with stout spines.

R. lingua and *R. flammula,* the spearwort, grow in marshes, ditches and wet places. *R. ficaria* is the pilewort or lesser celandine, an early spring flower in pastures and waste places, characterized by having heart-shaped entire leaves and clusters of club-shaped roots. The section *Batrachium* comprises the water buttercups, denizens of pools and streams, which vary greatly in the character of the foliage according as it is submerged, floating or aerial, and when submerged varying in accordance with the depth and strength of the current.

Inclusive of the water buttercups, about 70 native species of *Ranunculus* occur in North America, widely distributed throughout the continent. Representative species are *R. septentrionalis, R. abortivus* and *R. recurvatus,* of the eastern states, and *R. californicus,* of the Pacific coast. The ranunculus of the florist is a cultivated form of *R. asiaticus,* a native of the Levant, remarkable for the range of colour of the flowers (yellow to purplish black) and for the regularity with which the stamens and pistils are replaced by petals forming double flowers.

RANVIER, LOUIS ANTOINE (1835–1922), French histologist, born on Oct. 2, 1835, at Lyons, began his medical studies and worked in the hospitals there under such well-known clinicians as Charles-Jacques Bouchard and Raphaël Lépine. He was nominated interne in the Paris hospitals in 1860 and graduated M.D. five years later, presenting a thesis on the development and diseases of bone. By this time he had formed a close friendship with André-Victor Cornil (1837–1908), with whom he shared an intense interest in the rapidly developing science of histology. The two friends opened a private laboratory in the Rue Christine, where they gave special courses for students. Cornil soon obtained academic promotion and Ranvier, having attracted the attention of Claude Bernard, was appointed his assistant in 1867. In 1869–76 Cornil and Ranvier brought out their *Manuel d'histologie pathologique,* a revelation to their contemporaries and one of the landmarks in 19th-century medicine. In 1872 a special histological laboratory was opened for Ranvier at the Collège de France and in 1875 he became the first occupant of the chair of general anatomy.

Apart from the *Manuel* Ranvier's most important published works were his *Traité technique d'histologie* (1875 *et seq.*), *Leçons sur l'histologie du système nerveux* (1878) and *Leçons d'anatomie générale, faites au Collège de France* (1880–81). He also wrote many papers and edited seven volumes of the *Travaux* of his laboratory (1874–88). His own researches were concerned particularly with the histology of nerve fibres, the regeneration of nerves, the bipolar nature of ganglionic cells and the minute structure of the skin, conjunctival tissue and cornea. In 1878 he first described the constrictions seen in medullated nerve fibres which are known as the nodes of Ranvier. He was elected a member of the Académie de Médecine (1880) and of the Institut (1887). During his pioneer researches Ranvier had many pupils and disciples, but in the period 1880–85 the interest aroused by Lous Pasteur's discoveries in bacteriology led to a decline in histological studies. Ranvier's laboratory was no longer frequented, his courses lapsed and he made few further contributions to science. Thenceforth he spent most of his time on an ancestral estate at Vendrages (Loire), to which he finally retired *c.* 1900, occupying himself with country pursuits. He never married and in his later years was a solitary figure. He died on March 22, 1922, leaving part of his fortune to the town of Roanne for the erection of a sanatorium for tuberculosis.

A master of technical methods and a true scientist, he ranks as one of the great French biologists. (W. J. Bp.)

RAOUL DE CAMBRAI, the name of a French *chanson de geste.* The existing romance is a 13th-century recension of a poem by a trouvère of Laon called Bertholais, who professed to have witnessed the events he described. Raoul de Cambrai, the posthumous son of Raoul Taillefer, count of Cambrai, by his wife Alais, sister of King Louis (d'Outre-Mer), demanded the fief of Vermandois, which was the natural inheritance of the four sons of Herbert, lord of Vermandois. On King Louis's refusal, he proceeded to war. Bernier, a grandson of Count Herbert, eventually slew the terrible Raoul in single fight, but in his turn was slain, after an apparent reconciliation, and the blood-feud descended to his sons. The date of these events is exactly ascertainable. Flodoard (*Annales, Anno* 943) states that Count Herbert died in that year, and was buried by his sons at St. Quentin; that when they learned that Raoul, son of Raoul de Gouy, was about to invade their father's territory, they attacked him and put him to death.

See *Li Romans de Raoul de Cambrai et de Bernier,* ed. by E. le Glay (1840); "Raoul de Cambrai," ed. by P. Meyer and A. Longnon (*Soc. des anc. textes fr.,* 1882); J. M. Ludlow, *Popular Epics of the Middle Ages* (1865); G. Grober, *Grundriss d. roman. Phil.* (ii, pp. 567 ff.).

RAOULT, FRANÇOIS MARIE (1830–1901), French chemist, was born at Fournes (Nord), on May 10, 1830. In 1862, after holding various teaching posts, he became professor of chemistry in the *lycée* at Sens, where he prepared the thesis which gained him his doctor's degree at Paris in the following year. In this investigation of the heat of reaction and electromotive force of galvanic cells, he noticed that the two did not correspond on the theory that heat is a measure of affinity. In 1867 he was put in charge of the chemistry classes at Grenoble, and three years later he succeeded to the chair of chemistry, which he held until his death on April 1, 1901. His name is best known in connection with the work on solutions (*q.v.*). His first paper on the depression of the freezing points of liquids by the presence of substances dissolved in them was published in 1878. In 1882 he published a table showing that the product obtained by multiplying the depression of the freezing point for a solution containing 1 g. of solute in 1,000 g. of water by the molecular weight of the solute is a constant. Another conclusion, made in 1886, was that the diminution in the vapour pressure of a solvent, caused by dissolving a substance in it, is proportional to the molecular weight of the substance dissolved—at least when the solution is dilute. These two generalizations not only afforded a new method of determining the molecular weights of substances but were also used by J. H. van't Hoff, S. Arrhenius and others in working out the theory of solutions. In 1884 Raoult himself found that "contrary to what I have believed up to now, the general law of congelation does not apply to salts dissolved in water . . . on the contrary it applies to the radicals constituting the salts, almost as though the radicals were simply mixed in the solution."

See J. H. van't Hoff, Raoult Memorial Lecture, *Journal of the Chemical Society,* 81:969 (1902); F. Getman, *J. Chemical Education,* 13:153 (1936). (R. E. O.)

RAPALLO, a seaport and winter resort of Liguria, Italy, in the province of Genoa. Pop. (1936) 6,766, town; 13,947, commune. It occupies a beautiful and well-sheltered situation on the east side of the Gulf of Rapallo, 18½ mi. E. by S. from Genoa by rail. The bridge, known as "Hannibal's Bridge," is mediaeval. To the south lies the small seaport of Portofino (the Roman *Portus Delphini*) under the southeast extremity of the promontory of Portofino (2,001 ft.) crowned by the remains of a castle. On the way from S. Margherita to Portofino is the suppressed monastery of Cervara, in which Francis I of France was confined after the battle of Pavia on his way to Madrid. At all these places are beautiful villas.

On the south side of the promontory is the small village of S. Fruttuoso, with the tombs of some of the Doria family of Genoa (1275–1305).

RAPALLO, TREATY OF (April 16, 1922). During the Conference of Genoa (*see* Genoa, Conference of), at which it was designed to consider the economic relations of the participating powers with Russia, the Russian delegates showed no great desire to resume relations with the Allied and Associated Powers, but to the consternation of the latter signed an agreement with Germany, after secret negotiations. The treaty was initialled on April 16, 1922 by M. Chicherin and M. Rathenau. Germany and Russia renounced reciprocally all claims to war indemnities of any sort, including payment for the maintenance of prisoners of war.

Germany renounced any compensation for losses incurred by German subjects in consequence of Russian socialisation of private property "provided that the Soviet Government does not satisfy similar claims of other States." Diplomatic and consular relations were resumed, the principle of the most favoured nation was to be mutually applied, with a Russian reservation in favour of States formerly belonging to the Russian empire. Economic relations were to be regulated "with mutual feelings of goodwill." The treaty was made public immediately on signature. On Nov. 5, 1922, the treaty was extended to the Ukraine, White Russia, the Transcaucasian republics and the Far Eastern republic.

RAPE, a territorial division of the county of Sussex, formerly used for various administrative purposes. There are now six of these divisions: Hastings, Pevensey, Lewes, Bramber, Arundel and Chichester.

See the *Victoria County History, Sussex,* vol. i.; *New English Dictionary;* and M. A. Lower, *History of Sussex* (Lewes, 1870).

RAPE, in botany. Several forms of plants included in the genus *Brassica* are known as rape and cultivated instead of a turnip crop or as a "catch crop" for food for sheep or for their oil-yielding seeds. The nomenclature and relationship of these forms of *Brassica* are not clear as crosses are frequent. *B. Rapa* is grown in Great Britain as a green crop while *B. Napus* var. *oleifera* known as colza rape or coleseed is grown on the continent of Europe for oil. Its seeds contain from 30 to 45% of oil.

For further details *see* W. W. Robbins, *Botany of Crop Plants* (Philadelphia, 1924); R. Percival, *Agricultural Botany* (1926).

RAPE, in law, the crime of having carnal knowledge of a woman by a man, not her husband, forcibly and unlawfully, against her will. A felony at common law, it was reduced in England to a misdemeanour in 1275, but in 1285 was again declared a felony, with benefit of clergy. This was the state of the law until 1575, when the punishment was made more severe. Formerly a capital offence, by the Offences against the Person Act 1861, it is punishable by penal servitude for life.

The law of England regards as immaterial whether the woman is chaste or unchaste, married or single, provided the offence has been committed forcibly and without her consent. The offence is complete if consent is extorted by means of threats of death or immediate bodily harm, by fraud or by false pretences or representation. (Criminal Law Amendment Act 1885.)

In the United States the elements of the crime under statute are similar to those at common law. The age when effective consent can be given by the female has commonly been set by the various States between 14 and 18 years. Want of age on the part of the male is not a defence, as at common law, but simply presumptive evidence of lack of physical capacity. Many States require the testimony of the female to be corroborated by other evidence as well as requiring the prosecution to be initiated within a year or less after the commission of the offense. The punishment is imprisonment though a few southern States prescribe death as the penalty.

RAPE OIL, an important fatty oil, known also as "sweet oil," either expressed or extracted from the crushed seeds of cultivated varieties of the cruciferous genus *Brassica,* the parent form of the whole apparently being the wild navew, *B. campestris.* Under the general name "rape oil" is included the produce of several plants having distinct and fairly constant characters, and one of these oils—colza (*q.v.*)—is a very well-known commercial variety. In Germany, where the production of rape oil centres, two principal oil-seeds—rape and Rübsen—are recognized. (*See* Rape.)

The oil yielded by these seeds is, in physical and chemical properties, practically the same, the range of fluctuations not being greater than would be found in the oil of any specific seed under similar varying conditions of production; the winter varieties of all the seeds are more productive than the summer varieties. Newly pressed rape oil has a dark sherry colour with, at first, scarcely any perceptible smell; but after resting a short time the oil deposits an abundant mucilaginous slime, and by taking up oxygen it acquires a peculiar disagreeable odour and an acrid taste. Refined by the ordinary processes (*see* Oils), the oil assumes a clear golden yellow colour. In specific gravity it ranges between 0·9112 and 0·9117 (raw), and from 0·9127 to 0·9136 (refined); the solidifying point is from −4° to −6° Centigrade.

The principal uses of rape oil are for lubrication and lighting; but since the introduction of mineral oils for both these purposes the importance of rape has considerably decreased. It is but little employed in soap-making, as it saponifies with difficulty and yields only an indifferent product. In Germany it is very considerably used as a salad oil under the name of *Schmalzöl,* being for that purpose freed from its biting taste by being mixed with starch, heated till the starch is carbonized, and filtered after the oil has cooled. The offensive taste of rape oil may also be removed by treatment with a small proportion of sweet spirits of nitre (nitrous ether). In the East Indies rape oil and its equivalents, known under various names, are the most important of oils for native use. They are largely consumed as food instead of ghi under the name of "metah" or sweet oil, but for all other purposes the same substance is known as "kurwah" or bitter oil. Most natives prefer it for the preparation of their curries, and other hot dishes. Rape oil is the subject of extensive adulteration, principally with the cheaper hemp oil, rosin oil and mineral oils. These sophistications can be most conveniently detected, first by taste and next by saponification, rosin oil and mineral oil remaining unsaponified, hemp oil giving a greenish soap, while rape oil yields a soap with a yellow tinge. Rape oil and the other cruciferous oils are characterized by the presence of the unsaturated fatty acid *erucic acid,* $C_{21}H_{41}COOH$, the identification of which affords a means of detecting rape oil in admixture with other oils. Lead plaster (*Emplastrum lithargyri*) boiled in rape oil dissolves, and, sulphide of lead being formed, the oil becomes orown or black. Other lead compounds give the same black coloration from the formation of sulphide.

RAPHAEL, in the Apocryphal Book of Tobit, the name of the angel who in human disguise and under the name of Azarias ("Yahweh helps") accompanied Tobias in his adventurous journey and conquered the demon Asmodaeus (*see* Tobit). He is said to be "one of the seven holy angels [archangels] which present the prayers of the saints and go in before the glory of the Holy One" (Tob. xii. 15). In the Book of Enoch (ch. xx.) Raphael is "the angel of the spirits of men," and it is his business to "*heal* the earth which the angels have defiled." His name means "God heals."

RAPHAEL SANZIO (1483–1520), the great Italian painter, was the son of Giovanni Sanzio or Santi, a painter in the ducal city of Urbino. The house of Giovanni Santi, where Raphael was born (April 6, 1483) still exists at Urbino in the Contrada del Monte, and is now the property of the municipality. For many years both before and after the birth of Raphael (April 6, 1483) Urbino was one of the chief centres in Italy of intellectual and artistic activity, thanks to its highly cultured rulers, Duke Federigo II. of Montefeltro and his son Guidobaldo, who succeeded him in 1482. Giovanni Santi was a welcome guest at this miniature but splendid court, and the rich treasures which the palace contained, familiar to Raphael from his earliest years, helped to form and foster his early love for art. Raphael's boyish admiration of the oil-paintings of Jan Van Eyck and Justus of Ghent may have had something to do with the miniature-like care and delicacy with which some of his earliest works, such as the "Apollo and Marsyas," were executed.

Though Raphael lost his father at the age of eleven, he certainly owed to him a great part of his early training. The altarpiece painted by Giovanni for the church of Gradara, and a fresco, now preserved in the Santi house at Urbino, are clearly prototypes of some of Raphael's most graceful paintings of the Madonna and Child. On the death of his father in 1494 Raphael was left in the care of his stepmother (his mother, Magia Ciarla, died in 1491) and of his uncle, a priest called Bartolomeo.

First or Perugian Period.—Vasari's statement that Raphael was sent to Perugia during his father's lifetime is certainly a mistake. He probably did not enter Perugino's studio till the end of 1499. Of the thirty drawings contained in the so called Sketch Book of Raphael in the Venice Academy but two can be ascribed

to the master. (*See* G. Morelli, *Italian Masters in German Galleries,* 1882.)

Before long Raphael appears to have shared in the execution of paintings by his master; and his touch may perhaps be traced in some of Perugino's panels which were executed about 1502; examples are the Resurrection of Christ in the Vatican and the Diotalevi Madonna in the Berlin Museum.

About 1500 Raphael began to execute independent works. The portrait of Tangino in the Borghese Gallery, Rome, was probably painted about 1500. Four pictures for churches at Città di Castello appear to have been painted in the years 1502–04. The first is a gild-banner painted on one side with the Trinity, and below, kneeling figures of S. Sebastian and S. Rocco; on the reverse is a Creation of Eve, very like Perugino in style, but possessing more grace and breadth of treatment. These are still in the church of S. Trinità. Also for Città di Castello were the coronation of S. Niccolo Tolentino, now destroyed, though studies for it exist at Oxford and Lille (*Gaz. d. B. Arts,* 1878, i. p. 48), and the Crucifixion, now in the National Gallery (Mond collection), painted for the church of S. Domenico and signed RAPHAEL VRBINAS P. It is a panel 8 ft. 6 in. high by 5 ft. 5 in. wide, and contains noble figures of the Virgin, St. John, St. Jerome and St. Mary Magdalene. The fourth painting executed for this town, for the church of S. Francesco, is the exquisitely beautiful and highly finished Sposalizio, now in the Brera at Milan, signed and dated RAPHAEL VRBINAS MDIIII. This is closely copied both in composition and detail from Perugino's painting of the same subject now at Caen, but is far superior to it in sweetness of expression and grace of attitude. The Temple of Jerusalem, a domed octagon with outer ambulatory in Perugino's picture, is reproduced with slight alterations by Raphael, and the attitudes and grouping of the figures are almost exactly the same in both. The Connestabile Madonna (sold to the tsar of Russia in 1871) is one of Raphael's finest works, painted during his Perugian period; it is a round panel. The motive, the Virgin reading a book of hours, is a favourite one with him, as it was with his father Giovanni.

Second or Florentine Period, 1504–1508.—In the first half of 1504 Raphael visited Urbino, where he painted two small panels for Duke Guidobaldo, the St. George and the St. Michael of the Louvre. His first visit to Florence was made towards the end of 1504, when he presented himself with a warm letter of recommendation from his patroness Joanna della Rovere to the gonfaloniere Pier Soderini. At the time of his arrival in Florence artistic Italy was excited over the cartoons of the battle of Anghiari and the war with Pisa, to which Leonardo da Vinci and Michelangelo were then devoting their energies. With astonishing rapidity Raphael shook off the mannerisms of Perugino and put one great artist in painting or sculpture after another under contribution for some special power of drawing, beauty of colour, or grace of composition in which each happened to excel. The Carmine frescoes of Masaccio and Masolino taught this eager student long-remembered lessons of methods of dramatic expression. (*See* his cartoon of St. Paul preaching at Athens [Victoria and Albert Museum].) Among his contemporaries it was especially Signorelli and Michelangelo who taught him the necessity of a thorough knowledge of the human form. From da Vinci he learnt subtleties of modelling and soft beauty of expression (*see* the portrait of Maddalena Doni in the Pitti), from Fra Bartolommeo nobility of composition and skilful treatment of drapery in dignified folds. (*See* the Madonna del Baldacchino in the Pitti.) The friendship between Raphael and the last of these was very close. The architect Baccio d'Agnolo was another of his friends, at whose house the young painter enjoyed social intercourse with the chief artists of Florence, and probably learnt from him much that was afterwards useful in his practice as an architect.

The transition in Raphael's style from his first or Perugian to his second or Florentine manner is shown in the large picture of the Coronation of the Virgin painted for Maddalena degli Oddi, now in the Vatican, one of the most beautiful that he ever produced, and especially remarkable for its strong religious sentiment—in this respect a great contrast to the paintings of his last or Roman manner which hang near it. The exquisite grace of the angel musicians shows signs of his short visit to Florence, while the formality of the composition and certain details, such as the fluttering ribands of the angels, recall peculiarities of Perugino and of Pinturicchio, with whose fine picture of the same subject hung close by it is interesting to compare it. The predella of this masterpiece of Raphael is also in the Vatican; some of its small paintings, especially that of the Annunciation to the Virgin, display his careful study of the rules of perspective. Preparatory sketches for this picture exist at Lille and elsewhere. The Lille study is drawn from two youths in the ordinary dress of the time; and it is interesting to compare it with his later studies from the nude, many of which are for figures which in the future picture were to be draped. It was at Florence, as Vasari says, that Raphael began serious life studies, not only from nude models but also by making careful anatomical drawings from dissected corpses and from skeletons.

His first visit to Florence lasted only a few months; in 1505 he was again in Perugia painting his first fresco, the Trinity and Saints, for the Camaldoli monks of San Severo, now a mere wreck from injury and restorations. The date MDV and the signature were added later, probably in 1521. Part of this work was left incomplete by the painter, and the fresco was finished in 1521 (after his death) by his old master Perugino. It was probably earlier than this that Raphael visited Siena and assisted Pinturicchio with sketches for his Piccolomini frescoes. He probably had no hand in the actual execution of the paintings. The Madonna of S. Antonio (Metropolitan Museum of Art, New York) was also finished in 1505, but was probably begun before the Florentine visit. A record of his visit to Siena exists in a sketch of the antique marble group of the Three Graces, then in the cathedral library, from which, not long afterwards, he painted the small panel of the same subject now at Chantilly.

In 1506 Raphael was again in Urbino, where he painted for the duke another picture of St. George, which was borne to England as a present to Henry VII. by Guidobaldo's ambassador, the accomplished Baldassare Castiglione (*q.v.*), a friend of Raphael, whose noble portrait of him is in the Louvre. At the court of Duke Guidobaldo the painter's ideas appear to have been led into a more secular direction, and to this stay in Urbino probably belong the Chantilly Graces and the miniature "Knight's Dream of Duty and Pleasure" in the National Gallery (London), which also possesses its cartoon in brown ink, pricked for transference.

Towards the end of 1506 Raphael returned to Florence, and there (before 1508) produced a large number of his finest works, carefully finished, and for the most part wholly the work of his own hand. The following is a list of some of his chief paintings of this period: the "Madonna del Gran Duca" (Pitti); "Madonna del Giardino," 1506 (Vienna); "Holy Family with the Lamb," 1506 or 1507 (Madrid); the "Ansidei Madonna," 1506 or 1507 (National Gallery); the Borghese "Entombment," 1507; The Panshanger "Madonna" (now in America), 1508; "La bella Giardiniera," 1508 (Louvre); the "Eszterhazy Madonna," probably the same year, as well as the "Madonna del Cardellino" (Uffizi), the "Tempi Madonna" (Munich), the "Colonna Madonna" (Berlin), the "Bridgewater Madonna" (Bridgewater House), and the "Orleans Madonna" (Chantilly). The "Ansidei Madonna" was bought in 1884 for the National Gallery from the duke of Marlborough. It was painted for the Ansidei family of Perugia as an altar-piece in the church of S. Fiorenzo, and is a work of the highest beauty in colour, well preserved. The Virgin with veiled head is seated on a throne, supporting the Infant with one hand and holding a book in the other. Below stands S. Niccolo Tolentino, for whose altar it was painted; he holds a book and a crozier, and is clad in jewelled mitre and green cope, under which appear the alb and cassock. On the other side is the Baptist, in red mantle and camel's-hair tunic, holding a crystal cross. The rich jewellery in this picture is painted with Flemish-like minuteness. A favourite method of grouping his Holy Families is that seen in the "Madonna del

Cardellino" and the "Bella Giardiniera," in which the main lines form a pyramid. This arrangement is also used in the "Madonna del Giardino" and in the larger group, including St. Joseph and St. Elizabeth, known as the "Canigiani Holy Family," now at Munich. The "Entombment of Christ," now in the Galleria Borghese in Rome, was painted during a visit to Perugia in 1507 for Lady Atalanta Baglioni, in memory of the death of her brave and handsome but treacherous son Grifonetto, who was killed in 1500 by his enemies the Oddi party. (*See* Symonds, *Sketches in Italy*, the chapter on Perugia, mainly taken from the contemporary chronicle of Matarazzo.) The many studies and preliminary sketches for this important picture which exist in various collections show that it cost Raphael an unusual amount of thought and labour in its composition. It is, however, much injured by repainting. The "Madonna del Baldacchino," owing much to Fra Bartolommeo, is also unsatisfactory in execution; being left unfinished by Raphael, it was completed by Ridolfo Ghirlandajo. It was painted for the Dei family as an altar-piece for their chapel in S. Spirito, Florence. The "St. Catherine" of the National Gallery was probably painted in 1507; its cartoon, pricked for transference, is in the Louvre. To the Florentine period belong some of his finest portraits, and it is especially in these that da Vinci's influence appears. The portraits of Angelo Doni and his wife Maddalena (Pitti) are vivid and carefully executed paintings, and the unknown lady with hard features (now in the Uffizi) is a masterpiece of noble realism and conscientious finish. A fine but much-restored portrait of Raphael by himself, painted at Florence, exists in the Uffizi; it represents him at a very early age, and was probably painted during the early part of his stay in Florence.

Third or Roman Period, 1508–1520.—In 1508 Raphael was painting several important pictures in Florence; in September of that year we find him settled in Rome, from a letter addressed in the warmest terms of affectionate admiration to Francia, to whom he sent a sketch for his "Adoration of the Shepherds," and promised to send his own portrait in return for that which Francia had given him. Raphael was invited to Rome by his fellow-citizen Bramante, who was then occupied in the erection of the new church of St. Peter, the foundation-stone of which had been laid by Julius II. on the 18th of April 1506. At this time the love of the popes for art had already attracted to Rome Michelangelo, Signorelli, Perugino, Pinturicchio, Lorenzo Lotto, Peruzzi, Sodoma and many others, and it was among this brilliant assembly that Raphael, almost at once, took a leading position. Thanks to Bramante's friendly intervention, Julius II. (Della Rovere) soon became Raphael's most zealous patron and friend, as did also the rich bankers Agostino Chigi and Bindo Altoviti, of whom a portrait, by Giulio Romano, is now in Munich.

A series of rooms in the Vatican, over the Appartamenti Borgia, were already decorated with frescoes by Bonfigli, Perugino, Piero della Francesca, Andrea del Castagno, Signorelli and Sodoma; but so rapidly had the taste of the time changed that Julius II. decided to re-cover the walls with paintings in the more developed style of Raphael. It was not without regret that Raphael saw the destruction of this noble series of frescoes. One vault, that of the Stanza dell' Incendio, painted by his master Perugino, he saved from obliteration; it still exists, well preserved, a most skilful piece of decorative work; and he also set his pupils to copy a number of portrait-heads in the frescoes of Piero della Francesca before they were destroyed.

The Stanza della Segnatura (papal signature room) was painted in 1509–11. The first painting executed by Raphael in this room was the so-called Disputa, finished in 1509. In its religious sentiment it far excels any of the later stanze paintings, retaining much of the sacred character of earlier Florentine and Umbrian art. As a scheme of decoration it appears to have been suggested by some of the early apsidal mosaics. Gold is largely used, while the later purely pictorial frescoes have little or none. The subject is the hierarchy of the church on earth and its glory in heaven.

The painting on the vault of this room is the next in date, and shows further transition towards the "Roman manner." In his treatment of the whole Raphael has been partly guided by the painting of Perugino's vault in the next room (the Stanza dell' Incendio). The pictures are kept subordinate to the lines of the vault. A great part of the ground is gilt, marked with mosaic-like squares, a common practice with decorative painters. The principal medallions in each cell of this quadripartite vault are very graceful female figures, representing Theology, Science, Justice and Poetry. Smaller subjects are arranged in the intermediate spaces, and each has some special meaning in reference to the medallion it adjoins; some of these are painted in warm monochrome to suggest bas-reliefs. The fine painting of the "Flaying of Marsyas" is interesting as showing Raphael's study of antique sculpture: the figure of Marsyas is a copy of a Roman statue. The very beautiful little picture of the "Temptation of Eve" recalls Albert Dürer's treatment of that subject, though only vaguely. Much mutual admiration existed between Raphael and Dürer: in 1515 Raphael sent the German artist a most masterly life study of two nude male figures (now at Vienna); on it is written in Albert Dürer's beautiful hand the date and a record of its being a gift from Raphael. It is executed in red chalk, and was a study for two figures in the "Battle of Ostia."

On the wall opposite the Disputa is the so-called School of Athens. The subject of this noble fresco, in contrast to that opposite, is "Earthly Knowledge," represented by an assembly of the great philosophers, poets and men of science of ancient Greece. The central figures are Plato and Aristotle, while below and on each side are groups arranged with the most consummate skill, including the whole "filosofica famiglia" of Dante (*Infer.* iv. 133–144), and a number of other leaders of thought, selected in a way that shows no slight acquaintance with the history of philosophy and science among the ancient Greeks. Many interesting portraits are introduced—Bramante as the aged Archimedes, stooping over a geometrical diagram; a beautiful fair-haired youth on the left is Francesco Maria della Rovere, duke of Urbino; and on the extreme right figures of Raphael himself and Sodoma are introduced. The stately building in which these groups are arranged is taken with modifications from Bramante's first design for St. Peter's.

Over one window is a group of poets and musicians on Mount Parnassus, round a central figure of Apollo; it contains many heads of great beauty and fine portraits of Dante and Petrarch. Over the opposite window are graceful figures of the three chief Virtues, and at one side Gregory IX. (a portrait of Julius II.) presenting his volume of decretals to a jurist; on the other Justinian presents his code to Trebonianus.

The next room, the Stanza d'Eliodoro, was painted in 1511–14. The room is so called from the fresco representing the expulsion of Heliodorus from the Temple (2 Macc. iii.), which is an allusion to the struggles between Louis XII. of France and Julius II. Its chief motive is the glorification of the pontificate, with insistence on the temporal power. The main incident of this picture is the angel visitant on the horse. The group of women and children on the left is very beautiful, and the figures of Julius II. and his attendants are nobly designed. This picture was completed in 1512. Over one window is shown the scene of the Miracle at Bolsena of 1263, when the real presence was proved to a doubting priest by the appearance of blood-stains on the Corporal. (*See* Bolsena.) Julius II. is introduced kneeling before the altar; and the lower spaces on each side of the windows are filled with two groups, that on the left with women, that on the right with officers of the papal guard. The last group is one of the most masterly of all throughout the stanze: each face is a marvel of expression and power, and of technical skill. The next fresco in date is that of the Repulse of Attila from the walls of Rome by Leo I., miraculously aided by the apparitions of St. Peter and St. Paul; it contains another allusion to the papal quarrels with France. It was begun in the lifetime of Julius II., but was only half finished at the time of his death in 1513; thus it happens that the portrait of his successor, the Medici pope Leo X., appears twice over, first as a cardinal riding behind the pope, painted before the death of Julius II., and again in the character of S. Leo, instead of the portrait of Julius which Raphael was about to paint. A pen sketch

in the Louvre by Raphael shows Julius II. in the place afterwards occupied by Leo X. In 1514 he painted the "Deliverance of St. Peter from Prison," with a further political allusion. It is skilfully arranged to fit the awkward space round the window, and is remarkable for an attempt to combine and contrast the three different qualities of light coming from the room, the glory round the angel, and the torches of the sentinels.

For the so-called Stanza dell' Incendio Raphael designed and partly painted the "Incendio del Borgo," a fire in the Borgo or Leonine City, which was miraculously stopped by Leo IV. appearing and making the sign of the cross at a window in the Vatican. On the background is shown the façade of the old basilica of St. Peter, not yet destroyed when this fresco was painted. One group on the left, in the foreground, is remarkable for its vigour and powerful drawing; the motive is taken from the burning of Troy; a fine nude figure of Aeneas issues from the burning houses bearing on his back the old Anchises and leading the boy Ascanius by the hand. Many studies for this picture exist. This is the last of the stanze frescoes on which Raphael himself worked. Others in this room designed by him and painted by Giulio Romano and other pupils were the "Battle of Ostia," and the "Oath of Leo III. before Charlemagne." The enormous fresco of the "Defeat of Maxentuis by Constantine," in the Saladi Constantino, was painted by Giulio Romano, soon after Raphael's death, from a sketch by the latter.

The paintings in the stanze were only a small part of Raphael's work between 1509 and 1513. To this period belong the Madonna of Foligno (Vatican), painted in 1511 for Sigismondo Conti. Of about the same date are the gem-like Garvagh Madonna (National Gallery, once in the possession of the Aldobrandini family), the Diademed Virgin of the Louvre, and the Madonna del Pesce at Madrid. The last was executed in 1513 for S. Domenico in Naples. In addition to other easel pictures a number of his finest portraits belong to this period—that of Julius II. the original of which is lost (copies in the Uffizi and National Gallery, London); the Tommaso Inghirami in the Gardner Collection, Boston; the Baldassare Castiglione of the Louvre; and the portrait of a cardinal in the Prado, Madrid.

When Giovanni de' Medici became pope as Leo X., a period of splendour and magnificence succeeded the sterner rule of Julius II. Agostino Chigi, the Sienese financier, was the chief of those whose lavish expenditure contributed to enrich Rome with works of art. For him Raphael painted, in 1513–14, the very beautiful fresco of the Triumph of Galatea in his new palace by the Tiber, the Villa Farnesina, and also made a large series of magnificent designs from Apuleius's romance of Cupid and Psyche, which were carried out by a number of his pupils.[1] For the same patron he painted (also in 1513) his celebrated Sibyls in S. Maria della Pace—figures of exquisite grace, arranged with perfect skill over an arch in the nave. It is not without reason that Vasari gives these the highest position among his fresco-paintings. Agostino Chigi also employed Raphael to build for him a private chapel in S. Maria del Popolo, and to make a series of cartoons to be executed in mosaic on the inner dome. The central medallion has a figure of God among clouds and angel boys, surrounded by eight planets, each with its pagan deity and directing angel in accordance with Dante's scheme in the Paradiso. The execution of these brilliant mosaics was carried out in 1516 by the Venetian Luigi della Pace. Probably in the early years of Leo X.'s reign were painted the Madonna della Sedia (Pitti), the S. Cecilia at Bologna (not completed till 1516), the miniature Vision of Ezekiel (Pitti) and two important pictures at Madrid. The latest of these, known as Lo Spasimo, from the church at Palermo, for which it was painted, represents Christ bearing His Cross. The Madonna called Della Perla, "the pearl" of the Spanish royal collection, was originally painted for Bishop Louis of Canossa; it was sold by Cromwell with the greater part of Charles I.'s collection at Hampton Court. The portrait of Leo X. with Cardinals de' Rossi and de' Medici, in the Pitti, is one of his finest portrait-pictures. Little is known about the Madonna di S. Sisto, the glory of the Dresden Gallery; no studies or sketches for it exist.

One of Raphael's latest works is the large "St. Michael and the Devil," in the Louvre, signed "Raphael Urbinas pingebat, MDXVIII."

The tapestry cartoons, seven of which are in the Victoria and Albert Museum, were painted by pupils from Raphael's designs. They are part of a set of ten, with scenes from the Acts of the Apostles, intended, when copied in tapestry, to adorn the lower part of the walls of the Sistine chapel. The tapestries themselves, worked at Brussels, are now, after many vicissitudes, hung in a gallery in the Vatican; the set is complete, thus preserving the design of the three lost cartoons ("The Martyrdom of St. Stephen," "St. Paul's Conversion" and "St. Paul in Prison"). The existing seven, after being cut up into strips for use on the looms, were bought by Rubens for Charles I. The tapestry copies are executed with wonderful skill. The designs are reversed, and the colours far more brilliant than those of the cartoons, much gold and silver being introduced. The rich framework designed by Raphael's pupils, probably by Penni and Giovanni da Udine, exists in the tapestries and adds greatly to their decorative effect. The cartoons were executed in 1515 and 1516, and the finished tapestries were first exhibited in their place in the Sistine chapel on Dec. 26, 1519.

The "Transfiguration."—In 1519 Cardinal Giuliano de' Medici (afterwards Clement VII.), as bishop of Narbonne, ordered two altar-pieces for his cathedral—the one by Raphael, the other by Raphael's Venetian rival Sebastiano del Piombo. That by the latter painter is the Resurrection of Lazarus, now in the National Gallery. Several studies for Raphael's picture exist, showing that he at first intended to paint a Resurrection of Christ as a pendant to Sebastiano's subject, but soon altered his scheme into the Transfiguration. The eight or nine existing studies are scattered through the Oxford, Lille, Windsor and some private collections. A great part of the lower group was unfinished at the time of the painter's sudden death in 1520, and the heavy colouring of Giulio Romano is visible in it. On the death of Raphael the picture became too precious to send out of Rome, and Cardinal de' Medici contented himself with sending the Resurrection of Lazarus to Narbonne. The Transfiguration was bequeathed by him to the monks of S. Pietro in Montorio, in whose church it remained till it was stolen by Napoleon I. It now hangs in the Vatican Gallery.

Architectural Work.—Bramante, before his death in March 1514, requested that Raphael should be made his successor as chief architect of St. Peter's. To this important post he was appointed by Leo X., Aug. 1, 1514. The progress of St. Peter's was, however, too slow for him to leave much mark on its design. Another work of Bramante's, completed by Raphael, was the graceful Cortile di S. Damaso in the Vatican, including the loggie, which were decorated with stucco-reliefs and paintings of sacred subjects by his pupils under his own supervision, but only very partially from his designs. The Palazzo dell' Aquila, built for Giovanni Battista Branconio, and destroyed in the 17th century during the extension of St. Peter's, was one of Raphael's chief works as an architect. He also designed the little cross church, domed at the intersection like a miniature St. Peter's, called S. Eligio degli Orefici, which still exists near the Tiber, almost opposite the Farnesina gardens. According to M. Geymüller, *Raffaello come Architetto* (Milan, 1883), the Villa Farnesina of Agostino Chigi, usually attributed to Peruzzi, was, as well as its palace-like stables, designed by Raphael; but internal evidence makes this very difficult to believe. It has too much of the delicate and refined character of the 15th century for Raphael, whose taste seems to have been strongly inclined to the more developed classic style, of which Palladio afterwards became the chief exponent. Villa Madama, on the slopes of Monte Mario above Rome, was designed by Raphael, though its actual carrying out, and the unrivalled stucco-reliefs, are due to Giulio Romano and Giovanni da Udine, as mentioned in Vasari's life of the latter.[2] The original design for this villa made by Raphael himself has been discovered by M. Geymüller. Another architectural work was the little Chigi chapel

[1] Chiefly by Giulio Romano, Gianfrancesco Penni and Giovanni da Udine; much injury has been done to these frescoes by repainting.

[2] *See* Gruner, *Fresco Decorations, etc.* (London, 1854), pls. 6–12, and Raffaelle Santi, *Ornati della Villa Madama, etc.* (Rome, 1875).

in S. Maria del Popolo, built in 1516. At the time of his death, Raphael was preparing to build himself a handsome palace near the church of S. Eligio; the deed for the purchase of its site was signed by him only a few days before his last short illness. Though not completed till 1530, the Palazzo Pandolfini at Florence was also designed by him.

Sculpture.—That Vasari is right in attributing to him the model for the beautiful statue of Jonah which is in the Chigi chapel is borne witness to by two important documents, though there is no evidence to show that he ever worked in marble. One of these is a letter written to Michelangelo to warn him that Raphael had been invading his province as a sculptor by modelling a boy, which had been executed in marble by a pupil, and was a work of much beauty. Again, after his death his friend Baldassare Castiglione, in a letter dated May 8, 1523, asks his steward in Rome "if Giulio Romano still possesses a certain boy in marble by Raphael and what his lowest price for it would be." The statue of Jonah was executed in marble by Lorenzetto, a Florentine, and it remained in his studio for many years after Raphael's death. The Victoria and Albert museum possesses a small clay sketch for this beautiful group, slightly different from the marble; it is probably the original design by the master's own hand. The whole feeling of the group—a beautiful youth seated on a sea monster—is classical, and the motive is probably taken from some antique statue representing Arion or Taras on a dolphin.

A large number of Raphael's designs were engraved by his pupils Marcantonio Raimondi and Agostino Veneziano. These valuable engravings are from Raphael's sketches, not from his finished pictures, and in some cases they show alterations made in the execution of the picture. Raimondi's engraving of the S. Cecilia of Bologna in design is very inferior to that of the actual painting. Several of Raphael's most important compositions are known to us only by these early engravings; *e.g.*, the "Massacre of the Innocents" (engraved by Raimondi), which is one of his finest works. Another magnificent design is the "Judgment of Paris," containing a large number of figures; the nude figure of Minerva is a work of special force and beauty. A standing figure of Lucretia about to stab herself is also one of his most lovely figures. Many of Raphael's studies for Marcantonio's engravings still exist.

Archaeology.—Raphael's report to Leo X in 1518 is an eloquent plea for the preservation of ancient buildings. In 1515 he had been appointed by Leo X inspector of all excavations in Rome and within ten miles round. His study of the antique is clearly shown in many of his frescoes, and especially in the graceful stucco reliefs and painted grotteschi, in the Vatican loggia, the Villa Madama and elsewhere.

Raphael's Fame.—Among all the painters of the world, none has been so universally popular as Raphael, or has so steadily maintained his pre-eminent reputation throughout the many changes in taste which have taken place since his death. In the 17 or 18 years which composed his short working life he passed through stages of development for which a century would not have seemed too long, while other painters lived through the same changeful time with but little alteration in their manner of work. Perugino, who outlived his wonderful pupil, completed in 1521 Raphael's San Severo fresco in a style differing but little from his paintings executed in the previous century.

In versatility of power Raphael remains almost without a rival; whether painting an altar piece for a church, a large historical fresco, a portrait or decorative scenes from classical mythology, he seems to excel equally in each; and the widely different methods of painting in tempera, oil or fresco are employed by him with apparently equal facility. His range of scale is no less remarkable, varying from a miniature, finished like an illuminated manuscript, to colossal figures in fresco dashed in with breadth and vigour.

His personal beauty, charm of manner and kindliness of heart endeared him to all who knew him. He was as an equal to the princes of the church, the distinguished scholars and the world-famed men who formed the courts of Julius II and Leo X. In accordance with the spirit of the age he lived with considerable display and luxury. His pupils formed round him a sort of royal retinue, numbering about 50 youths, each talented in some branch of the arts. Giulio Romano and Gianfrancesco Penni, his two favourite pupils, lived with him in the Palazzo di Bramante, a house (now destroyed) near St. Peter's, where he resided during the greater part of his life in Rome.

Raphael died on Good Friday, April 6, 1520, at the age of 37, after an attack of fever which lasted only ten days. His body was laid out in state in his studio, by the side of the unfinished "Transfiguration," and all Rome flocked to the place for a last sight of the "divino pittore." His drawings and manuscripts he left to Giulio Romano and Gianfrancesco Penni, his newly bought land to Cardinal Bibbiena, the uncle of the lady to whom he had been betrothed. He desired to be buried in the Pantheon. His body is laid beside an altar, which he endowed with an annual chantry, and on the wall over it is a plain slab, with an inscription written by his friend Pietro Cardinal Bembo. (*See* PAINTING.)

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RAPID CITY, a city of South Dakota, U.S., beautifully situated in the western part of the state, on Rapid river, at the foot of the Black hills, 3,229 ft. above sea level; the county seat of Pennington county. It is on federal highways 14 and 16, and is served by the Chicago and North Western and the Chicago, Milwaukee, St. Paul and Pacific railways. The population in 1950 was 25,310 by the federal census, as compared with 13,844 in 1940. It is the centre of a wide agricultural and grazing region and of the mining district of the Black hills, which produces gold, silver, lead, copper, tin, antimony, tungsten and mica. Its manufactures include flour, lumber, meat, brick, stucco, cement, boxes and foundry and machine shop products. The South Dakota School of Mines was established here by the territorial legislature of Dakota in 1885. The city was founded in 1876 and incorporated in 1878.

RAPIER: *see* FENCING; SWORD.

RAPPOLTSWEILER: *see* RIBEAUVILLÉ.

RARE EARTHS, in chemistry the name originally given to a group of metallic oxides since they resemble the substances then known as earths (lime, magnesia, etc.). The corresponding elements comprising this group are unique in that they are so similar in chemical properties that they can be separated from one another only by taking advantage of the slight differences in their properties. Since there was no place for these elements in the older periodic tables they were grouped in the space allotted to lanthanum.

With a modern understanding of atomic structure it is now recognized that the rare earths include the elements with atomic numbers 58 to 71 and are now placed in a special group in the periodic table. The work of H. G.-J. Moseley (1913) definitely established the maximum number of rare earths and set up procedures by which their purity and existence could be determined. The theories of Niels Bohr and subsequent workers have shown that the electron structure of the trivalent rare-earth ions is: $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^{10}$, $4s^2$, $4p^6$, $4d^{10}$, $4f^x$, $5s^2$, $5p^6$. The neutral atoms contain three extra electrons which distribute themselves between the $6s$, $5d$ and $4f$ subshells. These three electrons, however, are removed to the negative ions in the rare-earth trivalent compounds and do not take a direct part in the electronic configuration of the rare-earth ions. The completed subshells produce diamagnetism in the rare earths. The true rare-earth group arises from the filling in of the $4f$ subshell and since this subshell can contain from 1 to 14 electrons there are only 14 true rare earths. These electrons give rise to the paramagnetic properties of the ions.

Since the rare-earth elements have the same configuration of outer electrons and since it is these electrons which mainly determine chemical properties, the elements are very similar chemically and physically. The relatively small progressive changes in the properties of these elements with the addition of $4f$ electrons make them particularly useful for testing various theories of matter such as the relation of the solid state to atomic structure. In fact, their properties are so similar that suggested procedures for the separation of isotopes are often first tested with the rare earths. Lanthanum (57), yttrium (39) and scandium (21) have external atomic structures similar to and always occur in mixtures of the rare earths. Hence, lanthanum and yttrium, and sometimes scandium, are also included in discussions of the rare earths and with the possible exception of scandium are never found free from the rare earths.

The principal source of the rare earths is the mineral monazite found as an alluvial sand in India, Brazil and Idaho. This material is es-

TABLE I.—*Properties of the Rare-Earth Ions and Salts*

Atomic number	Name	Symbol	Atomic weight	4f electrons	Effective Bohr magneton numbers	Colours of trivalent ions
57	Lanthanum	La	138.92	0	0.00	Colourless
58	Cerium	Ce	140.13	1	2.56	Colourless
59	Praseodymium	Pr	140.92	2	3.62	Yellow-green
60	Neodymium	Nd	144.27	3	3.68	Red-violet
62	Samarium	Sm	150.43	5	1.55–1.65	Pale yellow
63	Europium	Eu	152.0	6	3.40–3.51	Pale pink
64	Gadolinium	Gd	156.9	7	7.94	Colourless
65	Terbium	Tb	159.2	8	9.7	Very pale pink
66	Dysprosium	Dy	162.46	9	10.6	Pale yellow-green
67	Holmium	Ho	164.94	10	10.6	Brownish-yellow
68	Erbium	Er	167.2	11	9.6	Rose
69	Thulium	Tm	169.4	12	7.6	Pale green
70	Ytterbium	Yb	173.04	13	4.5	Colourless
71	Lutetium	Lu	174.99	14	0.00	Colourless
21	Scandium	Sc	45.10	0	..	Colourless
39	Yttrium	Y	88.92	0	..	Colourless

Adapted from various sources, especially D. M. Yost, H. Russell and C. S. Garner, 1944.

sentially a complex phosphate. Other important mineral sources are gadolinite (a silicate found in Norway, Sweden, Colorado and Texas), fergusonite (a columbate and tantalate found in Norway, Texas and Australia), samarskite (a tantalate and uranate found in the Urals and North Carolina), xenotime (a phosphate found in Brazil and Norway), yttrocerite (a fluoride found in Scandinavia), cerite (a basic silicate found in Sweden) and allanite (a silicate found in Greenland and Scandinavia). The relative abundance of these elements in the earth's crust is summarized in Table III. It will be noted that the elements with even atomic numbers are much more abundant than those with odd atomic numbers. Contrary to the earlier ideas, these elements are not so rare as the name implies; for example, cerium is more common than cadmium, tin, mercury, antimony, molybdenum, silver, tungsten, bismuth, gold or platinum. The rare earths, however, are widely distributed in low concentration and are so difficult to separate from one another that, with the exception of cerium, lanthanum and neodymium, they were not available for commercial distribution until after 1946.

Methods for separating the mixed rare earths from their ores vary with the type of ore. Prior to 1945, with the exceptions of certain rare earths such as cerium, europium, samarium and ytterbium which can have valencies different from three, the individual rare earths were separated from one another by laborious processes such as fractional crystallization, fractional decomposition, etc. Since these procedures had to be repeated thousands of times, only a few chemists had the patience to devote the required time to this routine work. Hence, only limited amounts of the scarcer rare earths were prepared in the pure state. In order to carry out these processes it was convenient to place the elements in subgroups such as the ceria group (57 to 64) and the yttria group (64 to 71); another classification introduces the terbia group (63 to 65). Such groups are arbitrary since there are no clear-cut separations between successive members of the series; they are based on the solubility relationships of various compounds of the elements. The solubilities of some of the rare-earth trivalent compounds are summarized in Table II.

Some of the rare earths are always found among the fission products of plutonium, thorium and uranium, and a number of new radioactive isotopes of the rare earths have been obtained from this source. In addition, it is now possible to make artificial radioactive isotopes of any of the rare earths and a large number have been identified. For details concerning these isotopes *see* the article on RADIOACTIVITY, ARTIFICIAL. In 1945 a rapid method for separating the rare earths was developed in connection with the atomic bomb research program. The procedure involves the use of adsorption columns of organic resins and subsequent elution with complexing agents such as citric acid. The separations are based on the slight differences in the equilibrium constants. It is expected that, by use of such procedures, the pure rare-earth metals eventually will become more available and less expensive for detailed scientific studies and possible industrial uses.

TABLE II.—*Solubilities of Several Rare-Earth Trivalent Compounds*

Compound	Cerium group (57–62)	Yttrium group (63–71)
Carbonates	Insoluble in water and in $(NH_4)_2CO_3$ solution	Insoluble in water; soluble in $(NH_4)_2CO_3$ solution
Hydroxides	Somewhat soluble in water	Slightly soluble in water
Fluorides	Insoluble in water	Insoluble in water
Formates	Slightly soluble in water	Moderately soluble in water
Nitrates	Soluble in water; less soluble in HNO_3	Soluble in water; less soluble in HNO_3
Basic nitrates	Moderately soluble in water	Slightly soluble in water
Double nitrates (*e.g.*, $Mg_3R_2(NO_3)_{12}.24H_2O$)	Easily crystallized	Not easily crystallized
Oxalates	Very insoluble in water and in $(NH_4)_2C_2O_4$ solution	Very insoluble in water; soluble in $(NH_4)_2C_2O_4$ solution
Phosphates	Insoluble in water	Insoluble in water
Potassium sulphates ($K_3R(SO_4)_3$)	Insoluble in K_2SO_4 solution	Soluble in K_2SO_4 solution

From D. M. Yost, H. Russell and C. S. Garner, 1944.

The common valence of the rare-earth elements is three and many of them possess no other valence in their compounds. Since their chemical properties differ so slightly from member to member, the customary methods of qualitative analysis for these elements are of no real value. All accurate analyses for their purity are therefore based on their physical properties. The five general criteria available are: average atomic weight, magnetic susceptibilities, absorption spectra, X-ray spectra and arc spectra. Several of these properties are listed in Table I.

In Table III are listed some of the physical properties of the rare-earth elements as known at mid-20th century. Since the pure rare earths have been so difficult to obtain, many of the properties and physical constants of the elements are probably inaccurate and may be altered considerably as better data become available through the use of new methods for their separation and purification. The metallic elements can be produced by electrolysis of the molten salts (such as the chloride or fluoride) or by chemical reduction of the oxides or halides by means of the alkali or alkaline-earth metals. All of them except promethium, formerly called illinium, have been produced in small amounts by the above methods, but in many cases the salt was not pure and most of them undoubtedly contained various amounts of the neighbouring rare-earth metals in solid solution.

TABLE III.—*Physical Properties and Abundance of the Rare-Earth Elements*

Atomic number	Symbol	Density	Melting point, °C.	Electrode potentials E^0(ox) (volts)	Atomic radius co-ordination no. 12 (A)	% in earth's crust x 10^5
57	La	(α)6.194 (β)6.180	820–850	+2.37	(α)1.870 (β)1.872	7
58	Ce	(α)6.78 (β)6.810	770–800	2.0	(α)1.81 (β)1.817	31
59	Pr	(α)6.776 (β)6.805	940–960	2.0	(α)1.824 (β)1.821	5
60	Nd	(α)7.004	800–900	2.0	(α)1.818	18
62	Sm	6.93	1,350	2.0	..	7
63	Eu	5.244	1,100–1,200	1.9	2.042	0.2
64	Gd	7.948	..	1.9	1.794	7
65	Tb	8.332	..	1.9	1.773	1
66	Dy	8.562	..	1.9	1.769	7
67	Ho	8.764	..	1.9	1.759	1.2
68	Er	9.164	1,250 (?)	1.8	1.748	6
69	Tm	9.346	..	1.8	1.742	1
70	Yb	7.010	1,800 (*c.*)	1.8	1.933	7
71	Lu	9.740	..	1.7	1.737	1.5
39	Y	4.34	..	..	1.814	..

Adapted from D. M. Yost, H. Russell and C. S. Garner, 1944.

As was so well stated by J. W. Mellor: "A large proportion of unconfirmed discoveries belongs to the rare earth series, and this may be taken as a tribute to the difficulties attending their isolation." A brief chronological summary of the isolation of the various rare earths follows. In 1794 J. Gadolin separated a new rare earth, yttria, from a black mineral found in Ytterby, Swed. In 1803 J. J. Berzelius, M. H. Klaproth and W. Hisinger independently found ceria in a mineral from the Bastnäs mine in Sweden. C. G. Mosander, in 1839, showed that ceria also contained a new oxide, lanthana; in 1842 he found didymia in the lanthana fraction. In 1843 he found that yttria contained terbia (called erbia since 1860) and erbia (called terbia since 1877). Erbia was subsequently found to contain ytterbia (J. C. G. de Marignac, 1878), holmia (J. L. Soret, 1878) and thulia (P. T. Cleve, 1879). In 1879 L. de Boisbaudran claimed the discovery of a new element in didymia which he called samarium, and in 1880 De Marignac found another element in samarium which he later called gadolinium. In 1885 C. A. von Welsbach split didymia into praseodymium and neodymium and in 1886 J. de Boisbaudran obtained dysprosia from holmia. In 1896 E. Demarçay separated europia from samaria and in 1906 G. Urbain found lutetia in ytterbia. In 1926 B. S. Hopkins announced the discovery of element 61 which he named illinium. In the same year J. C. Corke, C. James and H. C. Fogg obtained 61 independently and measured the lines of its X-ray spectrum. This discovery was challenged. (*See* PROMETHIUM.)

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Levy, *The Rare Earths* (1924); J. W. Mellor, *A Comprehensive Treatise on Inorganic and Theoretical Chemistry*, vol. v (1924); D. M. Yost, Horace Russell, Jr., and Clifford S. Garner, *The Rare-Earth Elements and Their Compounds* (1947). (F. H. Sp.)

RASHI (1040–1105), Jewish scholar. Rabbi Solomon Izhaqi (son of Isaac), usually cited as Rashi from the initials of those words, was born at Troyes in 1040 and died in the same town in 1105. He seems to have passed the decade beginning with 1055 in Worms, where a niche in a wall, where his mother was miraculously saved from death, was long shown. Within this, it is said, Rashi was wont to teach. A small edifice on the east of the synagogue is called the "Rashi chapel," and the "Rashi chair," raised on three steps in the niche, is one of the objects of the pious admiration of pilgrims. At Worms Rashi worked under Jacob ben Yaqar, and at Mainz under Isaac ben Judah, perhaps combining at the same time the functions of teacher and student.

Rashi was 25 years of age when he returned to Troyes, which became a recognized centre of Jewish learning. There he acted as rabbi and judge; he and his family worked in the vines of Troyes. His learning and character raised him to a position of high respect among the Jewries of Europe, though Spain and the east were long outside the range of his influence. As was said of him soon after his death: "His lips were the seat of wisdom, and thanks to him the Law, which he examined and interpreted, has come to life again." The latter part of his life was saddened by the massacres in the Rhineland at the time of the first crusade. Rashi died in Troyes in 1105.

Besides minor works, such as a recension of the prayer book (*Siddur*), the *Pardes* and *ha-Orah*, Rashi wrote two great commentaries on the whole of the Hebrew Bible and on about 30 treatises of the Talmud. His commentary on the Pentateuch, in particular, has been printed in hundreds of editions; it is still to Jews the most beloved of all commentaries on the Mosaic books. More than a hundred supercommentaries have been written on it. His influence in Christian circles was great, especially because of the use made of the commentary by Nicolaus de Lyra (*q.v.*), who in his turn was one of the main sources of Luther's version. Even more important was his commentary on the Talmud, which became so much the definitive interpretation that Rashi is cited simply as "the commentator."

Bibliography.—M. Liber, *Rashi* (1906), published as a memorial of Rashi on the 800th anniversay of his death. Rashi's commentary on the Bible has been translated into Latin by Breithaupt (1710–14); and into German (Pentateuch) by Dukes (1833–38) and others. The foundation of recent investigation into Rashi's life is Zunz's *Salomon b. Isaac* (1823), to which I. H. Weiss added much in his (Hebrew) biography in *Bet Talmud* ii, nos. 2–10. *See* also Graetz, *History of the Jews*, Eng. trans., vol. iii, ch. ix. A critical edition of Rashi's Pentateuch commentary was published by A. Berliner (2nd ed., 1905).

RASHTRAKUTA, an Indian dynasty which ruled in the Deccan (*q.v.*) from about A.D. 754 to 973. The Rashtrakuta or Ratta clan are supposed to have held power during the historical blank before the 6th century; but they came to the front in A.D. 754, when Dantidurga overthrew the Chalukya dynasty and made himself ruler of the Deccan. He was succeeded by his uncle Krishna I (*c.* 768), who completed his conquests and whose reign is memorable for the execution of the Kailasa, the rock-cut temple at Ellora. His grandson Govinda III (793–814) extended the power of the family from the Vindhya mountains and Malwa on the north to Kanchi on the south. The next king, Amogavarsha, reigned for 62 years. The reign of Krishna III (939–968) was remarkable for a war with the Cholas, in which the Chola king was killed on the field of battle in 949. The last of the Rashtrakuta kings was Karka II, overthrown by the Chalukyas in 973.

See R. G. Bhandarkar, *Early History of the Deccan* (Bombay, 1884); A. S. Altekar, *The Rashtrakutas and their Times* (Poona, 1934).

RASIN, ALOIS (1867–1923), Czechoslovak statesman, was born at Nechanice. While at the university he took an active part in politics, and his abilities as an orator, journalist and organizer brought him into the forefront of the Czech progressive movement. His anti-Austrian activities brought him into conflict with the authorities; he was tried in connection with the "Omladina" affair in 1893 and condemned to two years' imprisonment and the loss of his doctorate. After serving his sentence he gained a prominent position in the Czech Liberal ("Young Czech") party, which he represented both in the provincial diet of Bohemia and in the Austrian *reichsrat*. During the anti-Czech persecution in the World War I period, Rasin, together with Karel Kramar, was arrested in 1915, charged with treason and condemned to death. The sentence, however, was not carried out, and after the accession of the emperor Karl, Rasin, with other political prisoners, was amnestied. He then took part in the preparations for the revolutionary coup in 1918, which, as a member of the National committee, he helped to bring about. In the first Czechoslovak government he became finance minister. In Jan. 1923 he was attacked by a demented youth and died of his injuries six weeks afterward, on Feb. 16, 1923.

RASK, RASMUS CHRISTIAN (1787–1832), Danish scholar and philologist, was born at Brändekilde, Fünen, on Nov. 22, 1787. He studied at the University of Copenhagen, and in 1808 was appointed assistant keeper of the university library, and later professor of literary history. In 1811 he published, in Danish, his *Introduction to the Grammar of the Icelandic and other Ancient Northern Languages*, from printed and manuscript materials accumulated by his predecessors in the same field of research. The Arna-Magnaean institution then commissioned him to edit the manuscript of the Icelandic *Lexicon* (1814) of Björn Haldorson. Rask spent ten years in Iceland, mastering the language and familiarizing himself with the literature, manners and customs of the Icelanders. He was the first president of the Icelandic Literary society, established at Copenhagen early in 1816. In Oct. 1816 Rask left Denmark on a literary expedition, at the cost of the king, to prosecute inquiries into the languages of the east, and collect manuscripts for the university library at Copenhagen. He went first to Sweden, making an excursion into Finland to study the language. There he published, in Swedish, his *Anglo-Saxon Grammar* in 1817. In his *Essay on the Origin of the Ancient Scandinavian or Icelandic Tongue* (Copenhagen, 1818) he traced the affinity of Icelandic to the other European languages, particularly Latin and Greek. In the same year he brought out the first complete editions of Snorro's *Edda* and Saemund's *Edda*. From Stockholm he went in 1819 to St. Petersburg, and thence through Tartary into Persia, and resided for some time at Tabriz, Tehran, Persepolis and Shiraz. From Persia he went to India and Ceylon. Rask returned to Copenhagen in May 1823, bringing a considerable number of oriental manuscripts, Persian, Zend, Pali, Sinhalese and others, with which he enriched the collections of the Danish capital. He died at Copenhagen on Nov. 14, 1832.

During the period between his return from the east and his death Rask published in his native language a *Spanish Grammar* (1824), a *Frisic Grammar* (1825), an *Essay on Danish Orthography* (1826), a *Treatise respecting the Ancient Egyptian Chronology* and an *Italian Grammar* (1827), and the *Ancient Jewish Chronology Previous to Moses* (1828). Rask's Anglo-Saxon, Danish and Icelandic grammars were brought out in English editions by Thorpe, Repp and Dasent respectively.

See his collected essays, *Samlade Afhandlinger*, 3 vol. (Copenhagen, 1834–38).

RASMUSSEN, KNUD JOHAN VICTOR (1879–1933), Danish explorer, was born at Jakobshavn, Greenland, on June 7, 1879. In 1902 he made the first of several expeditions to Greenland and the northern polar regions. Between 1905 and 1924 Rasmussen visited all the extant Eskimo tribes and ascertained that they were originally red Indian tribes which had wandered east and west from the coast. Rasmussen, whose ancestors in the maternal line were Eskimos, gained a thorough knowledge of arctic peoples and customs and made them the subject of numerous tracts and publications, including *Nye Mennesker* (1905); *Myter og Sagn fra Gronland* (1921) and *Gronland Langs Polhavet* (1919; Eng. trans., *Greenland by the Polar Sea*, 1921).

RASPBERRY, an old and well-known fruit-bearing bush, was known to classic writers and was mentioned by Pliny as a wild fruit called *Idea* from Mt. Ida in Asia Minor on which it grew. Parkinson (*Paradisus*, 1629) speaks of red, white and thornless varieties of raspberries, and its culture began about this time. The raspberries (of the genus *Rubus*) bear juicy red or black (rarely

orange, amber or pale yellow) berries which pull off the plant, leaving the receptacle on the stem. This characteristic differentiates the raspberry from the blackberry in which the receptacle picks off the plant.

The raspberry section of *Rubus* probably evolved in eastern Asia, where upward of 200 species of raspberries are known. In Great Britain and throughout Europe only one species, *R. idaeus*, is known, from which the European cultivated varieties are derived. In the United States and Canada, three species (*R. strigosus*, the red raspberry; *R. occidentalis*, the eastern black raspberry; and *R. leucodermis*, the western black raspberry) are found. American red varieties are derived from *R. strigosus* and hybrids of it with *R. idaeus*. They are much hardier and less prickly than European varieties. Black varieties came from *R. occidentalis*, purple varieties are hybrids of the black and red.

Related edible berries often called raspberries are the two flowering raspberries of the northern woodlands, *Rubus odoratus* and *R. parviflorus;* the Rocky Mountain flowering raspberry, *R. deliciosus;* the salmonberry, *R. spectabilis*, of the Pacific northwest; and the baked-apple berry, *R. chamaemorus*, of the northern bogs, a circumpolar species.

Three other raspberries are grown slightly for their fruit in other parts of the world—the Andes black raspberry, *R. glaucus*, in northern South America, the Southern Asian black raspberry, *R. niveus*, and the wineberry, *R. phoenicolasius*, introduced from northeastern Asia. *R. kuntzeanus* from China has been hybridized with the Cuthbert to give the Van Fleet, and *Rubus biflorus*, also from China, has been hybridized with Latham to give the Dixie, both of these being varieties adapted to southern U.S.A.

The acreage of red raspberries in Great Britain was reported as 5,401 in 1937. In Scotland the Blairgowrie district is the centre of production; in England, Kent, the eastern counties and Worcestershire are important centres. It is grown in mixed plantings with other fruits, the plants being set 18 in. apart in rows 6 or 7 ft. distant. Lloyd George is the chief variety—having very large berries which are excellent for canning and jam. Red Cross and Pynes Royal are other good varieties.

The acreage of raspberries in the United States was 59,000 in 1939 with a crop value of $7,416,000. Black raspberries are nearly as important as the red. The acreage of purple varieties is small. Important red-raspberry sections are western Maryland, southern New Jersey, the Hudson river valley, western Michigan, near Minneapolis, Minn., the Puyallup valley of Washington, the Willamette valley of Oregon, and the Santa Clara valley of California. The largest acreage of black raspberries is in western Michigan. Smaller sections are in western Maryland, western New York, and the Willamette valley of Oregon. Few plantings in the United States, except in the Hudson river valley, are mixed with other fruits. Good red varieties are Cuthbert and Washington in the Pacific northwest, Ranere in California, Latham for eastern states, except for Sunrise for very early crop in New Jersey and southward, and Taylor and Milton in New York and New England. The Cumberland is the chief black variety. In eastern Canada, Viking and Newman red varieties are widely grown. Sodus and Potomac are desirable purple varieties. Ranere and Indian Summer are red sorts that also bear fruit on the young canes in late summer and fall.

Red raspberries are propagated by suckers which come from the roots of the parent plant. Root cuttings about 3 in. long are also used for rapid increase of new varieties. Black and purple varieties have arched canes and are propagated by tip layers, the tips of the shoots being buried about 2 in. deep in August and the rooted tips being dug in early spring. Leaf-bud cuttings may be used for the rapid propagation of new black varieties. Red raspberries are usually planted 2½ ft. apart in rows 6 to 9 ft. distant; the black and purple being planted about 4 ft. apart in rows also 6 to 8 ft. distant. Shoots are produced by these plants in spring and summer which bear fruit the following year and then die. These old canes are cut away each year just after the harvest to make room for the new shoots. The new shoots of the black varieties are tipped or cut off at 12 in. to induce branching; those of the purple are cut at 18 to 24 in. These branches are shortened the following winter to about 8 in. for the black and 12 in. for the purple. The canes of the red raspberries are either not pruned or are shortened to 3 to 5½ ft., depending on the variety and vigour. However, surplus suckers should be cut away early in the summer, leaving 7 or 8 of the strongest canes per plant or per 30 in. of row. The stouter the canes of both black and red varieties the more productive they are. Stakes or trellises are commonly used to support the canes of the red raspberry. Two wire trellises with a wire each side of the row about 3 ft. high or with one wire above the other at 30 in. and 54 in. are common types.

Virus diseases, leaf spot, anthracnose, crown gall, wilt and yellow rust are serious diseases, while the red spider mite, crown borer and fruit worms are serious insect pests. (G. M. D.)

RASPE, RUDOLF ERICH (1737–1794), the original author of the *Adventures of Baron Munchausen* (*see* MUNCHAUSEN), was born in Hanover in 1737, and studied at Göttingen and Leipzig. In 1767 he was appointed professor in Cassel, and subsequently librarian. In 1775 he went to Italy to buy curios for the landgrave of Hesse, to whom he was keeper of the gems, and sold the landgrave's valuables for his own profit. On orders being issued for his arrest, he decamped to England. Later, he found a patron in Sir John Sinclair of Ulbster, whom he deceived by pretending to discover valuable and workable veins on his estates; but Raspe had "salted" the ground himself, and on the verge of exposure he absconded. He betook himself to Ireland, and died at Muckross in 1794. His authorship of *Munchausen* was only revealed in 1824, by the biographer of its translator Bürger.

RASPUTIN, GREGORY EFIMOVITCH (1871–1916), Russian monk, was born in 1871 in the village of Pokrovskoe, near Tyumen, in the province of Tobolsk, Siberia. He was the son of a poor peasant whose disorderly behaviour resulted in his being given the name of Rasputin, meaning "debauchee." He received no education, and till the end of his life was unable to write properly. He spent the first part of his life till the age of 33 in his native village; he married in 1895 a well-to-do girl, Olga Chanigoff, and they had two daughters and a son. In 1904 Rasputin resolved to change his mode of living. He left his family and devoted himself to religious exercises, declaring to his people that he was inspired by God. His passionate nature, his great physical strength and the superstitious atmosphere in which he had been brought up, gave an unexpected direction to his religious exaltation. He adopted the views of the sect known under the name of "Khlysty," the leading idea of whose teaching was that salvation could be achieved only by repentance.

"Sin in order that you may obtain forgiveness"—was the practical rule which he drew from this doctrine. "A particle of the Supreme Being is incarnated in me"—he told his hearers. "Only through me you can hope to be saved; and the manner of your salvation is this: you must be united with me in soul and body. The virtue that goes out from me is the source of light, the destruction of sin" (E. J. Dillon, *The Eclipse of Russia*). This extravagant and dangerous teaching, which resulted in practice in the wildest orgies, not only created for Rasputin immense popularity and the reputation of a holy man among his fellow-peasants, but opened before him the doors of some of the most fashionable Russian houses and even those of the Imperial palace. Looking for new experiences Rasputin left his native village, and made long pilgrimages to various holy places, and even went to Mount Athos and Jerusalem. He spent some time in different monasteries and applied himself to the study of holy books, but his lack of elementary education reduced the results of his labours almost to nothing. He only retained by heart some incomprehensible passages, and often used them in his prophecies. He had, however, a strong magnetic power, the influence of which was recognized by his bitterest opponents.

In 1907, during a stay in St. Petersburg (Leningrad), Rasputin was introduced to the archimandrite Feofan, rector of the theological academy and confessor to the empress, who took an interest in the story of his conversion. The archimandrite, with the assistance of the grand duchesses Militza and Anastasia, presented Rasputin at court, and he produced a deep impression on the empress and emperor. The mystic atmosphere which always prevailed at the Russian court and the constant fear for the health of the tsarevich created a favourable background for the appearance of such a man. The eventual improvement in the health of the grand duke Alexis procured for Rasputin a commanding influence over the empress.

For some time Rasputin was satisfied by his social success, and at first he did not interfere in politics. But his activity was felt in church questions. His friendship with the famous monk, Heliodor, and the bishop of Saratov, Hermogen, which resulted in a complete rupture between them and in a series of scandals, had a painful echo in the country. The appointment of Varnava, an illiterate peasant and a friend of Rasputin, to be bishop of Tobolsk in 1911, and the servility with which the Holy Synod followed the wishes of the favourite, provoked a strong opposition among all classes of society. An unsuccessful attempt to kill him, made by a certain Guseva in 1914, incited by the monk Heliodor, only strengthened his influence. No important nomination was made without his approval, and the most unexpected people rose to the highest offices as the result of his influence. Rasputin was too ignorant to have any opinion on political questions: he was in most cases a mere instrument of the reactionaries. Numberless stories of the debauchery practised at the court, in which the name of Rasputin was coupled not only with some of the court ladies but even with that of the empress herself, became a common topic of conversation in all classes of Russian society. At length a small group of men of the highest social position, which included the grand duke Dimitri Pavlovich, Prince Yussupoff and Purichkevich determined to end the empire of Rasputin. He was invited to a supper at the Yussupoff palace on Dec. 17, 1916, and shot dead, after an attempt at poisoning him with a strong dose of potassium cyanide mixed with wine had not produced the desired effect. The empress had the body transferred to the park of Tsarskoe Selo, where a special chapel was erected, and she went every night to pray on his grave.

See *Letters of the Tsaritsa to the Tsar 1914–16* (1923); and further letters published in *The Manchester Guardian*, Jan. 9 and Feb. 7, 1924; also Prince Yussupoff, *Rasputin: His Malignant Influence and*

his Assassination (Eng. ed. 1927); M. V. Rodzianko, *Reign of Rasputin* (1927); R. Fülöp-Miller, *Rasputin, the holy devil* (1928).

RASSAM, HORMUZD (1826–1910), Assyriologist and traveller, was born at Mosul of native Christian parents. His first work was done as assistant to Sir A. H. Layard in his first expedition (1845–47). He then studied at Oxford, and was again sent by the British Museum trustees to accompany Layard in his second expedition (1849–51). Rassam continued the work (1852–54) in Assyria under the direction of the British Museum and Sir Henry Rawlinson at Nimrud and Kuyunjik. In 1866 he was sent by the British government to Abyssinia, where, however, he was imprisoned for two years until freed by the victory of Sir Robert Napier. From 1876 to 1882 he was again in Assyria conducting important investigations, especially at Nineveh, and during the Russo-Turkish War he was sent on a mission of inquiry to report on the condition of the Christian communities of Asia Minor and Armenia. His archaeological work resulted in many important discoveries and the collection of valuable epigraphical evidence.

See *The Times*, Sept. 17, 1910.

RASSKAZOVO (formerly Byelaya Polyana and Arzhenka), the name of two settlements in the Russian S.F.S.R., on the river Arzhenka, a tributary of the Tambov, and on the road and railway between Kirsanov and Tambov, in 52° 42′ N., 41° 46′ E. Population 25,168. One settlement, formerly called Byelaya Polyana, was noted for its fair in June. Both have cloth factories.

RAS TAFARI MAKONNEN: *see* MAKONNEN, RAS TAFARI.

RASTATT, a town of Germany, in the *Land* of Baden, on the Murg, 15 mi. by rail S.W. of Karlsruhe. Pop. (1939) 17,503. The old palace of the margraves of Baden, a Renaissance edifice in red sandstone, contains a collection of pictures, antiquities and trophies from the Turkish wars. The chief manufactures are stoves, beer, paper, sugar, furniture and tobacco.

Rastatt has been the scene of two congresses. The first congress culminated in the treaty of Rastatt between France and Austria, signed on March 7, 1714. The second congress, opened in Dec. 1797, was intended to rearrange the map of Germany by providing compensation for those princes whose lands on the left bank of the Rhine had been seized by France but it had no result.

RASTELL (or RASTALL), **JOHN** (*c.* 1475–1536), an English printer and author, belonged to a Coventry family, and was educated for the law. He succeeded his father as coroner at Coventry in 1506. He was also M.P. for Dunheved, Cornwall, from 1529 to the time of his death. He began his printing business some time before 1516, for in his preface to the undated *Liber Assisarum* he announced the forthcoming publication of Sir A. Fitzherbert's *Abbreviamentum librorum legum Anglorum,* dated 1516. In that year he undertook an expedition to America, but got no further than Ireland when his sailors left him. Among the works issued from the "sygne of the meremayd at Powlysgate," where he lived and worked from 1520 onwards, are *The XII. Mery Gestys of the Wydow Edyth* (1525), and *A Dyaloge of Syr Thomas More* (1529). The last of his dated publications was *Fabyl's Ghoste* (1533), a poem. In 1530 he wrote, in defence of the Roman doctrine of Purgatory, *A New Boke of Purgatory* (1530), dialogues on the subject between "Comyngs and Almayn a Christen man, and one Gymgemyn a Turke." This was answered by John Frith in *A Disputacion of Purgatorie.* Rastell replied with an *Apology against John Fryth,* also answered by the latter. Rastell had married, at some time before 1504, Elizabeth, sister of Sir Thomas More, with whose Catholic theology and political views he was in sympathy. More had begun the controversy with John Frith, and Rastell joined him in attacking the Protestant writer, who, says Foxe (*Actes and Monuments,* ed. G. Townsend, vol. v. p. 9), did so "overthrow and confound" his adversaries that he converted Rastell to his side. Separated from his Catholic friends, Rastell does not seem to have been fully trusted by the opposite party, for in a letter to Cromwell, written probably in 1536, he says that he had spent his time in upholding the king's cause and opposing the pope, with the result that he had lost both his printing business and his legal practice, and was reduced to poverty. He was imprisoned in 1536, perhaps because he had written against the payment of tithes. He probably died in prison, and his will was proved on July 18, 1536.

Rastell's best-known work is *The Pastyme of People, the Chronycles of dyvers Realmys and most specially of the Realme of England* (1529), a chronicle dealing with English history from the earliest times to the reign of Richard III., ed. T. F. Dibdin (1811). His *Expositiones terminorum legum Angliae* (in French, trans. into English, 1527; reprinted 1629, 1636, 1641, etc., as *Les Termes de la Ley*), and *The Abbreviacion of Statutis* (1519), of which 15 editions appeared before 1625, are the best known of his legal works.

To Rastell is generally attributed the morality play, *A new Interlude and a Mery of the IIII Elements* (*c.* 1519). The fullest details available on John Rastell's life are in A. W. Reed, *Early Tudor Drama* (1926). For the books issued from his press *see* a catalogue by R. Proctor, in *Hand-Lists of English Printers* (Bibliographical Soc., 1896).

RASTELL, WILLIAM (*c.* 1508–1565), English printer and judge, son of the preceding, was born in London about 1508. At the age of 17 he went to the university of Oxford, but did not take a degree, being probably called home to superintend his father's business. The first work which bears his own imprint was *A Dyaloge of Sir Thomas More* (1531), a reprint of the edition published by his father in 1529. He also brought out a few law-books, some interludes ascribed to John Heywood (*q.v.*), an edition of *Fabyan's Cronycle* (1533), and *The Apologye* (1533) and *The Supplycacyon of Soulys* of his uncle Sir Thomas More. He became a student at Lincoln's Inn on Sept. 12, 1532, and gave up the printing business two years later. In 1547 he was appointed reader. On account of his Catholic convictions he left England for Louvain; but upon the accession of Mary he returned, and was made serjeant-at-law and treasurer of Lincoln's Inn in 1555. His patent as judge of the Queen's Bench was granted on Oct. 27, 1558. Rastell continued on the bench until 1562, when he retired to Louvain where he died on Aug. 27, 1565.

It is difficult to distinguish between the books written by William and those by his father. The following are believed to be his: *A Colleccion of all the Statutes* (1559), *A Table collected of the Yeares of the Kynges of Englande* (1561), both frequently reprinted with continuations, and *A Colleccion of Entrees, of Declarations, etc.* (1566), also frequently reprinted.

RASTENBURG, a town in the province of East Prussia, Germany, on the Guber, 64 mi. S.E. of Königsberg by the railway to Lyck. Pop. (1939) 19,494. Its principal manufactures are flour, sugar, oil, beer and machinery.

RAT, probably in its original sense the designation of the rodent known as the black rat (*Rattus rattus*), but also applied to the brown or Norway rat (*R. norvegicus*), and in a wider sense to all the larger representatives of the family Muridae.

ABOVE: BLACK RAT (RATTUS RATTUS); BELOW: BROWN RAT (R. NORVEGICUS)

Rats have more rows of scales on the tail (reaching to 210 or more) than mice, in which the number does not exceed 180. For the distinctive characteristics of the family Muridae *see* RODENTIA. Of the two species the brown or Norway rat (*R. norvegicus*) is distinguished by its large size, brownish gray colour, short tail and ears, stout skull, and the possession of from 10 to 12 teats. It is fierce and cunning, and overcomes all allied species with which it is brought in contact. Its original home would seem to have been some part of Central Asia. Thence it has spread over much of the world, driving out the house-haunting species everywhere, as it has in England all but exterminated the black rat. The brown rat migrated westward from Central Asia early in the 18th century, and is believed to have first reached Great Britain about 1730. The black rat (*R. rattus*) is smaller in size than the brown rat, with longer ears and tail. It is typically glossy black in colour, but brownish varieties, which may be distinguished readily from the brown rat, are common, especially in southern lands. It frequents ships and on them

has reached most parts of the world. It is more common and more wide-spread in the tropics than the brown rat, which in these climes is often restricted to the coast or to ports. This long-tailed rat, originally a native of southern Asia, first penetrated to all parts of the world, in many places nearly exterminating the indigenous rats. After this followed the advance of the more powerful brown rat. The black rat first reached Europe in the 13th century. The Isle of Dogs and Yarmouth in Norfolk are chief English strongholds of the black rat. It is this species that is the chief disseminator of bubonic plague. Both species agree in their predaceous habits, omnivorous diet and great fecundity. They bear, four or five times in the year, from four to ten blind and naked young, which are in their turn able to breed at an age of about six months; the time of gestation being about 20 days.

See J. G. Millais, "The True Position of *Mus rattus* and its Allies," *Zoologist,* June 1905; M. A. C. Hinton "Rats and Mice . . .," *Brit. Mus. Pamphlets;* U.S. Fish and Wildlife Service, *Wild Life Circular 6* (1941).

RATAFIA. A liqueur or cordial flavoured with peach or cherry kernels, bitter almonds, or other fruits; many different varieties are made. The same name is given to a flavouring essence resembling bitter almonds, and also to a light biscuit.

RATCHET AND PAWL is an important mechanical device in a great many machines and appliances, enabling a movement to be effected in one direction, with slip or freedom in the opposite direction. The mechanism is used to lock something so that it cannot slip or reverse, to hold a load as in a winch, or to give a positive feed. Some ratchets are straight, or with a moderate curve, but the majority are circular. The teeth are usually V-shaped, and the pawl is pivoted so that it drops against any tooth and remains without danger of jumping out. Where a continuous movement is desired, the objectionable clicking of the pawl may be checked by a leather facing, or by the use of a ball or roller, or a set of these, to catch in the teeth, with gravity or spring action to ensure engagement. In the case of a silent ratchet, the wheel has no teeth but an eccentrically-pivoted pawl works frictionally against the periphery.

Various drives and brake mechanisms are made safe by ratchet mechanism, the ship's capstan being one of the oldest examples. Screwdrivers and wrenches are operated by ratchet for access in difficult situations, or to help the worker in manipulative power. Braces and metal drills are actuated by ratchet when it is not possible to make the complete revolution of a handle. So also are jack screws for lifting loads rapidly. Ratchet feed, by which an arm holding the pawl is moved over, and the ratchet-wheel and a feed screw are turned, is utilized in many types of machines and is usually automatic in action. The finest example occurs in cylindrical grinding machines, in which by means of an automatic feed the grinding-wheel travels along a shaft or spindle, the ratchet mechanism setting the wheel to cut a very little smaller before each traverse takes place, this process being repeated as often as is necessary to bring the shaft to size.

RATE. In England the term is specially applied to the levying of public money contributions for local purposes, as distinguished from the "taxes" raised for what are treated as general State purposes. By the Rating and Valuation Acts of 1925 and 1928 the English system of rating has been amended and the law partially consolidated as also for Scotland by the Rating Act, 1926, and the Rating (Scotland) Amendment Act, 1928. In the United States the term "rate" does not signify a form of taxation, but is used to indicate the assessment percentage. (*See* further POOR LAW; TAXATION; TAXATION, LOCAL.)

RATEL or **HONEY BADGER,** the name of certain Indian and African small clumsy-looking creatures of the size and appearance of badgers, representing the genus *Mellivora* in the family Mustelidae (*see* CARNIVORA). Only one living species of ratel is known (*Mellivora capensis*), represented by several races in various parts of Africa, south of the Sahara and in India. Ratels are normally black with whitish crown and grizzled back, a style of coloration that is found also in the grison (*q.v.*). Pure black individuals are known. The body is stout and thickly built; the legs are short and strong, and armed, especially the anterior pair, with long curved claws; the tail is short; and the ears are reduced to rudiments. The Indian ratel is found throughout India, chiefly in hilly districts, but also in the north of India in alluvial plains. It lives usually in pairs, and eats rats, birds, frogs, white ants, and various insects. Like its Cape congener it occasionally partakes of honey and is often destructive to poultry. In confinement the Indian ratel becomes tame and even playful.

RATEL, OR HONEY BADGER (MELLIVORA CAPENSIS)

(J. E. HL.)

RATHENAU, WALTHER (1867–1922), German statesman and industrialist, was born in Berlin on Sept. 29, 1867, the son of Emil Rathenau, the founder of the Allgemeine Elektrizitäts-Gesellschaft. After studying philosophy, physics and chemistry at Berlin and Strasbourg he graduated in 1889, and spent a year studying machine structure and chemistry at Munich. He was then engaged as a civil engineer by the Aluminium Industrie A.-G. of Neuhausen, Switzerland.

In 1893 he became a director of the Electrochemische Werke (Limited) at Bitterfeld for the utilization of a process for making chlorine and alkalis by electrolysis. He also built large works at Rheinfelden, in Russian Poland, and in France, and elaborated processes for the production of ferrosilicate, chrome, soda and magnesia. In 1899 Rathenau became a director of the Allgemeine Elektrizitäts-Gesellschaft, and built power stations at Manchester, Amsterdam, Buenos Aires and Baku. In 1902 he belonged to the board of directors of about 100 enterprises. During 1907 Rathenau accompanied Dernburg, the Secretary of State of the Imperial Colonial Office, to German East and West Africa, and also visited the British Colonies in Africa. His *Reflexionen* (1908) contain his two final reports on those visits.

Even at the beginning of World War I Rathenau foresaw the threat to the German supply of raw materials involved by the British blockade. In an astoundingly short time, with the acquiescence of the War Minister von Falkenhayn, he established a huge organization for the administration of the war raw materials then at Germany's disposal. This Board of the War Ministry, called the *Kriegsrohstoff-Abteilung,* which he left in splendid working order to his successor on March 31, 1915, alone made it possible for Germany to hold out with raw material.

After his father's death in the summer of 1915 Rathenau was made president of the Allgemeine Elektrizitäts-Gesellschaft. He published *Von Kommenden Dingen* (Eng. trans. *In Days to Come*), *Eine Streitschrift vom Glauben* and *Vom Aktienwesen.* In 1918 his collected works were published. After the War Rathenau endeavoured to found a middle-class Democratic Party which should bridge the gulf between the middle classes and labour caused by the revolution, and in this way to restore national unity. In 1919 he participated in the preliminary preparations in Berlin for the Conference of Versailles. From April 1920 to May 30, 1921, Rathenau was a member of the so-called "Socialization Commission" convoked by the newly founded *Reichswirtschaftsrat* to discuss the question of nationalizing the coal-mines.

He was government expert at the Spa conference of July 1920, and in the spring of 1921 took part in the preliminaries to the London Conference. At the end of May 1921 he was asked by the chancellor, Wirth, to join the Government. The two leading men of the Cabinet thus formed, Wirth and Rathenau, were united by trust and friendship. The combination of the chancellor's original and impulsive nature, his courage and love of responsibility, was a happy blend with Rathenau's far-sighted and extraordinary capability. Rathenau co-operated in the final conclusion of the Peace Treaty with the United States of America in Aug. 1921. As Minister of Reconstruction he concluded with Loucheur, the French Minister of the Liberated Regions, the Wiesbaden agreement, securing to France the privileged supply of deliveries in kind as reparation payment, which helped to relax the tension between France and Germany. But the disruption of the Upper Silesian coal and iron district, quite contrary to the German reading of

the Versailles Treaty and to the result of the plebiscite, provoked Rathenau to resign from the Cabinet by way of protest. He did not withdraw his support from the Cabinet, however, and went, in Nov. and Dec. 1921 to London, to enlist England's interest and understanding, and to secure a British loan for the next reparation instalment. This loan was refused on technical grounds. But in England Rathenau came in touch with members of the British Government. Under his influence arose the famous Lloyd George "Chequers scheme," which gave a practical form to the idea of a "United States of Europe" by proposing the reconstruction of Russia through the united economic forces of the other great European Powers, including Germany. The ideas underlying the later Pact of Locarno (1925) were also discussed. In Paris Rathenau found less support. Nevertheless, the project discussed at Chequers led to the conference of Cannes (Jan. 1922), where Rathenau, in an eloquent speech, exposed the impossibility of the London reparation demands and secured an essential diminution of the reparation payment of 1922.

Meanwhile, at the wish of the chancellor, Wirth, Rathenau had re-entered the Cabinet, this time as Minister for Foreign Affairs. The Genoa negotiations did not, unfortunately, lead to a united European work of reconstruction. But separate negotiations between British and French representatives took place with Russia to the exclusion of Germany. Rathenau, fearing that German interests would suffer, accepted on April 16, 1922, at Rapallo the Treaty of Peace and Friendship offered by the Russians, cancelling all reciprocal demands which had accrued from the War.

The climax of his endeavour to replace blind hatred by reason was shown in his great speech in Genoa on May 19, 1922, which ended with the cry of Petrarch: *"Pace—Pace—Pace!"* The question of the alleged War guilt of Germany was one that Rathenau had greatly at heart. He furthered the publication of the pre-War documents.

The effects of the inflation of the currency on the impoverished middle classes caused him the greatest anxiety, and he secured many relief measures. Yet he fully realized that German industry, when inflation ceased, would be faced with extraordinary dangers; but that the development of reparation payment in kind and the treaty with Russia would at least ensure some work for industry in the impending hard times of recovery.

Rathenau, however, was not to see the fulfilment of his plans. On his usual morning drive from his house to the Foreign Office on June 24, 1922, he fell a victim to the bullets and hand-grenades of misguided young Germans, who by this deed robbed their country, not only of a great philosopher and industrialist, but of one of its most fervent patriots and of the best Foreign Ministers of that time.

In philosophy Rathenau was an idealist. Adopting the evolutionary theories of Leibniz and Darwin, he saw the development of man's purpose in three stages—first, prehistoric man wholly guided by instinct, then historical man led by intellect and conscious purpose, and lastly the man of the future whose fulfilment will be in the kingdom of the soul. "The soul is no weapon," says Rathenau. It thus stands in contrast to the whole spiritual world of instinct and purpose resulting from the struggle of life. In the social world, whilst believing in an aristocracy of the mind, he realized that democracy was necessary to consolidate the crumbling foundations of the society of his day. A capitalist by birth and training, he held without repudiating his creed, that in countries like Germany, carrying the burden of a dense population, "Consumption, like all enormous activities, is not an individual but a communal affair"; "The equalization of property and income is prescribed both by ethics and by economics"; "The extant sources of wealth are: monopolies in the widest sense, speculation and inheritance"; "The restriction of the right of inheritance, in conjunction with the equalization of popular education at a higher level, will throw down the barriers which now separate the economic classes of society, and will put an end to the hereditary enslavement of the lower classes."

Rathenau's collected works (5 vol.) were published in 1925. The following were not included and appeared separately: *Die Neue Wirtschaft* (1918); *An Deutschlands Jugend* (1918); *Zeitliches* (1918); *Nach der Flut* (1919); *Der Kaiser* (1919); *Der Neue Staat* (1919) (Eng. trans. *The New Society*); *Krit. der dreifachen Revolution* (1919); *Die neue Gesellschaft* (1919); *Autonome Wirtschaft* (1919); *Was wird werden?* (1920); *Demokr. Entwicklung* (1920); *Albert Kollmann* (1921); *Reden* (1924); *Briefe* (1926); H. Kessler, *Walther Rathenau, sein Leben und sein Werk* (1928, English trans. *Walther Rathenau*, 1929) The *Rathenau Stiftung* (Berlin), founded after his death, collects all bibliographical material. (F. St.)

RATHENOW, a town in the Prussian province of Brandenburg, Germany, on the Havel, 45 mi. W.N.W. of Berlin. Pop. (1939) 33,531. Rathenow was incorporated as a town in 1295. In 1394 it was taken and partly destroyed by the archbishop of Magdeburg. It suffered much from the ravages of the Thirty Years' War. The Protestant church of St. Mary and St. Andrew, originally a basilica, was transformed to the Gothic style in 1517–89.

RATIBOR (Polish *Raciborz*), a town of Germany, in the Prussian province of Silesia, situated on the left bank of the Oder at the point where the river becomes navigable, 97 mi. S.E. of Breslau by rail, on the main line to Oderberg. Pop. (1939) 49,085. Ratibor, which received municipal privileges in 1217, was formerly the capital of an independent duchy, 380 sq.m. in extent, which existed from 1288 to 1532, and afterwards passed successively into the hands of Austria and Prussia. In 1821 a small mediate principality was formed and was conferred upon the landgrave of Hesse-Rotenburg, as compensation for some Hessian territory absorbed by Prussia. In the partition of Upper Silesia between Germany and Poland in 1921 (*see* SILESIA) Ratibor was retained by Germany. The most prominent buildings are the law-courts and the château on the right bank of the Oder.

RATIOCINATION, a term used in logic and psychology for those processes by which the mind proceeds from general to particular truths. The steps involved in ratiocination may perhaps be most clearly seen in the form of reasoning followed in the syllogism. (*See* SYLLOGISM.)

RATIONALISM is that trend of philosophy which intercedes for the rights of "natural reason" and sees in it the source of all truth. Common to all the historical forms of rationalism is the belief in the "autonomy of thought," *i.e.*, the view that thought can discover by its own strength, without support from a supernatural revelation and without appeal to sense perception, a system of "eternal truths," a system presented to thought within its own realm and comprehended by thought as necessary.

In the theoretical field there are certain "innate ideas" which form the basis of all certainty and from which all specific proofs are derivable by logical inference. The same is true also of practical consciousness. Beside the theoretical, especially logical and mathematical, truths, there are ethical truths which can be comprehended with certainty as unconditional obligations or imperatives of action.

Early History.—This fundamental conviction found its clearest expression in the Stoic doctrine of the κοιναὶ ἔννοιαι (notitiae communes), as it is developed in the writings of Cicero. From here it exercised a lasting influence. In modern philosophy this influence first appears within the religious sphere, in which also the terms "rationalism" and "rationalist" seem to have originated, and where they designate the assumption that there cannot be an insurmountable conflict between the "natural" cognition of reason and the "supernatural" truth of revelation.

Thus, in English religious philosophy of the 16th and 17th centuries, for instance, those are called "rationalists" who consider reason the highest authority not only in science but also in matters relating to religion and society. (*Cf.* Lechler, *Geschichte des englischen Deismus*, p. 61.) Also in the Netherlands it was customary at that period to distinguish between "rational" and "non-rational" theologians. (*Cf.* Bayle, *Dictionnaire historique et critique.*) In the introduction to his *Théodicée*, in the "Discours de la conformité de la foi avec la raison," Leibniz gave an outline of the development and significance of "theological rationalism."

It was especially in England and through Herbert of Cherbury (1581–1648) that religious rationalism received its complete foundation and its clear formulation. In his two works *De veritate* (1624) and *De religione gentilium* (1645), Herbert of Cherbury starts from the assumption that reason possesses in itself the capacity for all truths, including religious and moral

ones. Beside reason, there is no other higher authority; for even revelation can claim validity only because its content harmonizes with the principles of rational knowledge. The dogma of original sin, or the corruption of reason through the fall of man, is unconditionally rejected by Herbert. In every healthy and reasonable person there are universal and innate truths, by which our earthly mind, implanted as it were, from heaven, is enabled to participate in the recognition of things of God and of moral good. From the sphere of religion this doctrine passes to the science of law (doctrine of "natural law"); to the theory of the State (doctrine of "raison d'état," of the foundations of international law, etc.), to ethics ("autonomy" of morals). In its totality it represents the new "natural system of the sciences of mind" which, since the Renaissance, unfolds itself steadily and supercedes the mediaeval view of the world, which was theological and hierarchic.

Modern Science.—The strongest support was given to this movement by the new achievements of natural knowledge through the great scientists of the 17th century, Copernicus, Galilei, Kepler and Descartes. The new science rests on the basis of mathematics, and it recognizes as "clear and distinct" only what can be expressed in mathematical form. All such cognitions have this in common: that they go back to certain major premises, to "axioms" and "principles" which can be comprehended by reason as universal and necessary, as a priori propositions. Thus, according to Galilei, Truth is written in the great book of Nature, but only he can read it who can decipher the letters in which it is written. These letters, however, are the terms of mathematics, especially of geometry: the concepts of the straight line, the circle, the sphere, etc. None of these concepts is derived from experience; the mind rather takes them "from itself" in order to apply them to sense-perceptions. In the same way, Kepler considers the ideas of *number* and *magnitude* as "innate ideas," not drawn from experience but required for the scientific investigation of nature. (*Cf.* Cassirer, *Das Erkenntnisproblem,* 3rd ed., I., p. 328 *sqq.*) Descartes enlarges this view by setting forth a system of universal concepts of reason which are obtained by mental analysis from a contemplation of certain fundamental, logical and mathematical, relationships, and which can be applied to all empirical data. These concepts are valid—as he expounds in *Le monde*—not alone for the actual world but for all possible worlds, so that, in understanding by means of them every effect from its cause, we can obtain a priori knowledge of the universe as a whole. As instances of such fundamental concepts, Descartes cites primarily the concept of *Being,* then also the ideas of *Number* and *Time,* of *Space, Figure* and *Motion* (*Oeuvres,* ed. Adam-Tannery, III., 665).

As a middle term for making the transition from the rational to the empirical, from the "possible" to the "actual," a *metaphysical* idea is used by Descartes as well as by Kepler. The actual world must correspond to the supreme laws of reason, because it is the work of an infinite mind, because it is a creation of the divine intellect. The applicability of pure mathematics to physics, to the concrete phenomena of nature, seems explainable only on this presupposition. It is valid because nature itself is the product of a "divine mathematics": *cum Deus calculat, fit mundus.*

For Leibniz, too, there is a continuous harmony between "truths of reason" and "truths of fact," between the empirical and the rational world. The pure laws of thought as exhibited in logic, arithmetic, geometry and abstract dynamics, apply to all objects in nature, and to all changes taking place therein.

This metaphysical rationalism is further developed by Leibniz so that the eternal truths of reason constitute the essence of the divine mind, and God, therefore, cannot desert them in his activity, in his creation. Creation consists in transition from "essence" to "existence," from the "possible" to the "actual."

Leibniz developed this view of rationalism in two directions. It determines, first of all, the entire structure of his metaphysics; it forms the logical and methodical basis of his *monadology.* The system of "monads," *i.e.,* of perceiving minds, is graded, according to Leibniz, in such a way that each monad resembles the others as regards the content of its perception; for each of them represents and reflects the total universe from a definite angle. Accordingly, the difference between the various minds can consist in nothing other than the *form* of perception, the greater or lesser degree of clarity. Hence a gradation from the dim and confused mode of perception, such as we must assume, for instance, in plant or animal consciousness, up to the divine cognition which consists in completely distinct and adequate ideas. Human knowledge lies in the middle between the two extremes; it knows "confused" ideas, *e.g.,* those of sense-qualities, as well as "distinct" ideas, *e.g.,* those of logic and mathematics.

However, its specific task consists in referring progressively the former to the latter, in transforming all data into pure objects of thought, all merely factual presentations into notions continuously connected by proof and thus conceived by reason. This task can be accomplished in detail only by presupposing a general system of the possible forms of thought and of the universal laws of connection which those forms obey. Leibniz attempted to satisfy this demand in the grandiose outline of his "general characteristique" in which the primary elements of all cognition were to be set forth in conjunction with the demonstration of a method by which all truths, however complex, could be exhibited as combinations of those primary elements. Through this outline of his "general characteristique," Leibniz became the founder of that "symbolic logic" which reached its complete development only in the nineteenth century through the works of Boole and Schröder, of Peirce and Peano, of Whitehead, Frege and Russell. (*Cf.* Couturat, *La Logique de Leibniz,* 1901.)

In the eighteenth century, on the other hand, philosophical rationalism became dominant only in that more limited form which it had received in the system of Christian Wolff (1679–1754). Wolff's doctrine, too, rests entirely on the distinction between contingent "truths of fact" and necessary "truths of reason"; he, too, contends that the specific task of cognition, especially the task of philosophical knowledge, consists in transforming all contingent elements into rational ones by understanding them according to the principle of sufficient reason.

Consequently, we cannot claim a philosophic insight into a region of facts unless we succeed in bringing the factual details into a rational order so that each member can be completely understood from the context and from the necessary laws which determine this context. Accordingly, Wolff supplements each form of empirical cognition by a corresponding "rational" form. The propositions, for instance, which in the field of physics result directly from observation and from experiments, must be raised to the rank of genuine cognitions of reason by being deduced from the principles of general ontology and general cosmology. Specifically, Wolff's system is subdivided into *Logic* as the doctrine of the operations of the understanding in general, into *Ontology* as the doctrine of Being and its most universal determinations, *Cosmology* as the doctrine of the world, of the simple substances and their combination, *Psychology, Theology,* and, finally, universal *Teleology,* the doctrine of ends in general and of the end of human action in particular.

Kant.—It is against this rationalism of Wolff that the attack of Kant is directed in the *Critique of Pure Reason.* In the section on the "transcendental dialectic," he demonstrates the fact that, and the reason why, a rational psychology, a rational cosmology, a rational theology, such as Wolff had planned and developed, are impossible. The decisive ground for this impossibility lies, according to Kant, in the fact that mere reason does not suffice for the cognition of absolute Being, of God, Soul and World. Soul, God and World are transcendental "ideas"; but reason becomes involved in insoluble contradictions as soon as it tries to "hypostasize" these ideas; *i.e.,* as soon as it takes them for transcendent objects, for objects beyond all possible experience. All that reason can reach, lies within the boundaries of experience itself; it cannot recognize the nature of things in themselves, its sole task in theoretical cognition consists in "spelling phenomena in order to be able to read them as experiences."

The *metaphysical* rationalism of the dogmatic systems, as it is to be found in Descartes and Spinoza, Leibniz and Wolff, is thus opposed by the new attitude of *critical* rationalism. The

latter, too, retains the fundamental idea of the older rationalism; namely, that reason can recognize completely only that which it can produce according to its own design—"that we know a priori only so much of things as we ourselves put into them." (*Critique of Pure Reason,* 2nd ed., p. 18.) But this kind of "construction" is possible only in so far as we deal not with things-in-themselves, independently of all possible experience, but with experience itself and the conditions of its possibility. The understanding is able to recognize a priori and, as it were, to anticipate the *form* of experience in so far as it constitutes this form. It is, itself, "the legislation for nature"—but only in so far as we understand by "nature" not the subsistence and constitution of absolute objects, but the order and regularity of empirical phenomena. Thus rational cognition becomes fruitful only where, instead of dwelling in the world of "noumena," it concerns itself with phenomena. The characteristic of these, however, is that they form a spatio-temporal manifold. All efficacy of the "pure concepts of understanding" is, therefore, necessarily confined to space and time, to the forms of "pure intuition." Only in connection with pure intuition does cognition by understanding or cognition by pure reason receive a real content.

This fundamental idea of Kant's critical rationalism is more explicitly developed in his doctrine of the "schematism of the pure concepts of understanding." The categories of thought are merely directions for establishing certain relationships; but these directions need to be referred to sensuousness. Thus, the concept of substance, for instance, does not mean the Being-in-itself *as such* (as conceived by Spinoza), but the persistence of an object *in time,* and it immediately loses all possibility of application when we abstract from the order of time. In general, the "schemata" of the pure concepts of understanding are nothing but "determinations a priori of time according to rules," and these schemata are "the true and only conditions for securing for our concepts of understanding a reference to objects, *i.e.,* significance. The categories are, therefore, only of empirical use, inasmuch as they merely serve to subject phenomena to general rules of synthesis and thus make them fit for coherent correlation in experience." (*Critique of Pure Reason,* 2nd ed., p. 185.) Kantian rationalism, in other words, does not aim at the "existence of things," but at the form of experience itself, at the order and connection of phenomena. (*Cf.* TRANSCENDENTALISM.)

The mistake of Empiricism consists in overlooking the intellectual factor which is indispensable for any cognition of objects; the mistake of Rationalism consists in overestimating this factor, in isolating it from the sensuous conditions upon which its applicability depends. "Leibniz *intellectualized* the phenomena, just as Locke altogether *sensualized* the concepts of understanding, *i.e.,* regarded them as nothing but empirical or abstracted concepts of reflection." (*Critique of Pure Reason,* 2nd ed., p. 327.) In this form of *critical* rationalism, the original problem from which the *scientific* rationalism of the Renaissance had started, is restated; but it is now solved in a new sense. The scientific rationalism of Kepler and Galilei, too, asserted that "experience is possible only through the representation of a necessary connection between perceptions." (*Critique of Pure Reason,* 2nd ed., p. 218.) But it was able to explain this necessity only by founding it on a metaphysical proposition, namely, the contention that the world itself is the work of an infinite intellect. Kant removes this dependence of rationalism upon a proposition of dogmatic metaphysics: he treats the truth of experience as self-sufficient, although its form and order are based on the general orderliness of the understanding, without which they would be impossible.

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RATIONING, a term of military origin, meaning apportionment to each member of a group of his due share of supplies, was first applied to the nation-wide distribution of food in World War I. During World War II it was practised not only by belligerent governments but also in neutral countries faced with shortages and high prices.

Rationing of consumers is carried out by supplying them with a card or booklet containing numbered and dated sections which have to be presented for cancellation or surrender when a purchase is made. Separate cards with detachable coupons may be issued, like the bread cards first used in Berlin, Germany, in the winter of 1914; or a number of cards with different colouring or pattern may be bound together in a single ration book, like that first introduced in Great Britain in July 1918. The issue of ration books and identity cards from the same office is helpful for checking fraud and recording movements of the population.

Out of straight rationing of a single commodity there was developed in World War II a new "points" system of rationing for a group of articles such as clothing and footwear or miscellaneous groceries. Distinction may be drawn between rationing based on tying consumers to a particular shop, in which case retailers receive buying permits corresponding with the number of their registered customers and have no need to detach coupons; and the alternative system whereby customers are free to buy at any shop, and retailers replenish their stocks against the surrender of coupons collected. The former system was applied in Great Britain to meat, bacon, sugar, fats, milk and eggs; the latter to clothing, gasoline and soap and among foods to tea, chocolate and sugar confectionery and miscellaneous groceries.

German and Continental Rationing.—When bread rationing was first introduced in Berlin a few months after the outbreak of World War I, it was wrongly interpreted abroad as a sign of serious shortage rather than as a precautionary measure designed to prevent maldistribution. From the outset the German system embodied the principle of differential rations. Manual workers, later divided into light, heavy and very heavy workers, received more than the normal consumer; children under ten years, less. Rationing was administered by local authorities, who enjoyed more independence than in World War II and sometimes competed with one another for supplies. Co-ordination of supply and distribution by state-controlled war companies was never complete, and this opened the door to illicit trade. Evasion of the regulations from 1917 onward grew to such an extent that maldistribution of food was one of the chief factors in the collapse of the home front in 1918.

Before the outbreak of World War II thorough preparations had been made for rationing as an integral part of war economy. The reich food estate (*Reichsnaehrstand*) had already established centralized control over food supplies and distribution, and disciplinary action reduced illicit trade to the minimum. Rationing of bread, flour, sugar, meat and fats was introduced in Sept. 1939 and continued at a fairly adequate level until 1944. Further refinements were made in the system of differential rations to cover special categories of consumer and different age groups.

Rationing in occupied countries followed the German pattern but varied widely in efficiency and adequacy. Administration was left largely to local officials, and passive resistance by producers, traders and consumers led to an extensive black market.

Great Britain.—Rationing was unknown in Great Britain until toward the end of World War I. In Aug. 1914 a royal commission on sugar supplies had been set up to undertake bulk buying. Toward the end of 1916 sugar supplies fell short of demand, and distributors were allotted only half of their 1915 supplies. Retailers were left to share this out among their customers as best they could, but queues formed and discontent grew. After some months of hesitation the cabinet decided in June 1917 to introduce the first rationing scheme under which householders were invited to register with a particular shop, and retailers received supplies equivalent to the rations of their registered customers. One thousand eight hundred food control committees were appointed by local authorities to exercise powers delegated by the food controller. A local rationing scheme for meat and fats in London and the home counties, covering about 10,000,000 people, came into force on Feb. 25, 1918, as a result of which queues largely disappeared. On April 7 a national rationing scheme for meat was started, and on July 14 the whole population received ration books with separate cards for meat, fats, sugar and lard. By May 1919 rationing by coupons was

abolished, and sugar registration ended in Nov. 1920. Rationing had lasted for little more than two years.

By contrast in World War II rationing started early in 1940 and was still in force ten years later. Ration books, which had been printed in 1938, were issued by post from local food offices to every individual on the basis of a special census conducted for national registration on Sept. 29, 1939. Five types of ration books were issued: for children under 5, children 5 to 18, normal adults, travellers and seamen. Emergency cards valid for one week were issued to new arrivals or persons who had lost their books. Straight rationing, which entitled consumers to a fixed weekly amount of each food, was applied in 1940 to meat, bacon, sugar, fats and tea. In 1941 cheese and preserves were added, and milk and eggs came under a scheme of priority rationing. On Dec. 1, 1941, a new system of points rationing was put into force for miscellaneous groceries, under which each consumer received a number of points to spend in each four-week period on any food in the group, each food being given a points price varying according to the expected demand in relation to the supply; thus canned salmon and dried fruits had a high points price, and cereal foods, a low price. This system was adopted after the successful introduction of points rationing for clothing and footwear. In June 1941 everyone had been given a coupon currency of 66 points, roughly corresponding to 66% of prewar average consumption. Later the figure was reduced to 48 a year. Point prices for clothing were based on the amount of cloth used, but other garments were pointed to equate demand roughly to estimated supply. Rationing of expenditure by value coupons was rejected on the ground that it would have concentrated demand too much on the cheaper goods.

Soap rationing was introduced in Feb. 1942 on the basis of 16 oz. per four weeks for hard soap. Chocolate and sugar confectionery were first rationed in July 1942 under what was called the personal points scheme; distribution to retailers was based on coupons collected without consumer registration. Other foods subject to controlled distribution rather than strict rationing included milk, eggs, oranges and fish. Milk went first to priority consumers—mothers and children up to 5 years old were guaranteed a ration of seven pints a week; children of 5 to 18 years, three and one-half pints; and schools, hospitals and invalids also had priority supplies. The rest of the public got what was left with no definite guarantee of supply, the usual amount being two pints a week in the winter and three to four in the spring. Consumers were tied to one dairyman who received his share of the available supplies according to the number of priority and non-priority customers registered with him. Controlled distribution of shell eggs started in June 1941. Mothers and infants received priority supplies, and ordinary consumers got allocations as and when supplies permitted, varying from one a month in the winter to two or more a week in the spring. Up to the end of 1944 non-priority consumers received an average of 30 eggs a year, which was about one-fifth of prewar consumption. In June 1942 dried eggs, supplied by the United States under lend-lease, were distributed in packets containing an amount equivalent to 12 eggs at the rate of one packet or more per eight weeks; but later priority supplies were allotted to infants and nursing mothers, and the balance went on points. Oranges when available were sold to holders of children's ration books before other customers could be served. It was found impracticable to ration fish, but supplies to retailers were distributed as fairly as possible. Bread, flour and potatoes never had to be rationed during World War II. Bread rationing was introduced in July 1946 and lasted for two years; potatoes were rationed in 1947–48 when a poor potato harvest synchronized with world shortage of wheat.

In contrast with rationing schemes on the continent, differential rations for special categories of workers were kept to the minimum, and coupons did not have to be surrendered for meals in restaurants. The general principle was that everyone should be free to take meals out as a supplement to domestic rations, and caterers received an allocation of rationed foods on the basis of the number of meals served.

Food rationing in Great Britain was made easier by the fact that half the total food supply was imported and did not have to be collected off farms, and also by the willing co-operation of food traders and the public. There was general assent to the principle of fair shares which, though it involved some levelling down in the consumption of the majority, also allowed some levelling up of the diet of the poorest by means of food subsidies and welfare food schemes.

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United States.—During World War I consumer rationing was never extended to the U.S. civilian population to the extent that it was in Britain and continental Europe. Diversion of ships from the Cuban trade toward the end of 1917 made it necessary to reduce supplies to confectioners and sweetmakers; and from July 1, 1918, shipments of sugar to retailers were made on the authority of certificates issued by the food administration on the basis of the number of their customers. Restrictions placed on the sale of wheat flour were at first voluntary, but compulsory regulations were issued in Jan. 1918. These were dictated solely by the necessity of maintaining export to the European Allies.

World War II.—During World War II the U.S. economy was far more closely controlled, and as a result systems of rationing were imposed on industry and the civilian population alike. The rationing of materials, chiefly metals, to industrial producers was exercised through priorities and allocations. Priorities were largely relied upon until mid-1942; thereafter allocations became the principal instruments of production control.

The priorities system proved adequate only as long as the materials under control were not really scarce in relation to essential needs. Under such conditions, the priority ratings merely diverted materials from nonessential uses to essential uses. But as materials became scarcer and manufacturers and procurement officers found that their existing ratings could not get them needed materials, there was a steady cheapening of priorities "currency," because all producers and their government sponsors pressed for award of higher priority ratings.

Allocations were developed to cure the defects of the priorities system. Ideally, allocation of a material involved a periodic consideration of the total supply of the material for a given time period and the allocation of that supply among all essential users of the material, relative to the importance of the products being made. The two principal allocation plans for controlling the major output of U.S. industry during World War II were the Production Requirements plan and its successor after 1942, the Controlled Materials plan.

Consumer rationing was usually preceded by a consumer registration, to determine eligibility of each individual and to place in his hands an initial supply of ration stamps or coupons. Once a supply of ration currency of different kinds was distributed, additional rationing programs could be placed in effect without prior notice to the public. The first general consumer registration, which preceded sugar rationing, took place May 4–7, 1942.

Throughout the war years the Office of Price Administration was authorized by presidential order to ration items made scarce by the war. The delegation of this authority to OPA was first made experimentally on Dec. 27, 1941, when hostilities in the Pacific choked off rubber imports from the far east, and it became clear that automobile tires would have to be equitably distributed to essential users. Automobiles and typewriters were other commodities upon which war's impact was felt early.

Three basic methods of consumer rationing were employed during and after World War II. These were unit or specific rationing, point rationing and certificate or purchase-permit rationing. Each placed in the hands of consumers "ration currency" in the form of stamps or coupons, tickets, certificates or purchase permits.

Unit rationing was generally used to distribute specific quantities of single commodities, like sugar, shoes or gasoline, or two or more substitutable commodities, like margarine and cooking fats.

Point rationing's essential feature was that it permitted the consumer to select any item he wished from items rationed under the same program. For example, a single "red-point" program, using red stamps, grouped meats, butter, margarine, edible fats and oils, cheese, canned milk and canned fish. A "blue-point" program, using blue stamps, included canned fruits and vegetables, fruit juices, soups, baby foods and, for a limited time, dried fruits, peas and beans and preserves.

Certificate rationing involved issuance of a ration certificate or purchase permit only to those who could prove their need for the rationed goods. Examples in the U.S. were automobiles and tires.

Ration coupons were usually issued in series, differentiated by design, colour, numerals or letters. Designated coupons were usually valid for stated periods. In this way the number of coupons currently valid, which in effect determined ration demand, could be adjusted to available supplies. For some commodities, retailers were required to detach ration coupons. For others, they cancelled coupons presented to them in exchange for rationed goods. When cancellation was required, the consumer was permitted to buy only from the retailer with whom he was registered. The retailer used his registration for obtaining replacement stocks. When coupons were detached, they were used as money is used for buying goods. Ration "currency" passed through trade channels to the producer, the manufacturer or primary suppliers, who in turn accounted for the currency to rationing authorities by showing a balance between goods sold and currency received. Banks handled ration currency, and one-point "tokens" were also issued to facilitate retail transactions and reduce the volume of paper stamps handled.

As indicated above, most basic foods in the U.S. diet eventually were rationed. Restaurant meals were unrationed, though restrictions were placed on the allowances of food served.

Clothing rationing was considered in the spring of 1942, but optimism about the course of the war and resistance to additional economic controls caused the plan to be discarded. In consequence, clothing and textiles became increasingly scarce in the last two years of the war, and severe shortages developed when demobilized men began to put a heavy demand on already depleted stocks of suits, overcoats and shirts while production lagged. Heating and cooking stoves and mechanical refrigerators were the only household goods rationed in the U.S. Fuel oil was rationed in those parts of the U.S. heavily dependent on it for heating and cooking, and consumers were required to register with a single dealer. All automobile owners were provided with a basic gasoline ration, the amount fluctuating with the level of supply. Additional rations were provided for "home-to-work" driving, and preferential rations were given those with occupations considered essential to the war effort or to community health and welfare. Travel was subject to priorities.

At its peak, OPA administered 13 rationing programs. Reduced military demands, releasing large stores of supplies to the civilian population, made it possible for OPA to end its rationing programs for all but sugar and rubber tires before the close of Nov. 1945. Rationing of processed foods, gasoline, fuel oil and stoves was terminated immediately after the Japanese surrender, and rubber footwear, canned milk, cheese, automobiles, shoes and meats, fats and oils in the following two months. Rationing of rubber tires was ended at midnight Dec. 31, 1945. (*See* also War Control of Food.)

RAT KANGAROO or Potoroo, any member of the diprotodont marsupial subfamily Potoroinae (*see* Marsupialia). None of them exceeds a rabbit in size. They inhabit Australia and Tasmania, are nocturnal and feed on leaves, roots and bulbs, which latter they dig up with their forepaws. About ten species are known. The members of the type genus (*Potorous*) run, rather than leap, and do not use the hind feet for kicking. In the genus *Bettongia* the tail is prehensile. (*See* Kangaroo.)

RATLAM, formerly a princely state within the Central India agency, but from 1948 a district of Madhya Bharat, Dominion (later Republic) of India—the maharaja (a Rathor Rajput of the Jodhpur family) then ceasing to rule actively. Area, 687 sq.mi.; pop. (1951) 383,894. Chief town, Ratlam (pop. 1941, 37,675).

RATNAGIRI, a town and district of the Southern division of Bombay state, Republic of India. The town is on the coast 136 mi. south of Bombay. Pop. (1951) 27,082. There is no railway, but there is steamer connection with Bombay.

The District of Ratnagiri has an area of 4,982.8 sq.mi. It forms a strip between the Western Ghats and the sea. Nearly all the fertile land lies on the banks of the streams which intersect the country. Ratnagiri (pop., 1951, 1,711,964) formed part of the dominions of the Peshwa and was annexed by the British in 1818 on the overthrow of Baji Rao. The district is known for supplying men of outstanding quality to the Bombay police, to the army and to the intelligentsia.

RATNAPURA (*i.e.,* "The City of Gems"), the chief town in the province of Sabaragamuwa, Ceylon. It is the centre of a long-established industry in digging for precious stones—rubies, sapphires, cat's-eyes, etc. There are important tea and rubber plantations in the district, and rice and fruit are cultivated. The town has good rail and road connections with Colombo. Pop. of town: 8,497; of province (1946): 745,382.

RATON, a city of northeastern New Mexico, U.S., on the Raton range, spur of the Rockies; county seat of Colfax county. It is on federal highways 85, 87 and 64; is served by the Santa Fe railway system and by bus and air lines. Pop. (1950) 8,241. Its altitude is 6,666 ft., just south of the Raton pass, in the midst of forest and mountain scenery. Thirty miles southeast is the extinct volcano Capulin; 35 mi. N.E., the location of Folsom man; 60 mi. S.W., the Eagle Nest dam (keystone of an irrigation project) at the head of Cimarron canyon; and 30 mi. farther west, the Indian pueblo and artists' colony at Taos. The city lies in the richest coal-producing area of New Mexico. It has a municipal electric power plant and extensive railway shops and is a livestock and jobbing centre. Raton was a stage station on the Santa Fe trail; was established as a railway station in 1879 and was incorporated in 1891.

RATTAZZI, URBANO (1808–1873), Italian statesman, was born on June 29, 1808, at Alessandria, and from 1838 practised at the bar. In 1848 he was sent to the chamber of deputies in Turin as deputy of his native town. For a short time he held the portfolio of public instruction; afterward, in the Gioberti cabinet, he became minister of the interior, and on the retirement of Gioberti in 1849 he became practically the head of the government. The defeat at Novara compelled the resignation of Rattazzi in March 1849. His election as president of the chamber in 1852 was one of the earliest results of the so-called "connubio" with Cavour; *i.e.,* the union of the moderate men of the right and of the left. Rattazzi resigned in 1858, but again entered the cabinet under La Marmora in 1859 as minister of the interior. He again retired in Jan. 1860. He was entrusted with the formation of a new ministry in March 1862, but his policy of repression toward Garibaldi at Aspromonte led to his fall in December. He was again prime minister in 1867, from April to October. He died at Frosinone on June 5, 1873.

See Madame Rattazzi, *Rattazzi et son temps* (1881); B. King, *History of Italian Unity* (1899).

RATTLESNAKE, any snake of the genera *Sistrurus* and *Crotalus,* American pit vipers with the tail terminating in a rattle. The "pit" characteristic of these snakes is a deep depression on each side of the snout between eye and nostril. (*See* Pit Vipers.)

The rattle is developed as a modification of the single scale that covers the tip of the tail; instead of being a simple, conical sheath, as in ordinary snakes, it has two ringlike constrictions so that it resembles three hollow bulbs, gradually diminishing in size and each one opening into its neighbour; the largest is also open at its free end, where the tail enters. All snakes shed the horny, epidermal covering of their scales periodically, a new one forming beneath the old one before the latter is sloughed; when, however, the new covering of the end of the tail is developed in the rattlesnakes, the middle ring of the new segment develops within the basal segment of the old rattle and, though the rest of the old skin is sloughed, the old tail sheath remains loosely fitting over the new one but prevented from slipping off by its shape.

Thus, newly born rattlesnakes have no rattle but with each succeeding moult a joint is added; the older joints, however, gradually wear away and are lost so that the number of joints on the rattle is not a criterion of a snake's age unless the rattle is complete with the original terminal button.

The characteristic noise is produced by rapid vibration of the whole tail, when the loosely fitting horny shells produce a shrill sound, which may be audible 20 yd. away. The majority of the species are dwellers of the plains and open spaces and it has been suggested that the development of the rattle was to give a warning audible at a distance, to keep the snake from being trodden upon by hoofed animals, or from molestation by carnivores.

A.—A SINGLE SEGMENT OF THE RATTLE WITH ITS THREE RINGS. B.—FOUR RATTLES JOINED TOGETHER

The venom of the rattlesnakes is of the same general type as that of other pit vipers and all of the larger species inject sufficient venom to kill a man. They are, however, not easily provoked and will usually endeavour to escape or, if cornered, to frighten the aggressor by rattling and puffing themselves out as much as possible. In all species the eggs are retained within the body of the mother until the young are ready to emerge.

Sistrurus, with three species, is confined to the United States, southern Ontario and Mexico. *Sistrurus* may be distinguished from *Crotalus* by the presence of large, regularly arranged shields on the top of the head; all of the forms are small. *Crotalus,* with small irregular scales on the top of the head, contains about 20 species, most of which occur in North and Central America. The largest and most dangerous species is the diamondback (*C. adamanteus*) which reaches a length of about eight feet; it is confined to the southeastern United States. Other well-known species are the prairie rattler (*C. confluentus*), which occurs all over the great plains from Canada to Texas, the timber rattlesnake (*C. horridus*) of the eastern United States, and *C. terrificus,* which ranges from Mexico to the Argentine and is the only representative of the genus in South America. The sidewinder (*C. cerastes*) is a small, desert-dwelling form from southwestern North America and is characterized by the development of a blunt, hornlike process above each eye. (K. P. S.)

RAU, KARL HEINRICH (1792–1870), German political economist, was born on Nov. 29, 1792, at Erlangen, where he studied at the university, of which he subsequently became a professor (1818). In 1822 he was called to the chair of political economy at Heidelberg where the rest of his life was spent in teaching and research. He took some part, however, in public affairs: in 1837 he was nominated a member of the first chamber of the duchy of Baden; in 1845 he became a privy councillor; and in 1851 he was one of the commissioners sent to England on the part of the Zollverein to study the Industrial exhibition. A result of this mission was his account of the agricultural implements exhibited at London (*Die landwirthschaftlichen Geräthe der Londoner Ausstellung,* 1853). He was elected a corresponding member of the French institute in 1856. He died at Heidelberg on March 18, 1870.

His principal work is the *Lehrbuch der politischen Ökonomie* (1826–37), an encyclopaedia of the economic knowledge of his time, written with a special view to the guidance of practical men. The three volumes are respectively occupied with (1) political economy, properly so called, or the theory of wealth, (2) public administration science (*Volkswirtschaftpolitik*) and (3) finance. The two last he recognizes as admitting of variations in accordance with the special circumstances of different countries, while the first is more akin to the exact sciences, and is in many respects capable of being treated, or at least illustrated, mathematically. This threefold division marks his close relation to the older German cameralistic writers. The book passed through many editions; in that of 1870 by Adolf Wagner it was transformed into a new book.

His most important works are his early prize essay, *Über das Zunftwesen* (1815); *Ansichten der Volkswirtschaft* (1821); *Malthus und Say* (1821); *Grundriss der Kameralwissenschaft oder Wirtschaftslehre* (1823); *Über die Kameralwissenschaft* (1825); *Über die Landwirtschaft der Rheinpfalz* (1830); and *Geschichte des Pfluges* (1845). Rau founded in 1834 the *Archiv der politischen Ökonomie und Polizeiwissenschaft,* in which he wrote a number of articles, afterward issued in separate form.

RAVAILLAC, FRANÇOIS (1578–1610), the assassin of Henry IV of France, was born near Angoulême. He began life as a *valet de chambre,* but afterward became a lawyer and schoolteacher. He failed to obtain admission either to the recently founded order of Feuillants or to the Society of Jesus. Rumours that the king was intending to make war upon the pope suggested to him the idea of assassination, which he carried out on May 14, 1610. He was executed on May 27, 1610.

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RAVAISSON-MOLLIEN, JEAN GASPARD FELIX (1813–1900), French philosopher and archaeologist, was born at Namur on Oct. 23, 1813. He attended the lectures of Friedrich Wilhelm Joseph von Schelling at Munich and in 1837 published the first volume of his *Essai sur la métaphysique d'Aristote,* to which in 1846 he added a supplementary volume. He was professor of philosophy at Rennes (1838), inspector-general of public libraries (1840), inspector-general in the department of higher education (1860) and curator of the department of antiquities at the Louvre (from 1870). He died in Paris on May 18, 1900. He belonged to the school of Victor Cousin, with whom, however, he was at issue in many important points. The act of consciousness, according to him, is the basis of all knowledge. Ravaisson's chief philosophical works are: "Les Fragments philosophiques de Hamilton" (in the *Revue des Deux Mondes,* Nov. 1840); *Rapport sur le stoicisme* (1851); *La Philosophie en France au dix-neuvième siècle* (1868; 3rd ed., 1889); *Morale et métaphysique* (1893).

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THE RAVANASTRON, AN ANCESTOR OF THE VIOLIN

See Charles Bernard Renouvier, *L'Année philosophique* (1868); Dawriac, "Ravaisson philosophe et critique," *La Critique philosophique,* vol. ii (1885).

RAVANASTRON, an Indian stringed instrument played with a bow, used by wandering pilgrims. It consists of half a round gourd, over which is fixed a soundboard of skin or parchment, with strings, either one or four in number, above. It is considered by some to have been the first instrument played with a bow.

RAVEL, MAURICE (1875–1937), French musical composer, was born at Ciboure, near St. Jean de Luz, Basses-Pyrénées, March 7, 1875. He was the most outstanding figure in modern French music. More than that, he held an assured place in that line of composers beginning with the *clavecinistes* of the 17th century, who had so powerful an influence on French instrumental music. Educated at the Conservatoire de Paris, where his master in composition was Gabriel Fauré, Ravel won the second prix de Rome for composition in 1901. But he was not awarded the grand prix de Rome, and the judges were severely criticized for thus refusing to recognize his talent; the resignation of F. C. T. Dubois from the directorship of the Conservatoire was in fact attributed to this cause. When Ravel's piano pieces began to be known, notably *Pavane pour une infante défunte* and *Jeux d'eau,* played in Paris by Ricardo Viñes in 1902, a comparison was made between him and C. A. Debussy, whose *Pelléas et Mélisande* (Opéra-Comique, 1902) was then arousing heated controversy.

It is true that such diverse minds as Fauré, A. E. Chabrier, and Erik Satie exercised an influence on Ravel during his formative years, but his personality showed itself from the first. This personality became more clearly defined in his subsequent works, which included the *String Quartet in F,* the three *Schéhérazade* melodies for voice and orchestra or piano (both 1903); the

Histoires naturelles (1906); *Introduction et allegro* (septet for harp, strings, flute and clarinet) and the *Rapsodie espagnole* for orchestra (1907). For the piano he wrote *Miroirs* and *Sonatine* (1905); *Gaspard de la nuit* (3 pieces) (1909); *Ma mère l'Oye* (suite of five pieces) (1908); and *Valses nobles et sentimentales* (1911). The last two of these are best known in England as orchestrated by the composer.

However daring Ravel's harmony may appear, he was never experimental. He had an unerring sense of direction and knew where he was going, even if he sometimes seemed to watch himself going there with a smile of amusement. The cynical wit of his one-act opera, *L'heure espagnole* (Opéra-Comique, 1911), and the conscious pose of the ballet *Daphnis et Chloé* (choreography by Michel Fokine and produced by Sergei Diaghilev, 1912), emphasize in different ways the detached attitude of Ravel toward his art. His later works include a sonata for violin and violoncello, and a trio for piano and strings (1915); *La Valse* for orchestra (1920) and *Tzigane*, for violin and piano (1924).

(H. C. C.)

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RAVELLO, a village of Campania, Italy, in Salerno province, 3 mi. N.N.E. of Amalfi, 1,227 ft. above sea level. It commands a magnificent view, especially from the Belvedere of Cimbrone. Pop. (1936): 703 (town); 3,237 (commune). The history of Ravello begins in the 9th century. In the 11th it was called Rebellum, because it rebelled against Amalfi; in the 13th, at the height of its prosperity, it had 36,000 inhabitants. The Palazzo Rufolo, begun in the 11th century, has two lofty towers and beautiful Saracenic decoration in the courtyard. The former cathedral of S. Pantaleo has a good campanile, fine bronze doors by Barisanus of Trani (1179) and two pulpits in Cosmatesque work. The larger, supported by six columns resting on the backs of lions, was made in 1272 by Nicolaus of Foggia; the bust over the entrance may be a portrait of Sigilgaita Rufolo, or may symbolize the church. The smaller (*c.* 1130) has curious representations of Jonah and the whale. The parish church of S. Giovanni in Toro contains a splendid pulpit in Cosmatesque work, supported on four pillars, and the crypt some 14th-century frescoes. S. Maria Immacolata is another Romanesque church.

RAVEN, the largest bird of the order Passeres, and a member of the Corvidae. Quick-sighted, sagacious and bold, the raven preys on the spoils of fishers and hunters, also on weakly animals among flocks and herds. A sentiment of veneration or superstition has often been attached to it. Superstition has been generally succeeded by persecution, which in many districts has led to extirpation.

The raven breeds early in the year, in England resorting to its nest, which is usually an ancient structure, toward the end of January. Therein are laid from five to seven eggs of the common corvine coloration (*see* CROW), and the young are hatched before the end of February. The young have bright crimson throats. In more northern countries the breeding season is naturally delayed, but everywhere this species is almost, if not quite, the earliest breeder. The raven measures about 26 in. in length and has an expanse of wing exceeding a yard. It is entirely black, the feathers having a purple iridescence. The common raven (*Corvus corax*) inhabits the whole of Europe, northern Asia and northern America. In Africa its place is taken by allied species, one of which (*Corvus umbrinus*) has a brown neck; farther south are species whose plumage is varied with white.

RAVEN-HILL, LEONARD (1867–1942), English artist and illustrator, was born on March 10, 1867. He studied art at the Lambeth school and afterward in Paris under A. W. Bouguereau and Aimé Morot. He began to exhibit at the Salon in 1887 and at the Royal Academy in 1889. In 1893 he founded, with Arnold Golsworthy, the humorous and artistic monthly the *Butterfly* (1893–94, revived in 1899–1900). He contributed to many illustrated magazines and was with *Punch* from 1896 until his retirement in 1935. He illustrated Sir Walter Besant's *East London* (1901) and J. H. Harris's *Cornish Saints and Sinners*. His impressions of his visit to India on the occasion of the tour of the prince and princess of Wales appeared as *An Indian Sketch-Book* (1903); other published sketchbooks include *Our Battalion* (1902) and *The Promenaders* (1894). He died March 31, 1942.

RAVENNA, a city and archiepiscopal see of Emilia, Italy, capital of the province of Ravenna, in a marshy plain 13 ft. above sea level, 6 mi. from the sea and 45 mi. by rail east of Bologna. Pop. (1936): 31,251 (town); 81,086 (commune)—a considerable increase, as the population of 1881 was only 34,270 (commune). The town is a centre for agriculture, which has been much favoured by extensive drainage and reclamation works. There is also a sugar factory at Classe. The town is connected with the sea by the Corsini canal. Ravenna has railway communication with Bologna (via Castel Bolognese), Ferrara and Rimini, and by steam tram with Forlì. Though the external aspect of the town is not striking, no other in the world offers so many and such splendid examples of the ecclesiastical architecture of the centuries from the 5th to the 8th. The style is commonly called Byzantine, but the colonnades and the mosaics are not so much Byzantine as representative of early Christian art generally.

The cathedral of Ravenna, built by S. Ursus in 370–390, which had a nave and four aisles, was destroyed in 1734–44, only the (inaccessible) crypt and the round campanile remaining from the earlier structure; there are fragments of reliefs from a pulpit erected by Archbishop Agnellus (556–569) in the interior. The present cathedral contains several early Christian marble sarcophagi, a silver cross of the 11th century and the throne of the Archbishop Maximian (546–552), adorned with reliefs in ivory.

The period from the transference of the imperial residence to Ravenna to the death of Valentinian III (404–455) was the first period of great building activity in Ravenna, when the archiepiscopal see of Ravenna attained great importance. It was to it that is owed the erection of the Basilica Petriana at Classe (396–425), which has entirely disappeared, of the churches of S. Giovanni Evangelista (425), of S. Agata (425–432), of the chapel of S. Pier Crisologo (433–449), of the mausoleum of Galla Placidia (440), the church of S. Pier Maggiore (now S. Francesco) (433–458), the baptistery of Neon (449–458), S. Giovanni Battista and S. Croce.

S. Giovanni Evangelista, erected by Galla Placidia in fulfilment of a vow made on her voyage from Constantinople, has been entirely rebuilt, though the columns are ancient. The Gothic portal is fine, and the church contains a mosaic pavement of 1213 with representations of the 4th crusade and some frescoes by Giotto, painted during a visit to Dante between 1317 and 1320. S. Agata was almost entirely rebuilt in 1476–94. The chapel of S. Pier Crisologo in the archiepiscopal palace preserves its original mosaics; so also does the mausoleum of Galla Placidia (SS. Nazario e Celso), a small structure in the form of a Latin cross with a dome (in which, as in the baptistery of Neon, the old cathedral, etc., the constructional use of amphorae is noteworthy), with a plain brick exterior, and rich mosaics on a dark blue ground.

S. Francesco has been modernized, except for the crypt and campanile (10th century). The baptistery adjacent to the cathedral was either originally part of the Roman baths, converted to a Christian baptistery by the Archbishop Neon (449–452), or a Christian building dating from before A.D. 396. It is an octagon, with a dome; in the interior are two arcades one above the other. The mosaics of the 5th century, in the dome, are the earliest and perhaps the finest at Ravenna.

Of S. Giovanni Battista, also erected in this period, hardly anything remains after the restoration of 1683, and S. Croce has been overtaken by a similar fate. Honorius and Galla Placidia built a palace about A.D. 402, remains of which have been found under S. Croce.

The reign of Theodoric (493–526) marks another era of magnificence. In the eastern part of the city he built for himself a large palace. There still remains fronting the Corso Garibaldi a high wall built of square Roman bricks, with pillars and arched recesses in the upper portion, which goes by the name of Palazzo di Teodorico, but is a guardhouse erected by the exarchs, recent

explorations having made it clear that it was an addition to the palace, while mosaic pavements and a court once surrounded by colonnades and really belonging to the latter were found behind S. Apollinare Nuovo and the so-called Palazzo at a lower level and a different orientation. (*See* Ghirardini in *Monumenti dei Lincei*, xxiv, 737–838.) A mosaic in the church of S. Apollinare Nuovo gives some faint idea of the palace. The massive mausoleum of Theodoric stands still perfect outside the walls near the northeast corner of the city. It is circular internally and decagonal externally, in two stories, built of marble blocks, and surmounted by an enormous monolith, brought from the quarries of Istria and weighing more than 300 tons. It has been converted into a church dedicated to the Virgin.

S. Apollinare Nuovo, the most important basilica in the town, was built by Theodoric to be the largest of Arian churches. The exterior is uninteresting, and the church lost both atrium and apse in the 16th century. The interior has 24 columns of marble, with almost uniform capitals. The walls of the nave are adorned with mosaics of the 6th century; the scenes from the New Testament above the windows date from the time of Theodoric.

The campanile (850–878) is circular and has perhaps the earliest example of the use of disks of coloured majolica as a decoration. This, like the other campanili of Ravenna, is later than the church to which it belongs. Those of the cathedral of S. Apollinare in Classe, S. Maria Maggiore and S. Agata, also circular, probably belong also to the 9th century, while the two square campanili of S. Giovanni Evangelista and S. Francesco probably belong to the 10th century. The other churches erected by Theodoric are: S. Teodoro (or S. Spirito), erected by Theodoric for the Arian bishops, but entirely modified; the baptistery of this church (afterward the oratory of S. Maria in Cosmedin), formed out of the octagonal hall of a Roman bath, with mosaics of the 6th century; S. Maria Maggiore, founded by the Archbishop Ecclesius (521–534), but almost entirely rebuilt; and S. Vittore, which has suffered a similar fate. To the same period probably belong a few columns of the so-called Basilica of Heracles in the Piazza Vittorio Emanuele, with capitals like those of S. Apollinare in Classe.

The impulse given by Theodoric was continued by his successors, and during the regency of Amalasuntha and the reigns of Theodatus and Vitiges (526–539), S. Vitale and S. Apollinare in Classe were constructed by Julius Argentarius contemporaneously with S. Lorenzo in Milan and the cathedral of Parenzo—also S. Michele in Africisco, little of the original structure of which now exists; the apse mosaic is in the Berlin museum. The former, well restored by Ricci (except for the dome with its baroque frescoes which has not been altered), is a regular octagon, with a vestibule, originally flanked by two towers on the west, a choir added on the east, triangular outside and circular within; it is surrounded within by two galleries interrupted at the presbytery, and supported by eight large pillars, the intervals between which are occupied by open exedrae. The mosaics of the choir (547) are due to Justinian, and, though inferior in style, are remarkable for their splendour of colouring and the gorgeous dresses of the persons represented, and also for their historical interest, especially the scenes representing the emperor and the empress Theodora presenting offerings. The marble screens of the altar are wonderfully finely carved. The marble mosaic pavement (11th century) is very effective. Remains of the original marble wall lining and stucco decoration also exist.

The architecture of S. Vitale, according to Rivoira, was inspired not by Byzantium, where similar churches—S. Sofia and SS. Sergio and Bacco—are slightly later in date, but by the churches of Salonica (A.D. 495), while the plan is derived from a Christian baptistery, or from such a building as the so-called temple of Minerva Medica at Rome.

It has been ascertained that a 5th century building already occupied the site.

S. Apollinare in Classe, erected at the same time outside the walls of Classis, and now standing by itself in the lonely marshes, is the largest basilica existing at Ravenna. It has a nave and aisles with a closed vestibule on the west, and a fine round campanile of the 9th (?) century. The exterior brick walls are divided by shallow arches and pilasters, as in other churches of Ravenna. It has 24 columns of Carystian (cipollino) marble, with capitals probably of Byzantine work with swelling acanthus leaves; but the rest of the church is the work of native architects. The lofty presbytery and the crypt under it belong to the 12th century. The walls of the interior were stripped of their marble panelling by Sigismondo Malatesta in 1449, for the adornment of his church at Rimini. The apse has mosaics of the 6th and 7th centuries. The 18th-century series of portraits of the archbishops of Ravenna is no doubt copied from an earlier original. There are a number of fine carved sarcophagi in the church (5th to 8th century). The building activity of the Gothic kings was continued by Justinian, to whose time we owe the completion of S. Vitale and S. Apollinare in Classe, and some of the mosaics in S. Apollinare Nuovo.

The buildings of a subsequent period are of minor importance, but the Basilica of S. Maria in Portofuori near the ancient harbour (1096 *seqq.*), a basilica with open roof, with frescoes by masters of the Rimini school, may be noticed. The campanile dates from 1173–87. The tomb of Dante, who died at Ravenna in 1321, is close to S. Francesco; it is a square domed structure, with a relief by Pietro Lombardo (1483) representing the poet, and a sarcophagus below, in an urn within which lie the poet's remains. Close by is a small court with early Christian sarcophagi, containing the remains of the Braccioforte family. The important museum near S. Vitale has Roman and Byzantine antiquities, inscriptions, sculptures, jewelry, etc. The library has rare manuscripts (including the best extant manuscript of Aristophanes) and incunabula. The Accademia has pictures by local masters.

In the Piazza Vittorio Emanuele are two granite columns erected by the Venetians in 1483. The cloisters of S. Maria di Porto, erected in the town in the 16th century (because of malaria, as in the case of those of Classe), and of S. Vitale are pleasing 16th-century structures. The 15th-century castle in the northeast corner of the town erected by the Venetians is a picturesque brick building. The walls, 3 mi. long, which still surround the town, were also built by them.

History.—Strabo mentions a tradition that Ravenna was founded by Thessalians, who afterward called in the Umbrians and left the city to them. About 191 B.C., by the conquest of the Boii, the whole of this region passed definitely under the dominion of Rome. Under Augustus it rose into importance, when it was made the station for the fleet on "the upper sea." Two hundred and fifty ships could ride at anchor in its harbour. At the same time Augustus conducted a branch of the Po (the fossa Augusta) through the city into the sea. It also became important for the export of timber from the Alps. Strabo gives a description which corresponds closely with modern Venice.

On the other hand, good water was proverbially difficult to obtain at Ravenna—dearer than wine, says Martial. Trajan, however, built an aqueduct nearly 20 mi. long, which was restored by Theodoric in 503. Of this some traces still exist in the bed of the Ronco above Ravenna. Flies and frogs were also complained of, and Sidonius, writing in the 5th century, complains bitterly of the "feculent gruel" (*cloacalis puls*) which filled the canals of the city and gave forth fetid odours when stirred by the poles of the bargemen. The port of Ravenna, situated about three miles from the city, was named Classis. A long line of houses called Caesarea connected it with Ravenna, and in process of time there was such a continuous series of buildings that the three towns seemed like one. It had large gilds of *fabri* (smiths and carpenters) and *centonarii* (firemen).

A prehistoric station was found in 1894 at S. Zaccaria near Ravenna, belonging to a Terramare. Of Roman Ravenna nothing remains above ground. It was connected with Ariminum, 33 mi. to the south, by the coast road, the Via Popilia, which ran on north to Hatria, and joined the road between Patavium and Altinum at Ad Portum.

Early in the 5th century, Honorius, alarmed by the progress of Alaric in the north of Italy, transferred his court there. From

this date (404) to the fall of the Western Empire in 476 Ravenna was the chief residence of the Roman emperors. There Stilicho was slain; there Honorius and his sister Placidia caressed and quarrelled; there Valentinian III spent the greater part of his life; there Majorian was proclaimed; there the little Romulus donned his purple robe; there in the pinewoods outside the city his uncle Paulus received his decisive defeat from Odoacer. The great pinewoods to the east of the city, which is still one of the great glories of Ravenna, must therefore have been in existence in the 5th century. Odoacer made Ravenna his chief residence. Theodoric's siege of Ravenna lasted for three years (489–492); ten days after his entry into the city he slew his rival at a banquet in the palace of the Laurel Grove (March 15, 493). Ravenna was also Theodoric's chief residence (493–526).

In 535 Justinian sent an army to destroy the Gothic monarchy and restore Italy to the empire. The Goths at length, weary of the feebleness of Vitiges, offered to transfer their allegiance to Belisarius on condition of his assuming the diadem of the Western Empire. Belisarius dallied with the proposal until he had obtained an entrance within the walls of the capital, and proclaimed his inviolable fidelity to Justinian (539). Under the rule of Narses and his successors, the exarchs, Ravenna was the seat of Byzantine dominion in Italy. In 728 the Lombard king Luitprand took and destroyed the suburb Classis; about 752 the city itself fell into the hands of his successor, Aistulf, from whom a few years later it was wrested by Pippin, king of the Franks.

It formed part of the Frankish king's donation to the pope in the middle of the 8th century, though the archbishops, as a fact, retained almost independent power. It was an independent republic, generally taking the Guelph side in the 13th century, subject to rulers of the house of Polentani in the 14th, Venetian in the 15th (1441) and papal again in the 16th. St. Romuald and St. Peter Damian were both natives of Ravenna. From this time (1509) down to 1860, except for the interruptions caused by the wars of the French Revolution, Ravenna continued subject to the papal see and was governed by a cardinal legate. In 1849 Garibaldi's wife, Anita, who had accompanied him on his retreat from Rome, succumbed to fatigue in the marshes near Ravenna.

Charles the Great carried off the brazen statue of Theodoric and the marble columns of his palace to his own palace at Aix-la-Chapelle. Lord Byron resided at Ravenna for 18 months in 1820–21, attracted by the charms of the Countess Guiccioli.

BIBLIOGRAPHY.—The most important authority for the history of Ravenna is Bishop Agnellus, who wrote, about 840, the *Liber Pontificalis Ecclesiae Ravennatis*. The best edition is that by Holder-Egger in the *Monumenta Germaniae Historica* (1878). *See* G. T. Rivoira, *Lombardic Architecture* (London, 1910); C. Ricci, *Ravenna* (Bergamo, 1902), *Ravenna* (London, 1913); E. Hutton, *The Story of Ravenna* (London, 1926). To the careful restorations of Ricci the buildings of Ravenna owe much. (T. H.; T. A.)

BATTLE OF 1512

This battle, one of the principal events of the long Italian wars of Charles VIII, Louis XII and Francis I of France, is, like Marignan (*q.v.*), interesting in a tactical sense, from the fact that the feudalism of the past and the expert soldiership of the future were strangely mingled. It arose out of the attempt of the Spanish and Italian forces to relieve Ravenna, besieged by Gaston de Foix, duke of Nemours. The most celebrated captains of these wars were present on either side—under Gaston de Foix were Bayard, Yves d'Allègre, La Palisse; and under Cardona, the Spanish viceroy of Naples, Pedro Navarro, the great engineer, and Pescara, the originator of the Spanish tactical system. After some preliminary manoeuvres the two armies drew up face to face on the left bank of the Roneo, the Spanish left and the French right resting on this river. The Spaniards were entrenched, with their heavy artillery distributed along the front, but, thanks to Navarro, they had a more mobile artillery in the shape of 200 *arquebuses à croc* mounted in groups upon carts, after the German fashion. The battle opened with a prolonged cannonade from the Spanish lines. For three hours the professional regiments of all sorts in the French lines rivalled one another in enduring the fire unmoved, the forerunners of the military systems of to-day, landsknechts, Picardie and Piedmont, showing the feudal gendarmerie that they too were men of honour. There was no lying down. The captains placed themselves in the front, and in the centre 38 out of 40 of them were struck down. Molart and Empser, drinking each other's health in the midst of the cannonade, were killed by the same shot. Sheltered behind the entrenchments, the Spaniards scarcely suffered, for they were lithe active troops accustomed to lie down and spring up from the ground. But after three hours, Pescara's light horse having meantime been driven in by the superior light horse of the enemy, the artillery-loving duke of Ferrara conceived the brilliant plan of taking his mobile field guns to the extreme right of the enemy. This he did, and so came in sight of the prone masses of the Spaniards. Disciplined troops as they were, they resisted the temptation to escape Ferrara's fire by breaking out to the front; but the whole Spanish line was *enfiladed*, and on the left of it the papal troops, who were by no means of the same quality, filled up the ditch in front of their breastworks and charged forward, followed by all the gendarmerie. Once in the plain they were charged by the French gendarmes under Gaston himself, as well as by the landsknechts, and driven back. The advantage of position being thus lost, the Spanish infantry rose and flung itself on the attackers; the landsknechts and the French bands were disordered by the fury of the counterstroke, being unaccustomed to deal with the swift, leaping and crouching attack of swordsmen with bucklers. But La Palisse's reserve wheeled in upon the rear of the Spaniards, and they retreated to the entrenchments as fast as they had advanced. The papal infantry, the gendarmes and the light horse had already vanished from the field in disorder; but the Spanish regulars were of different mettle, and it was only after a long struggle that the landsknechts and the French bands broke into the trenches. The conflict continued, but at last La Palisse, with all the gendarmerie still in hand, rode completely around the entrenchments and charged the Spaniards' rear again. This was the end, but the remnant of the Spanish infantry retreated in order along the river causeway, keeping the pursuers at bay with their arquebuses. Gaston de Foix, recklessly charging into the midst of them, was killed.

RAVENNA, a city of northeastern Ohio, U.S., 33 mi. S.E. of Cleveland; the county seat of Portage county. It is served by the Baltimore and Ohio, the Erie and the Pennsylvania. Pop. (1950) 9,857. It has manufactures of structural steel, iron castings, rubber goods, power shovels and cranes, textiles and baby nursing units. It is the site of the Ravenna Ordnance plant. Ravenna was founded in 1852 and incorporated as a city in 1912.

RAVENNA, EXARCHATE OF, the official name of that part of Italy which remained in the allegiance of the Roman emperors at Constantinople from the closing years of the 6th to the middle of the 8th century. The civil and military head of these possessions, the exarch (*q.v.*), was stationed at Ravenna. The territory around the town, from the southern border of the modern Venetia to the beginning of the Pentapolis at Rimini, was under his direct administration and formed in a limited sense the exarchate. The other provinces were governed by dukes and *magistri militum*, titles which were generally, but not always, borne by the same person. But as all were subject to his authority, they were included in the exarchate of Ravenna, which was therefore another name for the province of Italy. Sicily formed a separate government. Corsica and Sardinia belonged to the exarchate of Africa. The organization of the exarchate is placed by modern investigators under the reign of Emperor Maurice (582–602), when the imperial government was confronted by the new problems created by the settlement of the Lombards (*q.v.*). At the end of the 6th century it included Istria; the maritime part of Venetia as distinct from the interior which was in the hands of the Lombard kings at Pavia; the exarchate proper, or territory around Ravenna on the eastern side of the Apennines, to which was added Calabria, which at that period meant the southeast and not the southwest of Italy; the Pentapolis, or coast from Rimini to Ancona with the interior as far as the mountains; the duchy of Rome, or belt of territory connecting the Pentapolis with the western coast, the coast of Naples, with Bruttium, the modern

Calabria, and Liguria, or the Riviera of Genoa. Piedmont, Lombardy, the mainland of Venetia, Tuscany and the interior of Naples belonged to the Lombards. The superior organization of the imperial government enabled it to regain lost territory and delay complete ruin. In 590 it recovered much of Venetia, but these revivals were not permanent. In 640 the Ligurian seacoast fell under the power of the Lombards. About a century later the exarchate had been greatly reduced, though the imperial officials endeavoured to conceal the fact by retaining and transferring names when the reality of possession was lost. About 740 it consisted of Istria, Venetia, Ferrara, Ravenna (the exarchate in the limited sense), Pentapolis, Perusia, Rome, the coast of Naples and the southwest of Italy, which was being overrun by the Lombards of the duchy of Beneventum, which with Spoletum held the interior. In Rome the pope was the real master. These fragments of the "province of Italy" were almost all lost either to the Lombards, who finally conquered Ravenna itself about 750, or by the virtual independence of the papacy. Subsequent Frankish intervention (*see* ITALY) made a revival of the exarchate impossible. It disappeared, and the small remnants of the imperial possessions on the mainland, Naples and Calabria, passed under the authority of the "patricius" of Sicily, and when Sicily was conquered by the Arabs in the 10th century were erected into the themes of Calabria and Langobardia. Istria was attached to Dalmatia.

In its internal history the exarchate was subject to the influences which were everywhere, in central and western Europe at least, leading to the establishment of feudalism. The great imperial officials gradually became landowners, and conversely the great landowners intruded on the imperial administration. The local militias, organized under imperial authority for defense against the Lombards, tended to become independent. These bodies formed the *exercitus romanae militiae,* who were the forerunners of the free armed burghers of the Italian cities of the middle ages.

See C. Diehl, *Études sur l'administration byzantine dans l'exarchat de Ravenne (568–751)* (1888).

RAVENSBURG, a town in the state of Württemberg, Germany, on the Schussen, 12 mi. N. of Friedrichshafen on the lake of Constance. Pop. (1939): 32,257. Ravensburg was founded in the 11th century by the Guelphs, and in their castle on the Veitsburg, Henry the Lion was born. In 1180 the town passed to the Hohenstaufens, and a century later it became a free town of the empire. It was ceded to Württemberg in 1810. It retains its walls and nine towers and its 15th century town hall.

RAVENSCROFT, THOMAS (*c.* 1590–*c.* 1633), English composer and musical editor, received his B.Mus. at Cambridge in 1607, and from 1618–22 was music master at Christ's hospital. He is best known by his *The Whole Booke of Psalmes* (1621), 48 of the harmonizings being his own. His other works, the first three of which show his appreciation of popular and humorous poems, are *Pammelia,* a collection of 100 rounds and catches (1609); *Deuteromelia,* a collection of 31 items, including "Three Blind Mice" (1609); *Melismata,* a collection of 21 items, chiefly short madrigals (1611); and *A Briefe Discourse of the True (but Neglected) use of Charact'ring the Degrees, by their Perfection, Imperfection and Diminution in Measurable Musicke, etc.* (1621).

RAVI, a river of Pakistan, one of the "Five Rivers" of the Punjab. It rises in the Kulu subdivision of Kangra district, flows through Chamba state and enters Gurdaspur district. Thence it flows through the plains of the Punjab, passing within a mile of Lahore, and finally falls into the Chenab after a course of about 450 mi. Its water is utilized for the Upper and Lower Bari Doab canals, with headworks at Madhupur, and the Sidhrai canal. The Upper Bari Doab canal irrigates about 1,177,000 ac., and the Lower Bari Doab canal (opened 1913) about 345,000 ac. The Upper Chenab canal enters the Ravi at Balloki, where the Lower Bari Doab canal has its headworks on the opposite bank, thus providing a level crossing of the Ravi. The Sidhrai canal, which starts a few miles above the Chenab junction, is frequently dry in winter, but the Haveli project, including a dam on the Chenab with a canal delivering water into the Ravi above the Sidhrai weir, will ensure a perennial supply when completed.

RAWALPINDI, a town of Pakistan, which gives its name to a district and a division in the Punjab. The town is situated on the north bank of the little river Leh, 1,726 ft. above the sea, 111 mi. E. by S. of Peshawar, and 1,443 mi. N.W. of Calcutta. Pop. (1941) 181,169. It was chiefly notable as the largest military station in India and the key to the British system of defense upon the North-West Frontier. It is the starting point of the cart road to the hill station of Murree and of the route into Kashmir. It was the headquarters of the northern army with a strong force of all arms, and contained an arsenal. Besides the locomotive works of the North-Western railway, there are gas-works, a tent factory, an iron foundry, an oil refinery and a brewery. An annual horse fair is held in April.

The DISTRICT OF RAWALPINDI has an area of 2,022 sq.mi. It contains the Murree hills. The district is traversed by the main line of the North-Western railway, crossing the Indus at Attock, and also by a branch toward the Indus at Kushalgarh. The population in 1941 was 785,231.

RĀWANDIS, a Persian sect (from Rāwand, a town near Isfahan). Its origin is unknown, but its members held ultra-Shiah doctrines (*see* ISLAM). They maintained that the spirit that was in Jesus was in ʿAlī, then in the imāms one after the other to Ibrahīm ibn Muhammad, and that thus these were divine. They believed in metempsychosis, or the transmigration of souls, and asserted that the Lord who fed them and gave them drink was Manṣūr. In 759 they came to the palace of Manṣūr in Hashimīya and began to hail him as Lord. The Caliph, however, secured their chiefs and threw them into prison.

See E. G. Browne, *Literary History of Persia* (1902).

RAWLINS, a city of southern Wyoming, U.S., 6,755 ft. above sea level, on federal highways 30 and 287 and the main line of the Union Pacific railroad; the county seat of Carbon county. The population in 1950 was 7,385; in 1940 it was 5,531 by federal census.

It is an important shipping point for livestock; a division point on the railroad, which maintains extensive shops and roundhouses there; and a centre of oil refining and producing, coal mining and agriculture.

RAWLINSON, SIR HENRY CRESWICKE (1810–1895), English soldier and orientalist, was born at Chadlington, Oxfordshire, on April 11, 1810. In 1827 he went to India as cadet under the East India company; and after six years as a subaltern he was sent to Persia in company with other English officers to reorganize the Shah's troops. He became interested in the hitherto undeciphered cuneiform character. In two years he transcribed as much as he was able of the great cuneiform inscription at Behistun (*q.v.*); but the friction between the Persian court and the British government ended in the departure of the British officers. He became political agent at Kandahar in 1840. Then, at his own desire, he was sent as political agent to Turkish Arabia; thus he was enabled to settle in Baghdad, where he devoted much time to his cuneiform studies. He was now able to make a complete transcript of the Behistun inscription, which he deciphered and interpreted.

During two years' leave in England (1849–51) he prepared a memoir on the Behistun inscription. He disposed of his valuable collection of Babylonian, Sabaean and Sassanian antiquities to the trustees of the British museum, who made him a grant to enable him to carry on the Assyrian and Babylonian excavations initiated by Layard. In 1851 he returned to Baghdad. In 1855 he resigned his post in the East India company and he received the K.C.B. and crown directorship of the East India company. The remaining 40 years of his life were mainly spent in London. In 1858 he was appointed a member of the first India council, but resigned in 1859 on being sent to Persia as envoy extraordinary and minister plenipotentiary. The latter post he held only for a year. Rawlinson rejoined the Council of India in 1868, and continued to serve upon it until his death. He was a strong advocate of the forward policy in Afghanistan. He died in London on March 5, 1895.

His published works include four volumes of cuneiform inscriptions, published under his direction between 1870 and 1884 by the trustees

of the British museum; *The Persian Cuneiform Inscription at Behistun* (1846–51) and *Outline of the History of Assyria* (1852), both reprinted from the Asiatic Society's journals; *A Commentary on the Cuneiform Inscriptions of Babylon and Assyria* (1850); *Notes on the Early History of Babylonia* (1854); *England and Russia in the East* (1875). He contributed to the *Encyclopædia Britannica* (9th ed.) the articles BAGHDAD; EUPHRATES; KURDISTAN; and several other articles dealing with the east; and assisted in editing a translation of Herodotus by his brother, Canon George Rawlinson (1812–1902).

See G. Rawlinson, *Memoir of Henry Creswicke Rawlinson* (1898).

RAWLINSON, HENRY SEYMOUR RAWLINSON, 1ST BARON (1864–1925), British soldier, was born on Feb. 20, 1864, son of Maj. Gen. Sir Henry Rawlinson, Bart. He joined the army in 1884 and a year later became aide-de-camp to Sir Frederick Roberts in India on whose staff he served intermittently for some years. He took part in the Burma operations in 1886–87 and on the Nile in 1898; he had succeeded to the baronetcy in 1891. He served throughout the South African War (1899–1902). Some months after his return to England he became commandant of the staff college and from 1910 to May 1914 commanded the 3rd division. Gen. Rawlinson was in charge of the forces sent to assist Antwerp in 1914, and took part in the first battles of Ypres and in the Neuve Chapelle and the Loos offensives. He commanded the 4th army during the battle of the Somme (1916), achieving important successes. At the end of 1917 he was transferred temporarily to the command of the 2nd army during Gen. Plumer's absence in Italy, and in February and March 1918 he acted for some weeks as British representative on the Supreme War council. Resuming his command of the 4th army in April, his troops on Aug. 8, in conjunction with the French, attacked the enemy near Amiens and gained a signal victory, which heralded the general advance of the Allies. After World War I he was raised to the peerage as Baron Rawlinson of Trent and received a grant of £30,000. In the latter part of 1919 he was sent to north Russia to conduct the withdrawal of the Allies from Archangel and Murmansk, and on his return he commanded at Aldershot for a year. At the end of 1920 he went to India as commander in chief. He died at Delhi on March 28, 1925.

See Sir F. Maurice, *Life of General Lord Rawlinson of Trent, from his Journals and Letters* (1928).

RAWMARSH, an urban district in the West Riding of Yorkshire, England, 7½ mi. N.E. of Sheffield on the L.M.S. and L.N.E. railways. Pop. (1938) 18,210. Area 4.1 sq.mi. It is 1½ mi. from the river Don, and is almost continuous with Rotherham. Rawmarsh has large iron-works, steel rolling-mills, and potteries.

RAW MATERIALS: *see* PHYSICAL RESOURCES.

RAWTENSTALL, municipal borough in the parliamentary borough of Rossendale, Lancashire, England, 18 mi. north from Manchester by the L.M.S.R. Pop. (1938): 27,070. Area: 14.9 sq.mi. Rawtenstall, which was incorporated in 1891, manufactures cotton and woollen goods and shoes.

RAY (or WRAY, as he wrote his name till 1670), **JOHN** (1627–1705), sometimes called the father of English natural history, was the son of a blacksmith of Black Notley, Essex, where he was born on Nov. 29, 1627. Educated at Catherine Hall and Trinity college, Cambridge, Ray became a fellow of Trinity college in 1649. He held many college offices.

His first botanical tour was undertaken in 1658, and on being compelled to give up his fellowship (1662), because he could not subscribe to the Act of Uniformity, Ray toured through Europe in 1663 with Francis Willughby (*q.v.*). From this tour Ray and Willughby returned with collections, on which they meant to base complete systematic descriptions of the animal and vegetable kingdoms. Willughby undertook the former part, but, dying in 1672, left only an ornithology and ichthyology, for Ray to edit; while the latter used the botanical collections for the groundwork of his *Methodus plantarum nova* (1682), and his great *Historia plantarum* (3 vol., 1686, 1688, 1704). The plants gathered on his British tours had already been described in his *Catalogus plantarum Angliae* (1670, 1677), which work is the basis of all later English floras. He published an account of his foreign travel in 1673, entitled *Observations topographical, moral, and physiological, made in a Journey through part of the Low Countries, Germany, Italy, and France.*

Ray's work shows signs of indebtedness to Joachim Jung of Hamburg and others. In his early work he classified his plants alphabetically but later he used the number of cotyledons as the basis of his classification. Ray also classified according to the fruit but eventually he used the flower for purposes of classification. He distinguished several natural groups such as the grasses, Labiatae, Umbelliferae and Papilionaceae. He was involved in a controversy with Rivinus upon Ray's indefensible separation of ligneous and herbaceous plants. In conjunction with Willughby, Ray wrote a paper on his experiments on the motion of sap in trees. In 1667 Ray was elected F.R.S. He died on Jan. 17, 1705. The Ray society, for the publication of works on natural history, was founded in his honour in 1844.

Ray was also the author of *Catalogus plantarum circa Cantabrigiam* (1660, appendixes in 1663 and 1685), written with John Nid; *Synopsis stirpium Britannicarum* (1690, etc.); *Stirpium Europaearum extra Britannias nascentium Sylloge* (1694); *Synopsis methodica Animalium Quadrupedum et Serpentini Generis* (1693); *Synopsis methodica Avium et Piscium* (1713); and *Historia Insectorum* (1710).

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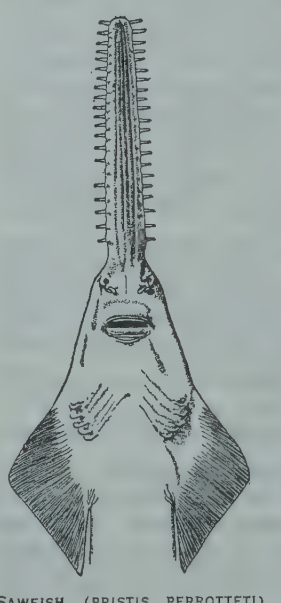
RAY, the name given to the short-snouted fish of the genus *Raia,* the skates and rays, and in a more general sense used for all the Selachians (*q.v.*) of the order Hypotremi, which are distinguished from sharks by their depressed form and by the large pectoral fins, produced forwards and attached to the sides of the head above the gill-openings, which are ventral in position. Generally the nostrils and the transverse mouth are placed on the flat under surface of the head. On the upper surface of the head, behind the eyes, are large holes leading to the pharynx; these are termed spiracles and serve for the intake of water for respiration. Rays are fitted, by their structure, for life at the bottom of the sea; most are viviparous, but the Raiidae have eggs enclosed in oblong horny cases similar to those of dogfishes.



SAWFISH (PRISTIS PERROTTETI). THE SAW MAY REACH A LENGTH OF SIX FEET AND IS A FORMIDABLE WEAPON

The Torpedinidae, or electric rays, form an isolated family, distinguished by possessing large paired electric organs, formed of vertical hexagonal columns, placed between the pectoral fins and the head, and capable of giving powerful shocks, either for defensive purposes or to kill prey. The electric rays have a smooth and naked skin; the head and trunk, with the pectoral fins, form a circular disc; the tail is short and stout.

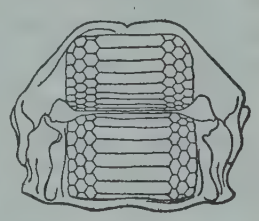
About 20 species are known from warm seas, some reaching a weight of 200 lb.; one or two species of *Torpedo* occur in British waters.

The other rays, without electric organs, generally have a rough skin, often bearing strong spines. The most sharklike are the Rhinobatidae, of which about 20 species are known, from tropical and subtropical seas; in most of them the pectoral fins are relatively small, and the trunk passes gradually into the tail. The sawfishes, or sawrays (*Pristis*), differ from them in that the snout is produced into a long blade armed with a series of strong teeth on each side; five species are known from warm seas, frequenting

sandy shores and estuaries. Some attain a length of 20 ft.; such large specimens are dangerous, the saw being a formidable weapon.

In the Raiidae the large pectoral fins extend to the snout, and form a disc distinct from the slender tail. Numerous species of the cosmopolitan genus *Raia* are known, some living at considerable depths; some species reach a weight of 500 lb. These rays swim by undulating or flapping movements of the pectoral fins; their teeth are small, and blunt in some species, pointed in others; their food consists of molluscs, crustaceans and fishes. One of the largest British species is the common skate (*R. batis*), with long, pointed snout and grayish belly; the commonest ray in British waters is the thornback (*R. clavata*). Numbers of skates and rays are trawled; the pectoral fins are cut off and used as food.

The remaining rays are collectively termed "whip-tailed," the tail being long and slender and bearing a strong barbed spine connected with a poison gland; this spine is capable of inflicting noxious wounds, and is a dangerous weapon when the tail is lashed. All the whip-tailed rays are inhabitants of warm seas, except a few kinds of sting ray in the rivers of South America. In the sting rays (*Trygon*, etc.), as in most of the rays previously described, the teeth are numerous, small and blunt, but in the eagle rays (*Myliobatis*), they are relatively few in number, hexagonal, forming a flat pavement, and in the spotted eagle rays (*Aetobatus*) are reduced to a single series of broad flat teeth, used by these large rays to crush the shells of oysters and other molluscs. Largest of all the rays are the devilfishes, *Manta* and *Mobula*, which may measure 20 ft. across the disc. These rays are peculiar in that the anterior ends of the pectoral fins are free, projecting forward, when rolled up looking like a pair of horns, but when unrolled meeting below the mouth to form a scoop; a party of these devilfishes has been observed in a shallow bay pursuing the shoals of small fishes and scooping them into their mouths. (*See* SELACHIANS; SHARK.) (C. T. R.)



JAWS OF AN EAGLE RAY. THE PAVEMENT-LIKE TEETH ARE USED FOR CRUSHING SHELLS

RAYAH, the name given to the subjects of a Mohammedan ruler; in later usage, to all who pay the poll tax levied on unbelievers (Arabic *ra'iyah*, "flock").

Five classes of rayahs existed under Turkish rule until the system was destroyed by the revolution following World War I. These were: (1) the Greek, or *Roum milleti;* (2) the Armenian, or *Ermeni milleti;* (3) the Catholic Armenians, or *Ermeni gatoliki milleti;* (4) the Latin Christians, or *Roum gatoliki milleti;* and (5) the Jews, or *Yahoudi milleti.*

The name rayah was most commonly used of the peasants, but did not apply only to the agricultural populations.

The same term ("ryot") was applied in India to peasants or landholding tenants.

RAYLEIGH, JOHN WILLIAM STRUTT, 3RD BARON (1842–1919), English physicist, was born in Essex on Nov. 12, 1842, and educated at Trinity college, Cambridge. He succeeded to his father's title in 1873. From 1879 to 1884 he was Cavendish professor of experimental physics in the University of Cambridge, and from 1887 to 1905, professor of natural philosophy at the Royal Institution of Great Britain. In 1896 he became scientific adviser to Trinity House, and in 1901 chief gas examiner. His early papers were mainly mathematical, including two on electromagnetic phenomena considered in connection with dynamical theory, and one on the stationary thermal conditions of a sphere exposed to radiation from distant sources. His paper on resonance was the first of a series of memoirs which culminated in his standard work, *A Treatise on Sound.* Other papers on sound dealt with the vibrations of a gas contained in a rigid spherical envelope, disturbances produced in sound waves by a spherical obstacle, general theorems relating to vibrations, absolute pitch and the resultant of a large number of vibrations of the same pitch and of arbitrary phase. He carried out experiments on the amplitude of the sound wave near the limit of audibility and on the direction of sound. Rayleigh also carried out investigations in optics and experiments in colour vision. He wrote on polarization, the scattering of light by particles, and the colour of the sky. Great experimental skill was shown in his reproductions of gratings by photographic methods. A series of four papers entitled "Investigations in Optics, with special reference to the Spectroscope," were published in the *Philosophical Magazine* in 1879 and 1880. These dealt with the general question of the resolving power of optical instruments. Later he dealt more particularly with the microscope. His contributions to hydrodynamics were important; he dealt with problems connected with the propagation of waves, showing how the wave velocity depends on the period. He applied this to the case of deep-sea water waves and showed the part played by waves in earthquakes.

Rayleigh's experiments on the instability of water jets led him to work on surface tension. While at the Cavendish laboratory he carried out his determination of the ohm. Rayleigh also worked out a formula for the distribution of energy in black-body radiation which holds for long wave lengths. His interest in Prout's hypothesis as to atomic weights led him to a series of experiments to determine the densities of gases. While working on nitrogen Rayleigh made observations which led to the discovery of argon. Sir William Ramsay co-operated with him in the latter stages of the work. Lord Rayleigh had an interest in abnormal psychological investigations, and became a member and vice-president of the Society for Psychical Research. He was one of the original members of the Order of Merit, instituted in connection with the coronation of King Edward VII. In 1904 he was awarded a Nobel prize, and at the end of 1905 he became president of the Royal Society, of which he had been elected a fellow in 1873, and had acted as secretary from 1885 to 1896. He remained president till 1908, in which year he succeeded the 8th duke of Devonshire as chancellor of Cambridge university. In 1909 the prime minister, Herbert Henry Asquith, set up a committee of aeronautics, of which Rayleigh was president. Rayleigh was the recipient of many academic and other honours. He died at Witham, Essex, on June 30, 1919.

Rayleigh's papers are collected in four volumes. An account of his life, by his son, was published in 1924. *See* obituary notice by Sir A. Schuster in *Proceedings of the Royal Society*, vol. 98 (1921).

RAYMOND, HENRY JARVIS (1820–1869), U.S. journalist, was born near the village of Lima, Livingston county, N.Y., Jan. 24, 1820. He graduated from the University of Vermont, Burlington, in 1840. After teaching, acting as correspondent for various papers, assisting Horace Greeley (*q.v.*) on the *New Yorker* and the *Tribune*, and serving on the *Courier and Enquirer*, Raymond obtained backing for a venture of his own, and the first issue of the *New York Times* appeared Sept. 18, 1851. Of this journal Raymond was editor and chief proprietor until his death. Raymond was a member of the New York assembly in 1850 and speaker in 1851 and again in 1862. He supported the views of the radical antislavery wing of the Whig party in the north. His nomination over Greeley on the Whig ticket for lieutenant governor and his election in 1854 led to the dissolution of the famous political "firm" of Seward, Weed and Greeley. He took a prominent part in the formation of the Republican party, and drafted the famous "Address to the People" adopted by the Republican convention which met in Pittsburgh, Pa., in Feb. 1856. He was a member of the national house of representatives in 1865–67. He retired from public life in 1867 and devoted his time to newspaper work until his death in New York city, June 18, 1869. Raymond was an able and polished public speaker, but his great work was in elevating the style and general tone of American journalism. He published several books, including a biography of Pres. Abraham Lincoln, which in substance originally appeared as *A History of the Administration of President Lincoln* (1864), and which with additions has been republished under varying titles.

See Augustus Maverick, *Henry J. Raymond and the New York Press for Thirty Years* (1870), which includes in the appendix an autobiographical fragment, various addresses by Raymond, etc., and "Extracts from the Journal of Henry J. Raymond," ed. by his son, Henry H. Raymond, in *Scribner's Monthly* (1879–80).

RAYMOND, a city of Pacific county, Wash., U.S., on Willapa harbour, at the mouth of the Willapa river, 15 mi. from the ocean and about 30 mi. N. of the estuary of the Columbia river. It is on federal highway 101, and is served by the Chicago, Milwaukee, St. Paul and Pacific and the Northern Pacific railways and by steamship lines.

The population was 4,110 in 1950, 4,045 in 1940 and 3,828 in 1930 by the federal census. Shipments from the harbour consist largely of lumber.

RAYMUND (1099–1149), prince of Antioch, called RAYMUND OF POITOU, was the son of William VII, count of Poitiers (William IX of Aquitaine), and Philippa of Toulouse. On the death of Bohemund II of Antioch, the principality devolved upon his daughter, Constance, a child of less than ten years of age (1130). Fulk, king of Jerusalem and, as such, guardian of Antioch, sent envoys to England to offer her hand to Raymund, who was then at the court of Henry I. Raymund reached Antioch in 1135, where he was married to Constance. As prince of Antioch he faced no easy task. Alice, the mother of Constance, who had expected Raymund to marry her, was hostile to him. The atabeg Zengi, now firmly established in both Mosul and Aleppo, was beginning to extend his possessions at the expense of Antioch, while the eastern emperor, John II Comnenus, was preparing to enforce his claims to suzerainty over the city. In 1137 Raymund was forced to do homage to the emperor, and even to promise to cede his principality as soon as he was recompensed by a new fief, which John promised to carve for him in the Mohammedan territory to the east of Antioch. The expedition of 1138, in which Raymund joined with John and which was to conquer this territory, failed. The emperor made a solemn entry into Antioch, but the city was never handed over to him, and at his death in 1143 he still did not control the principality. Zengi's conquest of Edessa in 1144 and the subsequent collapse of that Frankish county further weakened Raymund's position. He was forced to visit Constantinople and to renew his oath of homage to Manuel I Comnenus. In 1149 he fell in battle against Nureddin, Zengi's successor.

See C. Cahen, *La Syrie du Nord à l'époque des croisades* (Paris, 1940). (R. C. SMA.)

RAYMUND IV (*c.* 1042–1105), count of Toulouse, called also RAYMUND OF SAINT-GILLES (from his original countship), leader of the Provençal contingent on the first crusade, was the younger son of Pons, count of Toulouse (died 1061). Raymund became marquis of Provence through his marriage to his first cousin the heiress (1066); but this marriage was condemned by the church, and their son Bertrand held to be a bastard. Raymund's second marriage (1080) was with Matilda of Sicily, niece of Robert Guiscard, his third (1094) with Elvira, daughter of Alphonso VI of Castile. In 1093, on the death of his brother Count William IV (with whom he had already divided the paternal heritage), Raymund succeeded to the whole countship of Toulouse.

Having previously fought against the Moors in Spain, Raymund was the first of the princes of the west to take the cross after Pope Urban's sermon at Clermont. The oldest and the richest of the crusading princes, the count of Toulouse started, in Oct. 1096, with a large company, which included his wife, his son and Adhemar of Monteil, the papal legate. His march lay by Ragusa and Scutari to Durazzo, whence he struck eastward, along the route also used by Bohemund, to Constantinople. At the end of April 1097 he was with difficulty induced to take a somewhat negative oath of fealty to Alexius. He was present at Nicaea and Dorylaeum; but he first showed his hand in Oct. 1097, when, as the army neared Antioch and a rumour was spread that Antioch had been deserted by the Turks, he sent a detachment in advance to occupy the city—an action which presaged his future difficulties with Bohemund (*q.v.*), the would-be prince of Antioch.

In the siege of Antioch (which was far from having been deserted) Raymund played his part. When the city was taken by Bohemund (June 1098), the count garrisoned the palace of the emir Yagi Sian and the tower over the Bridge gate. He lay ill during the second siege of Antioch by Kerbogha; but in his camp a great spiritualistic activity culminated in the discovery of the Holy Lance by the Provençals. The miracle stimulated the crusaders to defeat Kerbogha: the Lance itself, discovered by the Provençals and carried thenceforward by their count, became a valuable asset in Raymund's favour. A struggle arose between the Provençals and the Normans, partly with regard to the genuineness of the Lance and partly with regard to the possession of Antioch. Raymund moved southward in the autumn of 1098 to the siege of Marra, leaving a detachment of his troops in Antioch. With Bohemund left in Antioch, with the Holy Lance to give him prestige and with the wealth which he had at his disposal, the count of Toulouse began to figure as the leader of the crusade. But he delayed the advance to Jerusalem to besiege Arca with the intention of founding a principality to check the extension of Bohemund's kingdom. A wave of indignation in the ranks, and the inducements which the emir of Tripoli offered to the other princes, forced Raymund to desist from the siege (May 1098) and to march southward to Jerusalem. Bohemund meanwhile had expelled Raymund's men from Antioch. Raymund took part in the storming of Jerusalem, but he hampered Godfrey in the campaigns which followed.

Raymund had come to the east with the intention of founding a principality. During the crusade his ambition had been thwarted at Antioch, Marra, Arca, Jerusalem and Ascalon. He then decided to advance his interests by upholding Byzantine claims in Syria. In Sept. 1099 he joined forces with the Greek garrison of Laodicea, then besieged by Bohemund. From Laodicea he went to Constantinople, where he fraternized with Alexius, the great enemy of Bohemund. Joining in the ill-fated crusade which followed the first, he escaped from the debacle and returned to Constantinople. In 1102 he went by sea from Constantinople to Antioch, where he was imprisoned by Tancred, regent of Antioch during the captivity of Bohemund, and dismissed only upon promising not to attempt any conquests in the country between Antioch and Acre. He broke his promise, attacking and capturing Tortosa and beginning to build a castle on the Mons Peregrinus for the reduction of Tripoli, of which he is recognized as the first count (Raymund I). In this policy he was aided by Alexius. In 1105 Raymund died. He was succeeded by his nephew William, who in 1109, with the aid of Baldwin I, captured the town and definitely established the county of Tripoli. William was ousted in the same year by Raymund's eldest son Bertrand, and the county continued in the possession of his house during the 12th century. After partition between Bertrand and Alphonse (*q.v.*; Raymund's son by his third marriage), the county of Toulouse was united under Alphonse alone on Bertrand's death in 1112.

BIBLIOGRAPHY.—Raymund of Agiles, a clerk in the Provençal army, gives the history of the first crusade from his master's point of view. For a modern account of Count Raymund's part in the crusading movement, *see* R. Grousset, *Histoire des croisades*, vol. i (Paris, 1934), and J. Richard, *Le Comté de Tripoli sous la dynastie toulousaine* (Paris, 1945).

RAYMUND III (*d.* 1187), count of Tripoli, was the most famous of the descendants of Raymund IV of Toulouse (reckoned as Raymund I of Tripoli), a great-grandson of his eldest son Bertrand and son of Raymund II and Hodierna, a daughter of Baldwin II of Jerusalem. He became count of Tripoli in 1152, on the assassination of his father. He was captured by Nureddin in 1164 and was released in 1172 after a captivity of eight years. In 1174 he claimed the regency on behalf of Baldwin IV (*q.v.*) (at once a minor and a leper) in virtue of his close relationship, and the claim was acknowledged. After two years the regency passed successively to the two husbands of Sibyl, the king's sister and heiress; but Raymund, who had married the heiress of the county of Tiberias, continued to figure in the affairs of the kingdom. His great ability procured him enemies; for two years, 1180–82, they induced Baldwin IV to exclude Raymund from his territories. But as Saladin grew more threatening, Raymund grew more indispensable; and in 1184, when Guy of Lusignan, Sibyl's second husband, had proved his incapacity, Raymund became regent for Baldwin V, on condition that, if the king died before his majority, his successor should be determined by the great powers of the west. Raymund conducted the regency with skill, securing a truce from Saladin in 1185; but when Baldwin V died, in 1186, the supporters

of Guy of Lusignan had him crowned, in defiance of the stipulation under which Raymund had become regent. Raymund, left in isolation, retired to Tiberias and negotiated a truce for himself with Saladin. His ambiguous position led contemporaries to accuse him of treasonable correspondence with Saladin; but his loyalty to the Christian cause was nobly shown in 1187, when he reconciled himself to Guy and aided him in the battle of Hattin, which was engaged, however, against his earnest advice. He escaped from the battle wounded and ultimately retired to Tripoli, where he died. With the growth of faction which marked the reign of Baldwin IV, Raymund emerged as leader of the native baronage against the "court" party that included the Lusignans, the Courtenays and Raynald of Châtillon. He was the most able statesman among the Syrian Franks and might well have saved the Latin kingdom from its destruction by Saladin.

William of Tyre knew Raymund well and in his *Historia* left a first-rate account of him. Of modern writers, *see* R. Grousset, *Histoire des croisades*, vol. ii (Paris, 1935); M. W. Baldwin, *Raymond III of Tripolis and the Fall of Jerusalem* (*1140–1187*) (1936). (R. C. Sma.)

END OF VOLUME EIGHTEEN

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